Identification of Craters on Lunar Surface Using Hyperspectral Chandrayan Data

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ABSTRACT

The aim of this paper is to identify Craters on Lunar surface on spectral basis by using Hyperspectral data since each landform of Moon have different spectral signature. Although Hyperspectral images contain a wealth of information due to its fine spectral resolution, the information is often redundant. It is therefore expedient to reduce the dimensionality of the data without losing significant information content then fractal based dimensionality reduction applied on high dimensional Hyperspectral data can be proved to be a better solution desired at a reduced computational complexity. Amongst a number of methods of computing fractal dimension, Multi Resolution Box Counting Method has been applied here. The experiments have been performed on a Hyperspectral data set acquired from HySI sensor of Chandrayan Satellite.

Index Terms: Catering Density**,** Classification Accuracy, Dimensionality Reduction, Impact Craters, Hyperspectral Data, MRBC.

1. INTRODUCTION

The study of lunar surface and its geosciences has become important to understand its formation, evolution and composition of the moon which can provide information about the mantle melting process over space and time. The Satellite data in the early 1990s with the launch of Galileo and Clementine satellites that imaged the lunar surface at specific spectral bands. Several advancements have been made in the resolution of the satellite to observe features on the lunar surface with high spatial and spectral resolution. One of the recent advancement has been the use of Hyperspectral sensors for remote sensing of the lunar surface.

Hyperspectral data had been used extensively for studying the morphology of craters and to understand the impact cratering mechanism over lunar highlands and mare basalts. Impact craters are the remains of collisions between an asteroid, comet, or meteorite and the Moon. The impact sprays material ejecta out in all directions this bring out the minerals from inside of moon and by studying the craters we can found out the minerals in the moon crust. Irregular Craters with irregular shapes or multiple impact craters formed at the same time can be created by impacts striking the surface at a very low angle. There is no atmosphere on the moon to help protect it from bombardment from potential impactors also, there is no erosion by wind or water and little geologic activity to wear away these craters, so they remain unchanged until another new impact changes it [1]. The number of craters on a surface increases with the time that surface has been exposed to space. These rather being simple ideas are the basis for a very powerful tool, called crater counting, that scientists use to unravel the age of a planetary surface. TMC data was used for absolute dating of lunar surface by employing Crater Size-Frequency-Distribution (CSFD) technique. This method was evaluated over regions of Apollo Landing sites 14, 15 and 17 and through CSFD technique matches with that obtained from radiometric dating of the returned samples as well as with the earlier reported results [2].

Craters can be distinguish on the basis of shape as they have circular shape but for this high resolution satellite images are required for example TMC (Terrain Mapping Stereo Camera) Panchromatic images of the Chandrayan-1 satellite having 5 meter spatial resolution but for this large number of images are required to cover the same area in comparison to the HySI Image as it has 80 meter spatial resolution. So to study single crater TMC image will be well suited but to identify craters over large surface of moon HySI data will be best suited.

This paper aims to study the lunar surface by the identification of craters based on its spectral signature and to identify craters on lunar surface using the spectral characteristics derived from the Hyperspectral data of Chandrayan-1 HySI Imager.

2. THEORY

In Hyperspectral data as craters have different Spectral Response Curve than other landforms on moon surface like highland region and ejecta blanket etc. so they can be easily identified. The most fundamental contrast is between volcanic craters and impact craters. According to multivariate statistical model the two processes yield crater shapes that are all similar. With respect to the distribution of mass, most volcanoes are positive landforms. Whereas impact craters are always negative features in the terrain of Moon thus there reflectance also varies [2].

In figure 1 it is clear that we can see that different landforms have same reflectance in the initial visible bands but in the later bands i.e. in Near Infrared region different landforms have a significant difference in the reflectance value so on the basis of reflectance craters can be identified on the basis of spectral signature in the bands ranging from 7-62. But there is problem related to Hyperspectral data that is redundancy of data and stripping effect in some bands which needs to be considered wile selection of band. Also Craters can be distinguish on the basis of shape as they have circular shape but for this high spatial resolution satellite images are required but for this large number of images are required to cover the same area in comparison to the HySI Image as it has 80 meter spatial resolution. So to study single crater TMC image will be well suited but to identify craters over large surface of moon HySI data will be best suited.

