IMAGE ANALYSIS TECHNIQUES WITH SPECIAL REFERENCE TO ANALYSIS AND INTERPRETATION OF GEOLOGICAL FEATURES FROM LANDSAT IMAGERY

D.S.Kamat, K.L.Majumder, S.D.Naik, and V.L.Swaminathan

Remote Sensing Area
Space Applications Centre
Indian Space Research Organisation
AHMEDABAD 380053 INDIA

ABSTRACT

The principal component analysis enhances the contrast existing between the different cover types present in an imagery. A procedure is presented in this paper with regards to the determination of the principal components. The method is tested for a portion of the LANDSAT imagery pertaining to Anantapur region. Another technique, using the concept of non-linear contrast stretching is defined and developed and carried out on the same imagery. The results are presented as photographs. An interpretation of the geology of the region is derived from these photographs.

1. INTRODUCTION

For processing of LANDSAT imagery usually three distinct techniques are used. One technique is to process the imagery with the help of computers, the second one is to interpret the imagery visually, and the third is a hybrid approach where both automatic and visual interpretation are used.

In computer processing of LANDSAT MSS imagery, there are two steps. The first step is to preprocess the image in order to remove noise, and to improve contrast. The second step is to use the multispectral imagery and classify the cover types. The multispectral classification is very effective for some specific applications like study of landuse, forestry and agricultural inventory. By this classification it is possible to generate thematic maps also (1).

In some applications like in geology, thematic mapping is not of relevance because geological interpretation does not wholly depend on surficial properties and signatures as there is a limited correlation between vegetative and other surface cover and geology. For this reason the interpreter or the photogeologist usually prefers to study the image itself visually in order not to leave out any significant data or clue. However in some cases visual interpretation of the imagery is not possible because of the low contrast existing between different objects present in the imagery or due to some inherent drawbacks of the photographic recording devices. To avoid these drawbacks various numerical techniques have been used to enhance the satellite acquired data. Some of the commonly used techniques are contrast stretching, band-to-band ratioing and spatial filtering.

In this paper an attempt is made to develop procedures for enhancing the contrast between different objects in MSS imagery. These procedures will be useful for the analysis and interpretation of LANDSAT imagery for geological applications. As a result of these enhancement techniques, one can obtain certain information which is otherwise not available for visual interpretation.

The basic idea of one of these procedures is the use of the concept of principal component analysis as discussed in (2,3). The method allows for shifting of gray values in the photograph after getting principal components. The analysis depends on the multispectral classification approach but additionally processes the signals so as to achieve better contrast in the picture.

The second procedure described in this paper also uses the multispectral classification technique and evolves a non-linear weighting function to obtain contrast stretching.

2. PROCEDURE FOR ANALYSIS

The method of analysis can be considered in three steps namely the classification of the multispectral data, the computation of covariance matrices and finally the determination of principal components.

2.1. CLASSIFICATION

The first step is to classify the area considered, using the available multispectral data. The classification procedure will identify and separate out the different cover types. An unsupervised classification technique is used for this purpose (4).

2.2. COVARIANCE MATRICES

After completing the classification, the next step will be the computation of the covariance matrices for the different cover types. Because of inherent spectral correlation which the surfacial features of theearth possess in different spectral channels, the covariance matrices will have invariably non-zero elements. The covariance matrix is denoted by C_m where 'm' represents cover type.

2.3. PRINCIPAL COMPONENTS

The last step will be the determination of Principal Components. This step involves the computation of eigen values and the corresponding eigen vectors for each cover type. The eigen values are arranged in the descending order.

The principal components are obtained from the original N spectral bands by the following transformation

$$Y = T_m (X-U_m) \qquad (1)$$

where X is the N-dimensional vector of spectral intensities associated with each pixel or ground resolution element,

U_m is the mean vector of dimension N for a cover type 'm',

Y is the vector of principal components, and

T_m is the N x N orthogonal matrix derived from the covariance matrix C_m of each cover type 'm'.

The rows of T_m are the N normalised eigen vectors of C_m .

Using Eqn. (1), new gray values for all the pixels are obtained. The procedure will generate as many number of principal components as there are number of spectral channels. Essentially a new set of pictures are generated from the given four channels by mapping into new four components.

