IMAGE PROCESSING TECHNIQUES FOR THE INFORMATION EXTRACTION OF THE LANDSAT TM IMAGERY APPLICATION TO GEOLOGICAL MAPPING OF THE NE JAVA BASIN *)

by

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ABSTRACT

The image processing for geological feature extraction mainly concerns with information extraction. With the aid of computer, various techniques are possible to manipulate or modify, therefore the expected information will be enhanced and the unexpected are suppresed.

The study area is the NE-Java Basin, data used is Landsat TM imagery. The techniques proposed for this study area are as follows :

- band selection.
- false colour composite (after appropriate contrast stretching).
- multi image enhancement (ratioing).

The band selection is a technique to select three bands among seven bands of Landsat TM. By using Index of Optimal Band Triplet Selection or Venn Diagram a set of 145 and 147 contain maximum information. A conventional contrast stretching, ie : selected linear stretching, histogram equalization, combination of linear stretching and histogram equalization, is satisfactory. However, it suffers from a colour bias. The Balance Contrast Enhancement Technique is proposed to minimize the colour bias. The combination of 4, 5/7, and 1/2 is reasonably useful as complement, especially to distinguish among limestones (Karren, Orbitoid and Platen).

I. INTRODUCTION

Human visual system is a perfect system, however, these systems obviously cannot extract all the information that is composed of the original image. These problems are due to radiometric degradation, and geometric distortion, etc. The aim of the Image Processing is to eliminate or minimize those distortions, therefore, the processed image will provide maximum information that can be perceived by the interpreter.

This paper will discuss a set of techniques namely: band selection, colour composite and contrast enhancement and band ratio, that are applied to geological mapping of Cepu-Bojonegoro area (NE Java Basin). Data used is Landsat TM, the study area is part of path 119/row 065 (Fig. 1 and Fig. 3).

A LEMIGAS geological map (1971)was used as a reference. The area is composed of three kinds of limestones (karren, orbitoid and platen), the variation among these limestones is reflected by differences of physical properties and chemical components (composition of calsite and dolomite), sandstone (quartz and tuffs) and claystone.

II. BAND SELECTION

Colour composite imagery is constructed by three bands that assign to the red, green and blue refresh memory channels. Most of the remote sensing imagery contain more than three bands (in the case of Landsat TM contains 7 bands), therefore, techniques of band triplet selection should be developed. One of the most important factors for these selections is the triplet bands containing maximum information and least noise.

This paper proposed the index of optimal band selection (IOBS) that has been developed by Liu Jian Guo (1989), and the author proposed venn diagram techniques. These techniques are concerned with the maxi-

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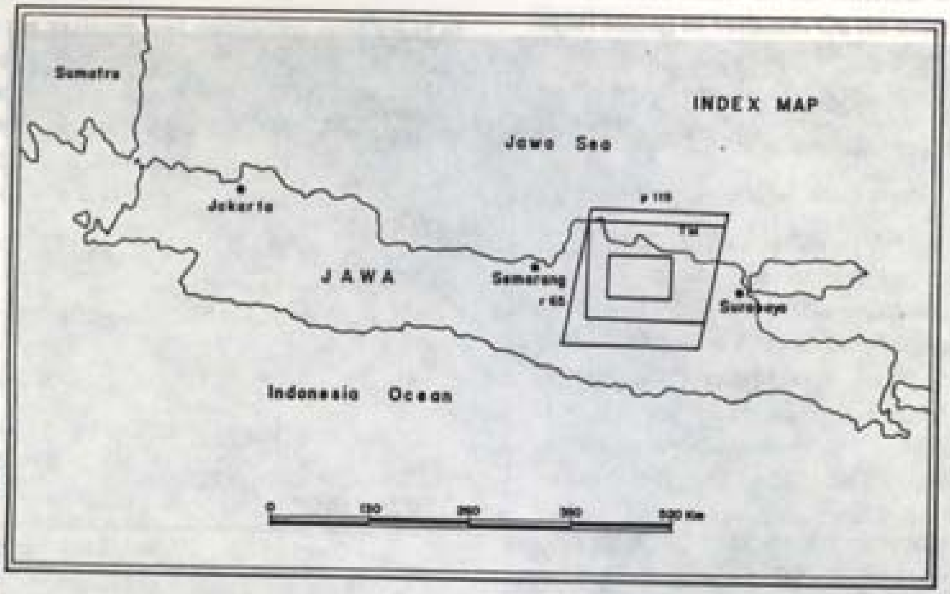


Figure 1. Index map of the study area

mum information (therefore less correlation), but the approach is in the different manner.