3. DATA SET

The dataset belongs to HySI (Hyperspectral Imager) is an ISRO instrument, designed at developed at SAC, Ahmedabad, India. The dataset belongs to HySI (Hyperspectral Imager) is an ISRO instrument, designed at developed at SAC, Ahmedabad, India. It operates in the visible and near infrared spectral region is one of the three imaging instruments on board Chandrayan-1 satellite. The instrument is observing in the band 400-930 nm with a spectral resolution of less than 15 nm and a spatial resolution of 80 m (from 100 km orbit) on a swath of 20 km. HySI is designed to map entire lunar surface in 64 contiguous bands with 12 bit quantization. The 248 X 662 pixels Hyperspectral image is a subset of image of Orbit number 2448 of Moon's North Pole side as specified by ISRO.

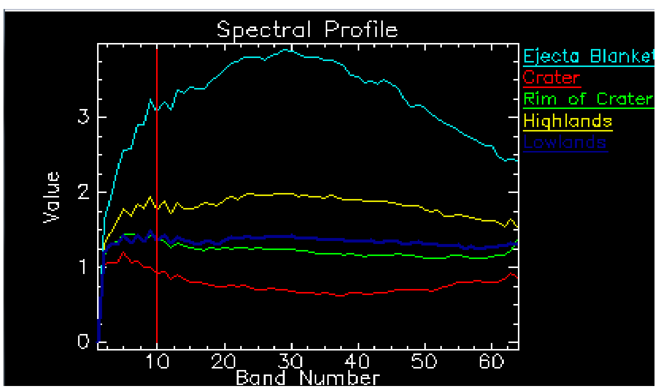


Figure 1 Spectral Profile of different classes

Figure 2 FCC of Input Image

4. METHODOLOGY

Working in the original dimensionality of Hyperspectral data is associated with many problems. The most challenging problem of Hyperspectral data is that it contains a large number of bands and therefore a huge amount of information ii required to be process. Thus processing of Hyperspectral images at their original dimension involves a huge computational burden. It has also been observed that the bands of adjacent wavelength regions of Hyperspectral data show a high correlation with each other. Thus, the information content may be redundant. Information redundancy is a direct consequence of the fact that a high dimensional space is mostly empty .It has been mathematically proved that the volume of a hypercube concentrates in the corners and the volume of a hyper sphere concentrates in an outside shell [4].

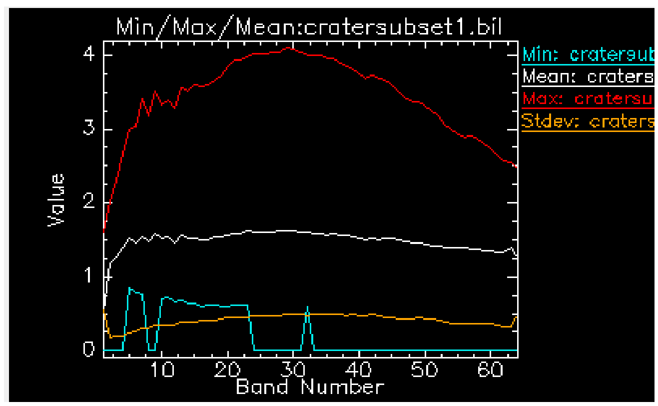


Figure 3 Min/Max/Mean/ Standard Deviation Plot of Input Image

The advantage of Hyperspectral image lies in its good spectral resolution, but this is achieved at the cost of low signal to noise ratio [5]. As a result, information Extraction from data is also prone to the effect of noise. The accuracy of information extraction decreases with the increase in dimensionality, also known as "curse of dimensionality" or Hughes phenomenon [6]. Thus dimensionality reduction plays a significant role in information extraction from the Hyperspectral data. Dimensionality reduction techniques can be broadly divided into two categories, feature extraction and feature selection [5]. In feature extraction, the original data are transformed into a new and reduced data space based on some mathematical projection techniques. In feature selection a set of statistical decision rules are applied to select a few dimensions (features) from the original data space. Another recent technique for dimensionality reduction using the spectral response curve (SRC) of each pixel is by using fractal mathematics is used in this paper. Fractal mathematics is based on the premise that a straight line has a dimension one whereas an irregular boundary may have a fractional dimension between one and two. In Euclidean geometry, the topological dimensions are integers, which remain fixed no matter how irregular a line or an area may be. Thus, in topological representations, the information about the irregularity of objects is lost. In contrast, in fractal mathematics, the irregularity, which is directly proportional to the value of fractal dimension, is taken into account.