The covariance matrix of the principal components is then $C_y = T_m C_m T_m^t =$

$$\begin{bmatrix} \lambda_1 & & 0 \\ & \lambda_2 & \\ 0 & & \ddots \lambda_N \end{bmatrix} \qquad (2)$$

where $\lambda_1, \lambda_2, \ldots, \lambda_N$ are the variances of the principal component and are also the eigen values of C_m. It is evident from C_y that the principal components are uncorrelated and each component has variance less than the previous component.

2.4. NON-LINEAR CONTRAST STRETCHING

In order to enhance the contrast of imagery besides the principal component technique, various techniques have been tried. Bond and Thomas (5) have reported a method that performs contrast stretching. In a similar fashion, but using a different criterion, a technique for contrast stretching is formulated here. In this new gray values for pixels belonging to each cover type are obtained using non-linear stretching over the gray values of the original channels of LANDSAT imagery.

Using the knowledge that a particular pixel belongs to a certain cover type, the gray value of this pixel is modified to a new value, by a weighting factor. This weighting factor, is given by

$$G(j, k) = \frac{U(j,k)}{\sum_{k=1}^{n} U(j,k)} \qquad (3)$$

where $G(j,k)$ is the weighting factor for 'k'th class in the 'j'th band or channel, and
$U(j,k)$ is the mean value of reflectance of the 'k'th cover type in the 'j'th band.

3. IMPLEMENTATION OF THE PROCEDURE

The analysis procedures as described in the previous section are carried out on LANDSAT imagery, pertaining to Anantapur region (I.D.No.2053-04265, 16th March 1975).

3.1. SITE FOR STUDY

A portion of the imagery covering an area of 30 Km x 30 Km is considered for this purpose. The area includes rocks of varied lithological entities like granites, quartzites, limestones and shales, shales and sandstones, and basic igneous intrusives. Penner is the major river flowing through the test site. Central belt of the area trending NNW-SSE comprises hills of varying heights and different rock units. Eastern part of the area is almost plain and shows the presence of basic dykes.

Figures 1 and 2 represent gray values of LANDSAT bands MSS 5 and 7 respectively. Sinuous course of the river Penner can easily be deciphered in Figure 2 than in Figure 1 due to its contrast in gray tone from the surroundings. Central belt of hilly terrain corresponds to limestones and shales and appears more clear in Figure 2. The hill range at the north-western part of the area is perhaps less visible in gray value photographs of bands 5 and 7.

3.2. DATA ANALYSIS

The portion of the imagery has been digitized using the Optronics P-1000 photoscan system. The digitizer uses 256 gray levels, gives out one byte of data for each resolution element. The digitized data for each spectral band is stored in a sequence on a CCT. For convenience of handling and analysis, the data is transferred to a magnetic disc.

For analysis purposes, the registration of the imagery in all the bands is an important step. The Sequential Similarity Detection Algorithm (4,6) is used to achieve the correct registration. The analysis of the imagery is performed in segments, each segment covering an area of 10 Km x 10 Km having 10,000 pixels. Each pixel will have four components corresponding to the spectral intensities in the four channels.

3.2.1. THE PRINCIPAL COMPONENTS. The inherent differences existing between different cover types is utilized in the derivation of principal components.

The data present in the above area is classified using the unsupervised classification algorithm (6). The analysis is carried out in nine segments each of 100 square kilometer. In a typical segment there are six cover types, the statistics of which is presented in Table I. The covariance matrices of all the cover types are then computed. The computed covariance matrix for a cover type is given in Table II.

TABLE I. STATISTICS OF A TYPICAL SEGMENT

Cover Type	Population.	Mean Reflectance				Standard Deviation			
		MSS 4	MSS 5	MSS 6	MSS 7	MSS 4	MSS 5	MSS 6	MSS 7
1	1827	220.7	192.2	183.6	206.1	7.7	10.2	10.9	8.7
2	2981	214.7	173.8	165.0	194.9	7.5	7.6	9.0	7.5
3	2401	207.4	159.7	152.0	185.8	8.4	7.4	8.2	6.9
4	1405	203.9	152.0	139.5	171.3	9.1	10.3	8.4	7.2
5	1098	217.6	187.6	153.2	178.0	7.9	13.6	8.6	9.2
6	288	217.4	196.4	170.4	187.9	20.7	37.7	31.1	26.3

TABLE II. COVARIANCE MATRIX, EIGEN VALUES, AND EIGEN VECTOR MATRIX FOR A COVER TYPE.