A. Index of optimal band triplets selection (IOBS)

Suppose three bands of i,j and k have correlation factors rij, rik and rjk. Liu Jian Guo (1989) has defined the IOBS

IOBS =F(rij, rik, rjk) minimum (1)

To achieve maximum information this value should be minimum. Consider those correlation factors are length, width, and height of a cube, therefore :

length,

F1 = |rij| + |rik| + |rjk| - minimum (2)

a volume,

F2 = |rij * rik * rjk| - maximum (3)

a diagonal,

F3 = Sqrt(rij^2 + rik^2 + rjk^2) - min. (4)

Mathematical consideration is as follows :

Both combinations are expected which has minimum F1. In this case of F1 minimum belongs to more than one combination, the best of them is expected from a combination with the F2 maximum.

The alternative is F3 the less correlation combination will be monitored by F3 minimum. The F3 appoach is better than the F1 and F2 approaches. However, if two bands have high correlation but low to third band, the F3 may fail as an indicator.

Based on the analyses, IOBS is finally defined as:

IOBS=Max(rij,rik,rjk)*(sqrt(rij^2+rik^2+rjk^2))/3 - min (5)

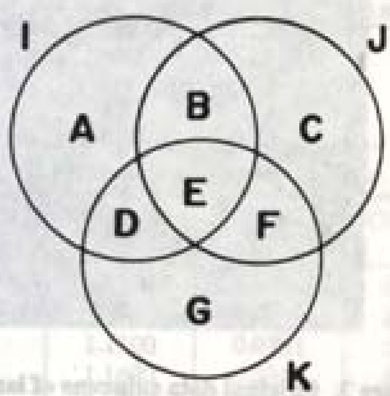


Figure 2. Venn diagram

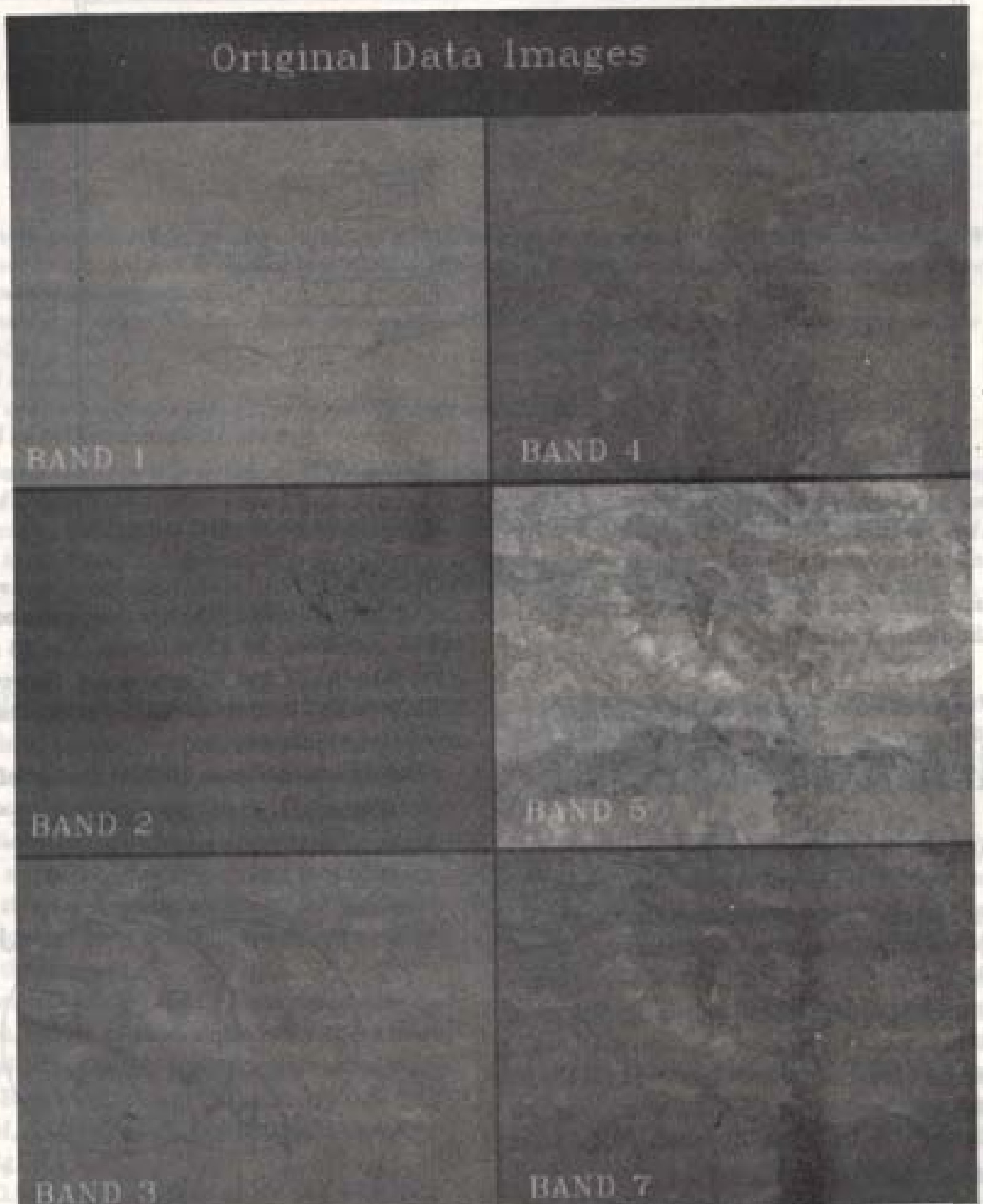


Figure 3. Original data subscene of landsat TM p119/r 65 August 24, 1991 (column = 1974, line = 1524)