In this research work, Multi Resolution Box Counting fractal dimension computation methods have been applied in Hyperspectral data set. Because MRBC methods have provided the more accurate estimates of the fractal dimension for all fractal waveforms than the Katz and Sevcik's methods and have shown comparable estimation performance as that of Higuchi method. Also it is observed that the MRBC methods are comparatively faster than Higuchi, Katz and Sevcik's method as illustrated in Raghavendra et al [3]. In this approach, Spectral Response curve is covered with a collection of area elements called square boxes, and the number of elements of a given size is counted to see how many of them are necessary to completely cover the curve. This can be expressed mathematically as

$$D_B = \lim_{r \to 0} \left(\log (N(r)) / \log (1/r)\right)$$

Where $N(r)$ is total number of boxes of size r required to cover the curve entirely. The box counting algorithm estimates Fractal dimension (FD) of the curve by counting the number of boxes required to cover the curve for several box sizes, and fitting a straight line to the log-log plot of $N(r)$ versus r. That is

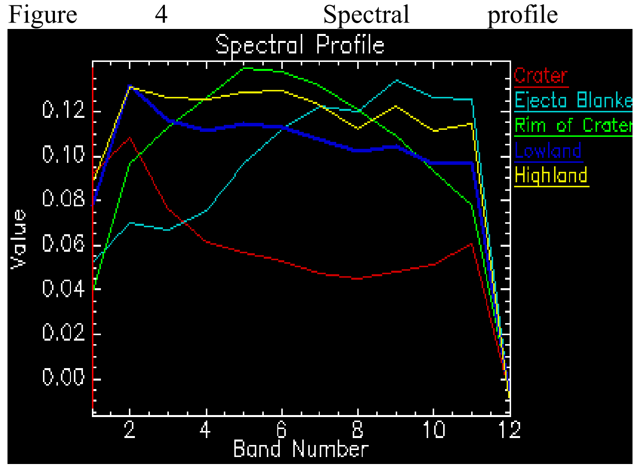
$\log N(r) = DB \log(1 / r) + C$, where C is a constant. The slope of the least square best fit straight line is taken as an estimate of the box counting dimension DB of the curve [3]. But before dimension reduction Preprocessing is necessary in hyperspecrtal data processing, as illustrated in [9]. It involves two steps: First, Removal of Bad bands, the bands from 1-2, 39-41 and 64 are deleted since they were bad bands and stripping effects were observed in them. Second, Smoothing using lowpass filtering of the spectral response curve followed with interpolation using cubic spline interpolation [10]. The later step is performed to increase the number of data points available on each SRC. Now by using MRBC method of dimension reduction the Input Hyperspectral image is reduced to 12 bands and the Spectral response curve of the craters become smooth as shown in figure 4.

Now for the classification of the reduced image ISODATA (Iterative Self Organising Data Analysis Technique A) algorithm of Unsupervised classification is used because we do not have the ground truth. Next step is Acuracy Assesment of the classified image. It is done by comparing the classified image with the Region of interest of different classes in orignal dataset with the classified image the region of interest are selcted on the basis of the Spectral curve of the different features on image as shown in figure 5.

5. OBSERVATIONS

Classified Image has five classes the red class represent the craters on the lunar surface, it has the most posiblity of showing error of commision and omision with green class i.e. rim area of the crater. But in this classification we are not able to distinguish between the simple crater and the irregular crater because both craters have allmost the same Spectral response curve. Class represented by cyan , blue and yellow colour are ejecta blanket low lands and highlands respectively as shown in Figure 6.