COVARIANCE MATRIX	EIGEN VALUES	EIGEN VECTOR MATRIX
$\begin{bmatrix} 56.48 & 7.67 & -7.61 & -2.00 \\ 7.67 & 58.72 & -3.37 & 1.52 \\ -7.61 & -3.37 & 80.54 & -3.74 \\ -2.00 & 1.52 & -3.74 & 56.28 \end{bmatrix}$	84.32 62.64 56.82 48.23	$\begin{bmatrix} -0.31 & 0.56 & -0.21 & 0.74 \\ -0.22 & 0.73 & 0.35 & -0.54 \\ 0.92 & 0.33 & 0.12 & 0.16 \\ -0.11 & -0.20 & 0.90 & 0.36 \end{bmatrix}$

The new gray values for all the pixels are then determined using the matrix transformation given by Eqn. (1). The principal components are then obtained and are stored on a magnetic disc in a format of a total segment. These are later used for writing the image on a film transparency in each of the principal components.

Figures 3 and 4 show the prints of first two principal components obtained.

3.2.2. CONTRAST STRETCHING. As explained earlier, an alternate scheme for contrast stretching is to use the information regarding the cover types to which the pixels belong. For this purpose, the gray values of the contrast stretched imagery are obtained by multiplying the original gray values of the pixels by the weighting factor, defined by Eqn.(3).

Figures 5 and 6 show the prints of contrast stretched imagery 1 and 2 respectively.

4. VISUAL INTERPRETATION FOR GEOLOGICAL STUDIES

The visual interpretation discussed here is supported by limited field checks of the area under study. Three major units, namely hills comprising sedimentary rocks, water bodies and dark gray belts corresponding to dykes, are considered for assessing the interpretability of MSS bands 5 and 7, principal components 1 and 2 and contrast stretched imagery 1 and 2.

4.1. INTERPRETATION OF PRINCIPAL COMPONENTS

Using the photographic data from Figures 3 and 4 corresponding to principal components 1 and 2 respectively, a visual interpretation of the geology of the area is carried out. Central belt of limestones and shales is represented in almost uniform gray tone in principal components 1 and 2. River Penner is discernible in principal component 1. Due to the sharp tonal contrast the hill range at the north-western part can be picked up easily in principal components 1 and 2 in comparison to gray value pictures of MSS 5 and 7.

Figure 7 shows the interpretation. A band of quartzite separating limestones and shales from granites is delineated in Figure 7. In the eastern part of the area, dykes running NW-SE are detected in shales. Same can also be seen in principal component 2 where it is less visible. Due to very little gray tone variations, it has not been possible to delineate these units from principal components 3 and 4. For this reason the prints of the principal component 3 and 4 are not included in this paper.

4.2 INTERPRETATION OF CONTRAST STRETCHED IMAGERY

River Penner and the hill range at NW corner appears more clearly in Figure 6. In addition, several hill and sedimentary rocks can be easily picked up on Figures 5 and 6 of the contrast stretched imagery.

Using the photographic data from Figures 5 and 6, a visual interpretation map is generated and is shown in Figure 8. A quartzite hill range separating limestones and shales from sandstones and shales, and basic igneous intrusives are clearly discernible on the enhanced images. These are delineated in Figure 8.

5. CONCLUSION

Two methods are presented to enhance the contrast among different cover types present in an imagery. It is noted that the principal component analysis has compacted all the information content present in the imagery especially to the first two components. The non-linear contrast stretching method has significantly improved the contrast among the cover types of the area under study. Certain geological formation like quartzite, limestones and shales, and basic igneous intrusives are more clearly seen in the principal components and also in the contrast stretched imagery.

ACKNOWLEDGMENT

The authors wish to thank Mr. B.S.Joshi for typing the manuscript neatly and Mr. A.C.Dave for preparing the drawings.