B. Venn diagram method

Suppose the variance and correlation coefficient of each bands are S and r respectively. The geometric approach of three bands means that those bands are a set of information A, B, C, D, E, F, G. Therefore total variance is the commulation of its segment (Fig. 2),

$$T = A+B+C+D+E+F+G \quad (6)$$

If a set value of band i, j, k is Si, Sj and Sk, the segment value of

$$A = Si-B-D-E$$
$$C = Sj-B-F-E \quad (7)$$
$$G = Sk-D-F-E$$

For a set of i and j which its intersection smaller or equal to min(Si,Sj),

$$B = rij * \min(Si,Sj) - E \quad (8a)$$

With same idea for D and F :

$$D = rik * \min(Si,Sk) - E$$
$$F = rjk * \min(Sj,Sk) - E \quad (8b)$$

To obtain maximum information, total amount of B, D, E and F must be minimum. These can be achieved if

$$E = \min(rjk*\min(Si,Sj), rjk*\min(Si,Sk), rjk*\min(Sj,Sk)) \quad (9)$$

From equations (7),(8) and (9), the variance (6) is

$$T = Si+Sj+Sk-(B+D+F)-2E \quad (10)$$

Finally, % total variance is :

$$\frac{T}{\Sigma S_n} \times 100\%$$

(Sn = variance of n-th band)

Table 1. Minimum and maximum DN and range of data before and after cutting 1%

Band	Before tail cutting			After tail cutting		
	DN max	DN min	Range	DN 99%	DN 1%	Range
1	234	85	149	109	90	19
2	127	38	89	55	42	13
3	197	46	151	85	52	33
4	144	32	112	85	45	40
5	255	18	237	151	58	93
7	255	4	251	75	19	56

If three bands do not correlate with, value T, it is equal among its variance. On the other hand if the correlation is high, the value of T will be (*Si,Sj,Sk*). It is clear that the best combination will expect the value T to be maximum.

C. Analysis from the study area

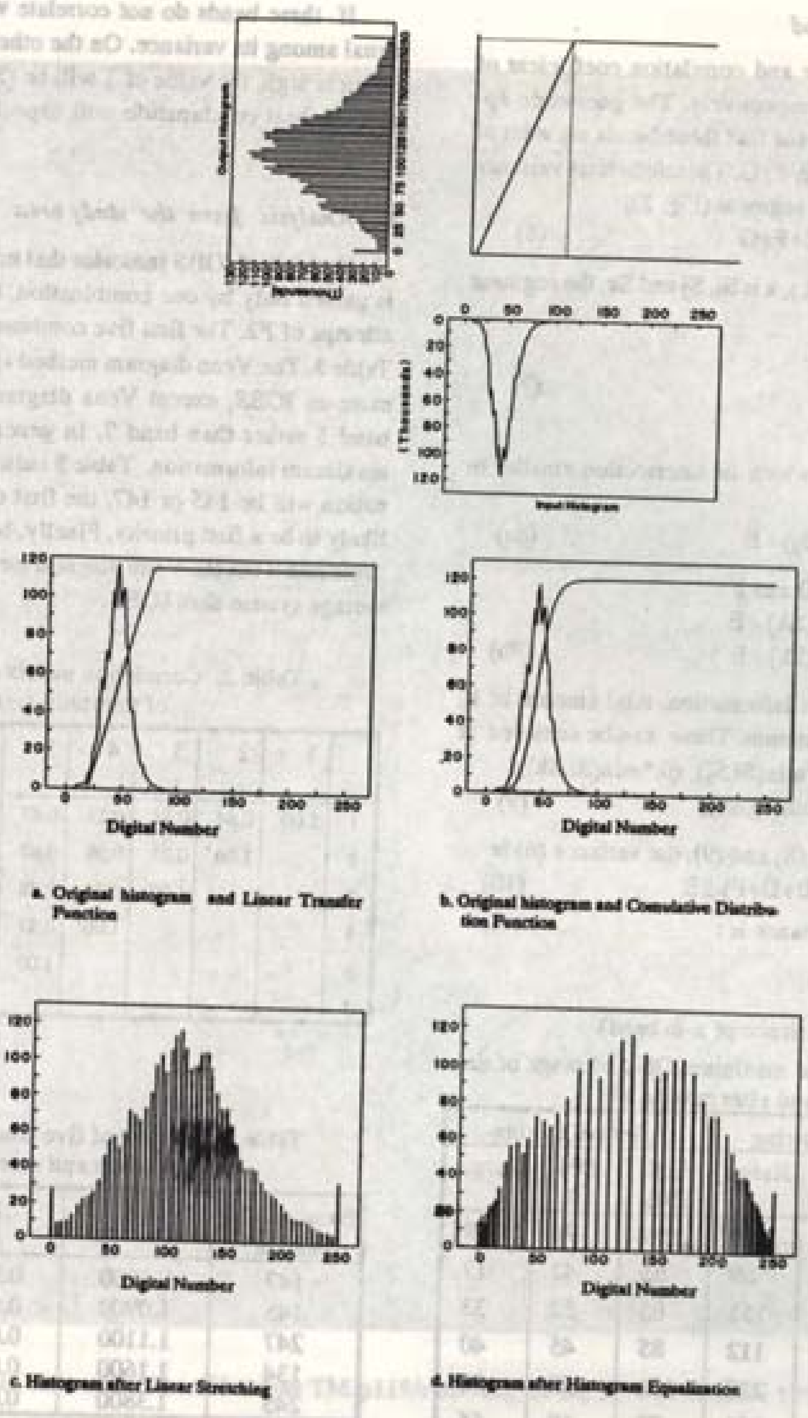
A result of IOBS indicates that minimum value of F1 is gained only by one combination, therefore no further attemps of F2. The first five combinations are showed at Table 3. The Venn diagram method apparently results the same as IOBS, except Venn diagram method preferred band 5 rather than band 7. In general, band 5 contains maximum information. Table 3 indicated the best combination will be 145 or 147, the first combination is more likely to be a first priority. Finally, both method have the same result but the Venn diagram method needs only less storage system than IOBS.