Figure 4 Spectral profile of



different classes in MRBC reduced Image

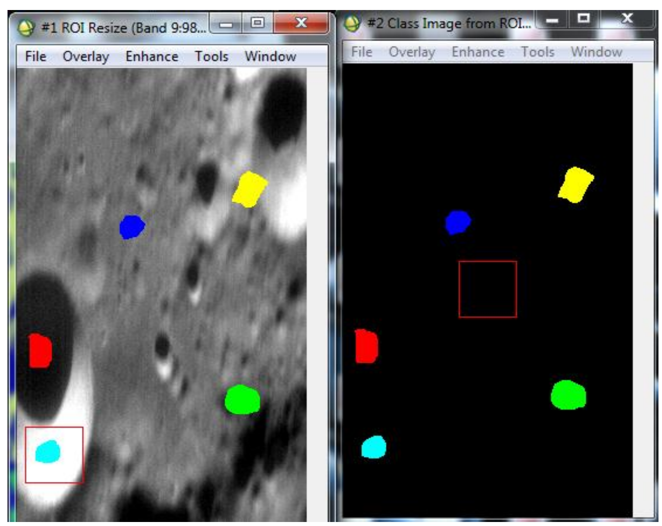


Figure 5 ROI's of Different classes

6. RESULT

Acuracy assesment of the classified image shows that it has overall accuracy of 84.180 %. It also shows that Craters are classified with highest accuracy of 93.85 % and lowlands are classified with lowest accuracy of 71.98 % and it also has greater error of commision i.e. 28.01%. Error of omission is highest in Ejecta Blanket class of 27.33 %. Kappa coefficient calculated from it is 0.8129 Error matrix of the classified image is given in Table 1.

Table 1 Error Matrix

class	Region 1	Region 2	Region 3	Region 4	Region 5	Total
Red	489	32	0	0	0	521
Green	29	311	21	0	0	361
Blue	0	0	519	115	87	721
Yellow	0	0	51	440	36	527
Cyan	0	0	0	21	327	348
Total	518	343	591	576	450	2478

7. DISCUSSION

In the classified image well defined boundary of craters is not seen when compared to the high spatial resolution images and also it is not able to distinguish between the simple crater and irregular crater formed by multiple impact of asteroid or meteor because in the dimensionally reduced data both have the same spectral response curve i.e. from this data we cannot distinguish by using spectral properties but by using spatial property i.e shape and irregularity of shape we can distinguish between irregular crater and simple crater.

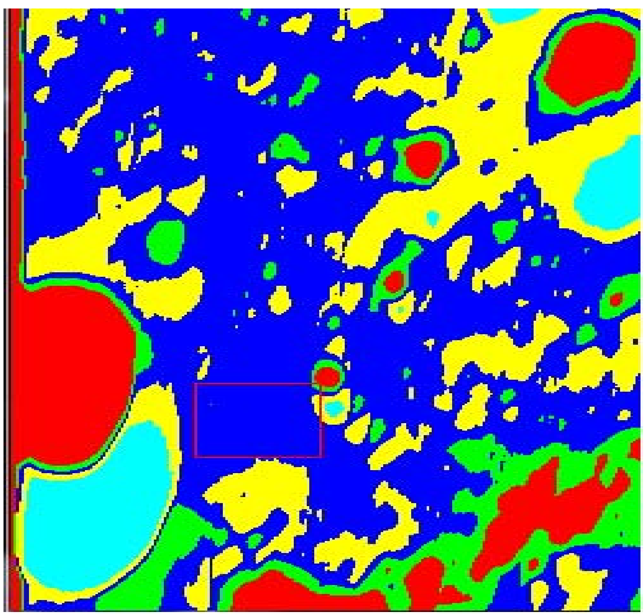


Figure 6 Classified Image of Reduced data

8. CONCLUSION

The hyperspectral spectral image HySI acquired by Chandrayaan-1 serve as a highly valuable image data for identification of craters over large area at the spatial resolution of 80 meter . Further HySI data has redundancy in it but it can be concluded that the Multiresolution Box Counting Method fractal based approaches of dimensionality reduction of HySI data, which applied on spectral space are able to reduce the dimensionality of hyperspectral data with high classification accuracy specially of crater class i.e. it able to identify the craters in the HySI image dimensionally reduced to 12 band and with much reduced computational burden than the Orignal data of 64 bands.

Future scope of this study is to distinguish irregular crater from simple crater by using HySI data on the basis of Geometric properties like irregularity in shape.

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