REFERENCES

1. Kamat D.S. et al, " Machine Processing of„Aerial Data for Agricultural Resources Inventory and Survey Experiment, RSA-IP/TN16/76, Space Applications Centre, Ahmedabad, January 1977.

2. Fontannel A., et al, " Enhancement of LANDSAT Imagery by Combination of Multispectral Classification and Principal Component Analysis", Proc. of Third NASA ERSS Symposium, Vol. I-B, pp 991-1011, June 1975.

3. Ready, P.J. and Wintz P.A., " Information Extraction, SNR Improvement, and Data Compression in Multispectral Imagery", IEEE Trans. on Communication, Vol. COM-21, No.10, October 1973.

4. Kamat D.S. et al, " A Programming System for Digital Image Processing at PRL and SAC, Ahmedabad", RSA-IP/TN09/76, September 1976.

5. Bond A.D. & Thomas D.T. " Automatic Information Extraction for Land Use and Agricultural Applications", Proc. of Symposium on Management and Utilization of Remote Sensing Data, Sioux Falls, South Dakota, pp.257-267, October-November 1973.

6. Barnea D.I. and Silverman H.F., " A Class of Algorithm in Fast Digital Registration", IEEE Trans. on Computers, Vol. C-21, No.2 February 1972.

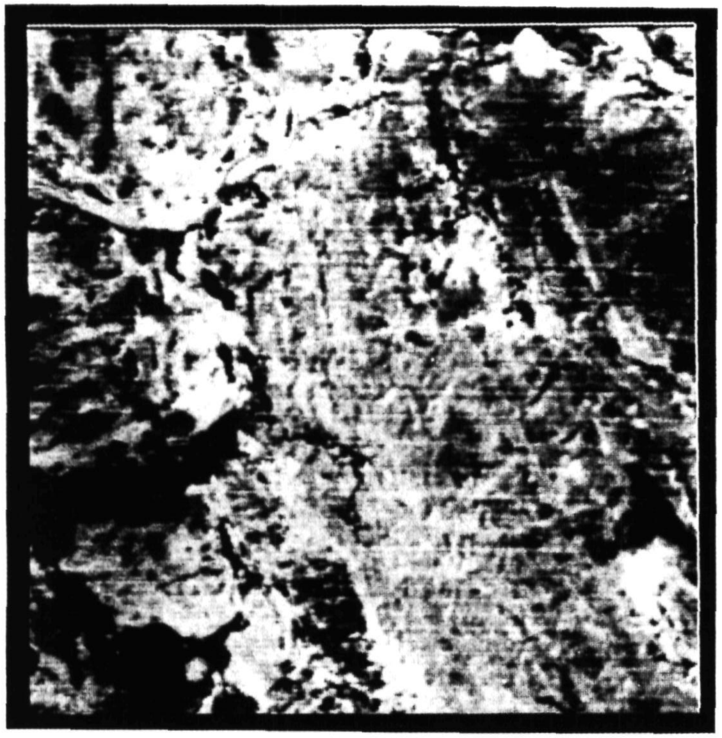

FIGURE 1. GRAY VALUES OF MSS 5.

FIGURE 2. GRAY VALUES OF MSS 7.