Table 2. Correlation matrix and variance of the study area

	1	2	3	4	5	7	Variance	%
1	1.00	0.84	0.71	0.25	0.47	0.46	17.80	2.27
2		1.00	0.85	0.39	0.62	0.60	8.50	1.28
3			1.00	0.20	0.78	0.81	47.20	7.09
4				1.00	0.37	0.12	70.30	10.56
5					1.00	0.91	388.50	58.34
7						1.00	133.60	20.06

Table 3. The best of five combination of F1, F3 parameters and corrected venn

Band combination	F1	F3	Corrected venn
147	0.8300	0.5371	2.2900
145	1.0900	0.0435	2.1600
247	1.1100	0.0281	2.0100
134	1.1600	0.0355	2.0152
245	1.3800	0.0895	2.0400



a. Original histogram and Linear Transfer Function

b. Original histogram and Cumulative Distribution Function

c. Histogram after Linear Stretching

d. Histogram after Histogram Equalization

Figure 4. Histogram data of band 7

III. CONTRAST ENHANCEMENT

Quality of the image usually means a good appearance. Contrast enhancement is a technique that benefits a range of Digital Number (DN) available to the computer system (in this case 0 - 255/8 bits), hence, a processed image will contain maximum information that can be perceived by human eyes.

This paper proposed a technique of linear stretching, histogram equalization and balance contrast enhancement as the most suitable contrast stretching techniques of Landsat TM to the study area.

A. Selected linear stretching

The most simple contrast enhancement technique is a linear transfer function, formulate as Y = aX + b (Fig. 4). A slope of this function will control degree of stretching or compressing, whereas an intersection to the ordinat Y indicates an average brightness. The main characteristic of this technique is output histogram will remain the same as input. The changes are expected from its mean and standard deviation (Table 4 and Fig. 5.b.).

The equation of this transfer function :

G = {9Mo-mo)F+(Mimo-Momi)}/(Mi-mi) (11)

where :

Mi, mi = Max and min input intensity level
Mo, mo = Max and min output intensity level
Mi,mi,Mo,mo are user defined
F = input DN
G = output DN

The linear transfer function offers flexibility to which an area will be stretched to a maximum available grey level. In the case of study area, 1% cutting of minimum and maximum values have been attempted (Table 1). The grey level which is less than minimum will be assigned to O, whereas the grey level bigger than maximum will be transfered to 255. The elimination value of those tails stimulate more information.

The main drawback of linear transfer function is the stretching just based on its distribution, regardless the frequency of occurance.

Table 4. Mean comparation

Band	Orig-inal	Linear streching	Histo-gram equali-zation	BCETP E=128	BCETC E=115
TM1	99.11	121.32	137.19	128.80	114.52
TM4	61.61	104.89	133.52	127.52	114.20
TM5	98.81	110.90	130.75	127.70	114.50

B. Histogram equalization

One of non-linear transformation is histogram equalization. This technique will reduce contrast to an area of extremely bright and dark (Fig. 4.d), hence, the contrast of the image usually appears a little bit harsh.