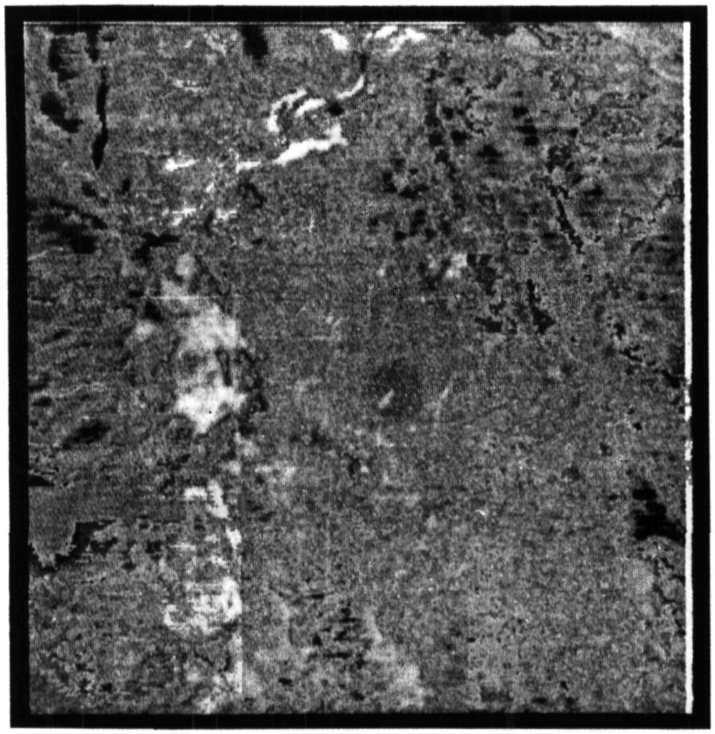

FIGURE 3. PRINCIPAL COMPONENT 1.

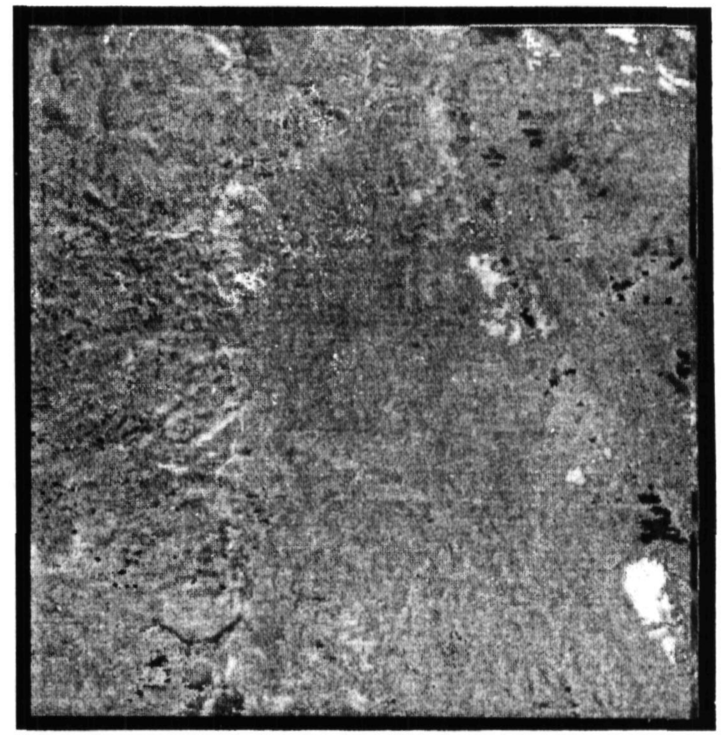

FIGURE 4. PRINCIPAL COMPONENT 2.

FIGURE 5. CONTRAST STRETCHED IMAGERY 1.

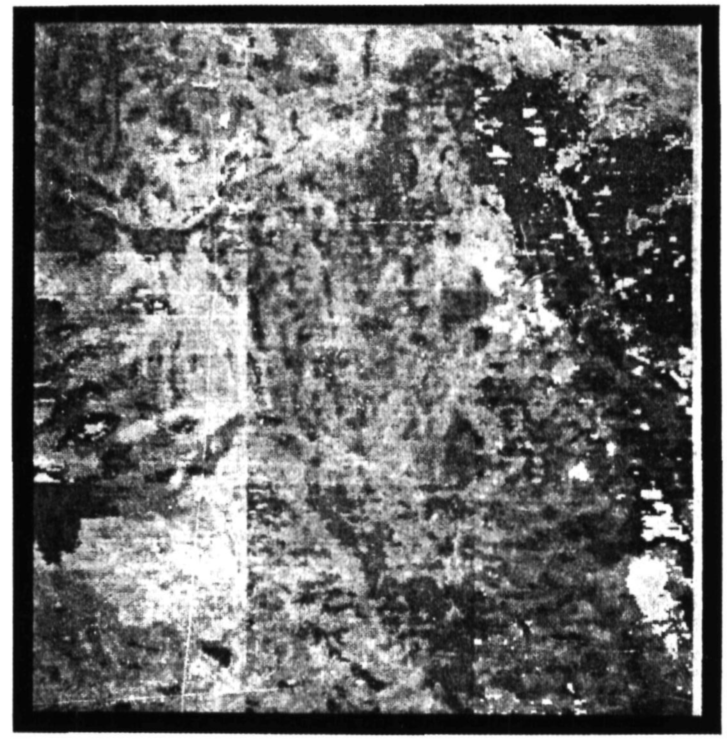

FIGURE 6. CONTRAST STRETCHED IMAGERY 2.