The operation of histogram equalization is employed in Cumulative Distribution Function (CDF) of the original as their transfer function. The value of the k^{th} is a sum of grey level values of the first k in the histogram. Suppose the histogram is H and CDF is C, the relationship is :

$$C(J) = \frac{1}{N}\sum_{i=1}^{j} H(J) \qquad (12)$$

$$T(J) = C(J) \times 255 \qquad (13)$$

Fig. 5.c. clearly indicates a higher frequency of occurance which will be stretched bigger than those the lower one. These phenomena are manifested by hyperbolic belly shape.

The main characteristic of this technique, the image tends to appear very bright. This is particularly true to the image which has Gaussian shape as in the case of the study area.

To reduce over-bright as mentioned above, a combination of linear stretch and histogram equalization is attempted. The equation of this combination technique is :

CLH(I) = (100-x) G(I) + x T(I) (14)

CLH (I) = Combination Stretching
G (I) = Linear Stretching
T (I) = Histogram Equalization
x = percent of combination

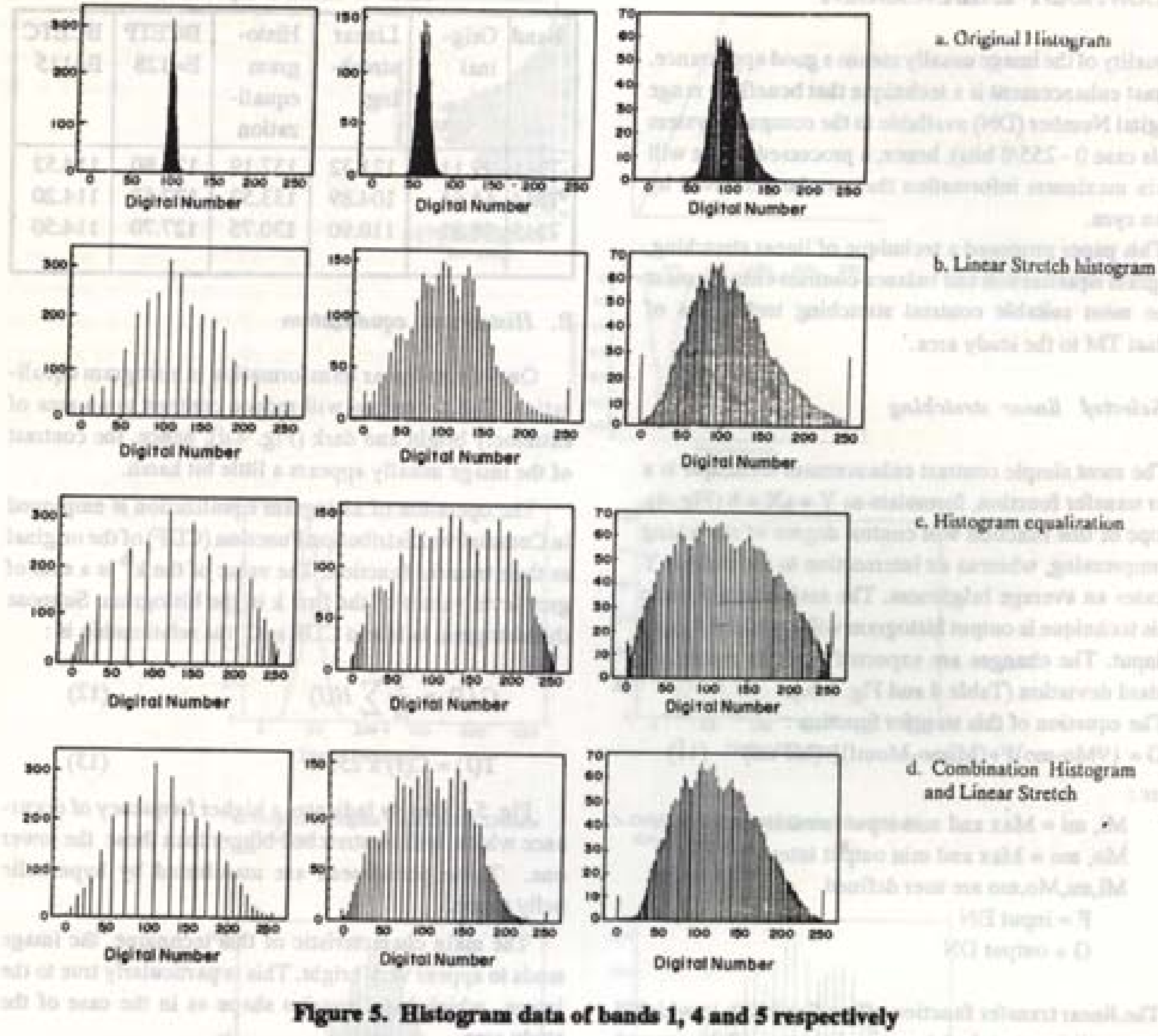


Figure 5. Histogram data of bands 1, 4 and 5 respectively

Fig. 5.d. is 50% combination, the grey level between 0-50 and 200-255 (normal belly histogram) will be suppressed.

C. Balance contrast enhancement technique (BCET)

The bands with proper contrast and low interband correlation may produce poor color composites if one of three bands used for is much higher or lower average brightness than the other two, called as colour bias.

Colour bias can be avoided without losing or changing the information in the original images by contrast enhancement (Liu Jian Guo), as follows :

- **a. Stretch (or compress) each image to a given minimum, maximum and mean, so the three bands will have the same value range and average brightness after the stretch.**
- **b. It will not change the basic shape of the histogram of an image being processed; thus the information in the image will not be changed.**

Previous contrast techniques cannot ensure the balance of mean brightness of each band. Liu Jian Guo (1989) presented balance contrast enhancement techniques (BCET) which can avoid colour bias. The method is easy and simple.

To simplify the application, parabola and cube are used in this paper.

BCET using a parabolic function (BCETP)

A parabolic function :

$$Y = A\,(X-B)^2 + C \qquad (15)$$

where :

X = input image

Y = output image

It is an even function and controlled by three coeficients A, B, and C. A section increasing monotonically will be used by BCET. It is possible for most cases in image contrast enhancement if those coefficients are derived from input image X and the maximum, minimum, and mean given for the relevant output image Y.

Solution of Eq. (15) is as follows :

$$L = A(l - B)^2 + C \qquad (16)$$

$$H = A(h - B)^2 + C \qquad (17)$$

$$E = \frac{1}{N}\ \Sigma A(Xi-B)^2 + C = C + \frac{A}{N}\ \Sigma(Xi - B)^2 \qquad (18)$$

where :

h = maximum input

l = minimum input

e = mean input

H = maximum output

L = minimum output

E = mean output

Three cases may occur in these solutions :

a. If B < l then A > 0, the parabola is open upward and the right section of the parabola will be used by BCETP.

b. If B > h then A < 0, the parabola is open downward and the left section of the parabola will be used by BCETP.

c. If l < B < h, the parabola will not be used.

Then, BCETP is performed pixel by pixel on the input image X,

$$Yi = A * (Xi - B)^2 + C \qquad (19)$$

Finally, an output image Y with a certain the given value range (L,H) and mean E will be produced by BCETP.

BCET using a cubic function (BCETC)

The cubic function :

$$Y = A(X - B)^3 + C \qquad (20)$$

If A > 0, then Y' > 0 and the function is monotonically increasing, The part of the curve will be used by BCETC. Among the point of inflection the curve will change its shape from convex to concave. This part and nearby the curve will not be used, then it can be avoided in balance contrast enhancement if the coefficients A, B, and C are derived as a similar way as BCETP.