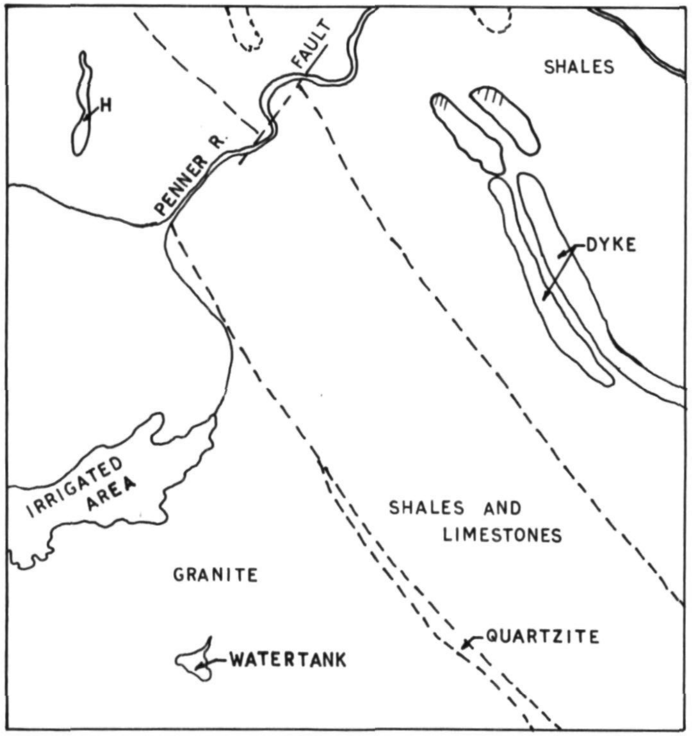

Figure 7 - VISUAL INTERPRETATION FROM PRINCIPAL COMPONENTS

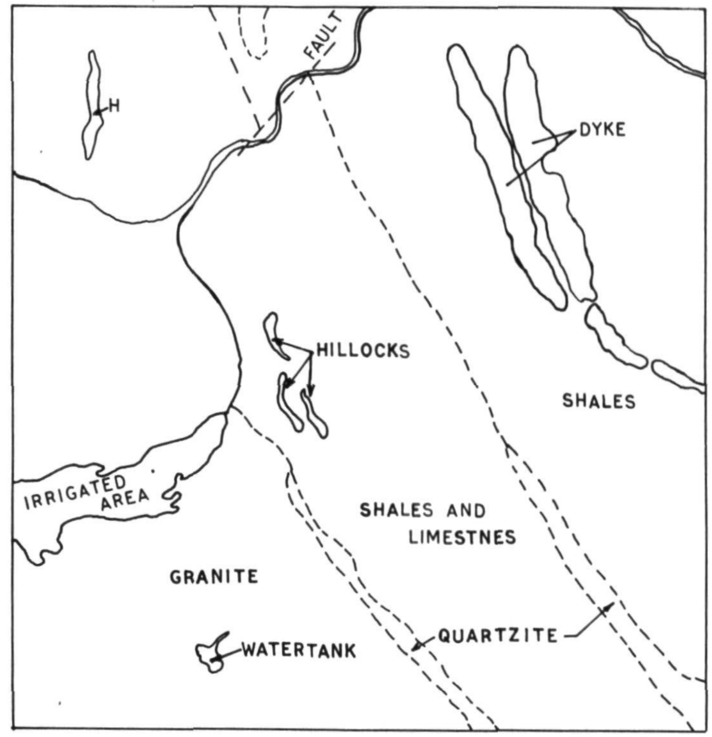

Figure 8 - VISUAL INTERPRETATION FROM CONTRAST STRETCHED IMAGERY