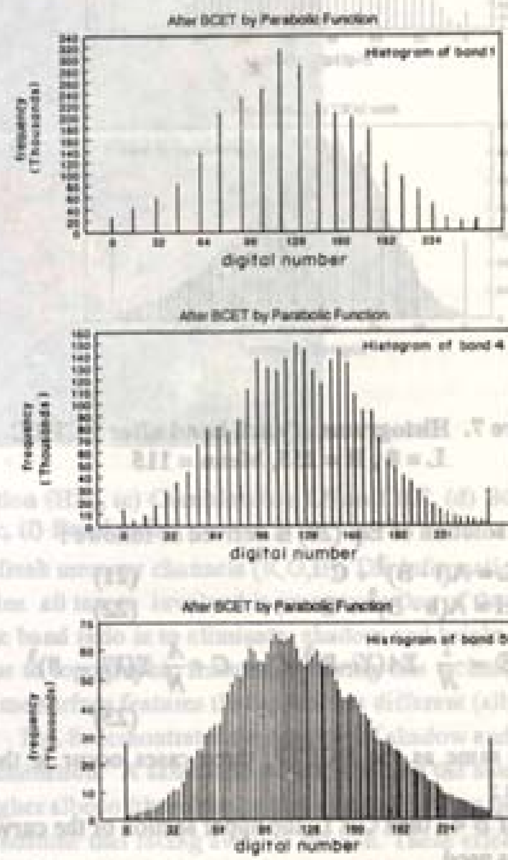


Figure 6. Histograms of each band after BCET L = 0 , H = 0 , Mean = 128

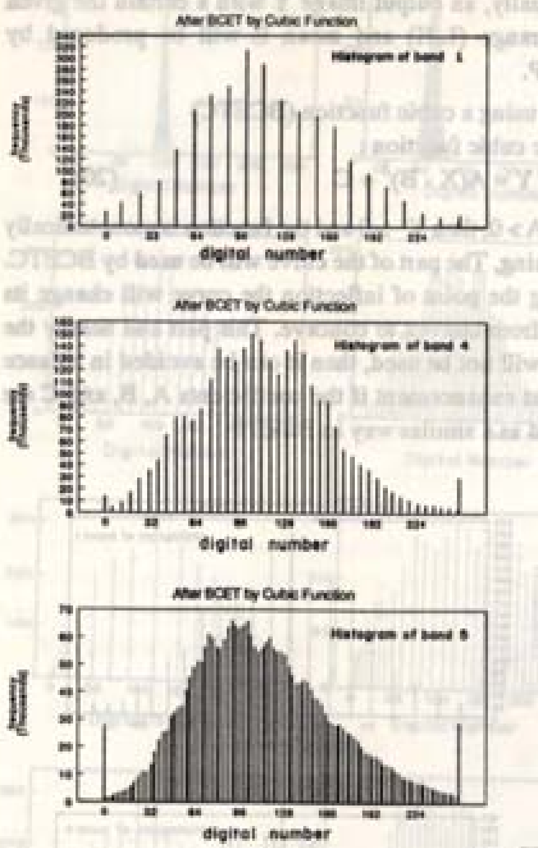


Figure 7. Histograms of each band after BCETC L = 0 , H = 255, Mean = 115

The solution of Eq. (20) is derived as follows :

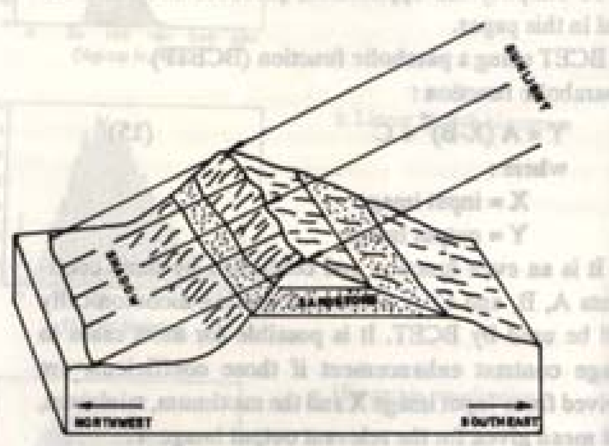
$$L = A(l - B)^3 + C \quad (21)$$

$$H = A(h - B)^3 + C \quad (22)$$

$$E = \frac{1}{N} \Sigma A(Xi - B)^3 + C = C + \frac{A}{N} \Sigma (Xi - B)^3 \quad (23)$$

The same as the BCETP, three cases occur in the solution :

1. If B < l then C < L, the upper section of the curve is used.
2. If B > h then C > H, the lower section of the curve is used.



SANDSTONE REFLECTANCE

ILLUMINATION	BAND 4	BAND 5	RATIO 4/5
SUNLIGHT	28	42	0.66
SHADOW	22	34	0.65

Figure 8. Concept of shadow effect elimination (Introduction to Geology R/S, BCS, 1988)

3. If l < B < h then L < C < H, the middle section with the point of inflection of the curve is used.

The first two cases satisfy the requirement of BCET, but the third case will change a shape of the histogram. Hence, this case is not qualified for balance contrast enhancement.

Then, using BCETC with the proper A, B, and C, the input image is transfered a pixel by a pixel as :

$$Yi = A\,(Xi - B)^3 + C \quad (24)$$

Finally, output image Y will have an exactly range value (L,H) and mean E.

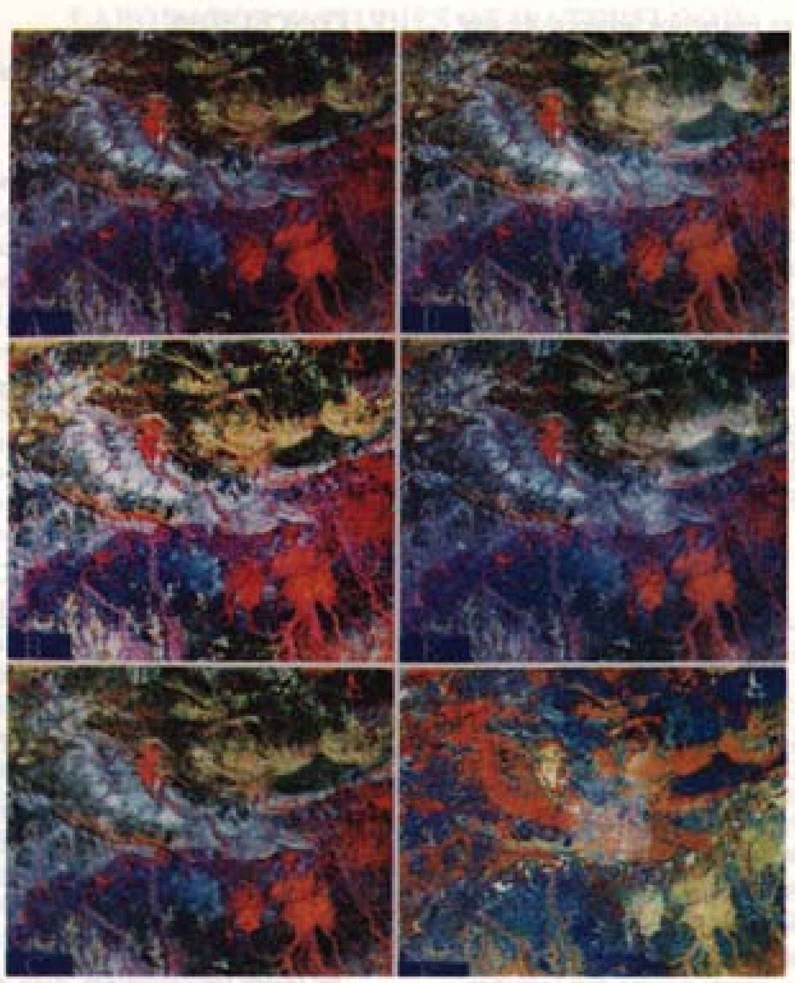


Figure 9. (a) Linear stretching (*LS*), (b) Histogram equalization (HE), (c) Combination LS and HE, (d) BCET parabolic, (e), BCET cubic, (f) Band ratio

According to the experimental processing, the output images produced by BCETP and BCETC are almost the same for the same given parameters. The application of both BCET for the study area gives the best colour composite images (Fig. 9d and 9e) without color bi*a*s. The average brightness of each band and histogram after being processed are given in Table 4 and Fig. 6 and 7.

VI. BAND RATIO

Band ratio is the most popular technique for multispectral image enhancement. The ideas are the three refresh memory channels (R,G,B). The information contains all image involved is preserved. One of the aim of the band ratio is to eliminate shadow and bright effects due to topographic features, by using this technique the same surface features that appear are different (albedo).

Fig. 8. demontrates the concept of shadow and bright elimination. A sandstone which is facing the sun has a higher albedo (therefore its digital number) than the same sandstone that facing away to the sun. These effects obviously exist to all bands involved. Ratio operation (A/B), indicates that those sandstones remain the same.

The basic formula of an interaction between the sun elimination and the object is :

$$L(m) = tau(m)*Ld(m)*rho(m) + Lp(m) \quad (25)$$

Where :

L(m) = Upward flux density
tau(m) = Transmitance
m = band number (wavelenght)
Ld(m) = Downward flux density
rho(m) = Reflectance
Lp(m) = Path radiance

For ratio operation the Eq. 25 will be :

$$\frac{L(A)}{L(B)} = \frac{tau(A)Ld(A)rho(A)+Lp(A)}{tau(B)Ld(B)rho(B)+Lp(B)} \quad (26)$$

If those both bands are close, assumption can be made as follows :

$$\begin{aligned} tau(A) &= tau(B) \\ Ld(A) &= Ld(B) \\ Lp(A) &= Lp(B) \end{aligned} \quad (27)$$

Therefore Eq. 26 will be :

$$\frac{L(A)-Lp(A)}{L(B)-Lp(B)} = \frac{\rho(A)}{\rho(B)} \quad (28)$$

The last equation clearly indicates that ratioing depends upon to the reflectance. Therefore, reflectance information of objects to be investigated is essential.

Instead of topographic suppression, there are another ones to distinct of band ratio, i.e. :

1. Band ratio tends to exaggerate a noise, this is particularly true if among bands are less or uncorrelated.
2. If two kinds of object have the same reflectance differences, the band ratio result will also be the same. Therefore those objects are indistinguishable.

A. Analysis

The best result of this process is colour composite of 4, 5/7, 1/2 (R,G,B). This process is useful as compliment groups (three kinds of limestone occur in the study area). In this colour composite, Karren limestone (KK) appears blue, the Orbitoid limestone (OK) appears yellow and the Platen limestone (Pt) appears cyan.

V. CONCLUSION

Statistic inspection will be useful as preliminary processing of either single spectral or multispectral image enhancement.

The transfer function of contrast enhancement technique obviously depends on histogram of an original image. The critical inspection of this histogram is main information fo this technique that will be selected. No instant regulation of this selection. However, the BCET seems to be a good way, especially to suppress colour bias.

The band ratio of 4, 5/7, 1/2 (R,G,B) is helpful for limestone differentiation.

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