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Performance evaluation of lineament extraction methods in ASTER satellite images

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Abstract

Minerals mapping has been studied for many years. Remote sensing image acquired from the ASTER sensor has great potential to map the minerals prospective area on earth accurately. Various methods, algorithms are proposed for exploration of minerals by detecting geologic lineaments in the study area. The aim of this study is to compare the performance of lineament detection methods like Hough transform, Mask Based Clustering (MBC), Fuzzy C-Means Clustering (FCM) and the Lineament Identification (LI) algorithm in the context of locating the mineral potential zones from the given input image. Hough transform is the first and foremost line extracting algorithm. It maps lines from the given input image, but it is not at all correlated with the lineaments obtained using other methods. And also, lines differ from lineaments which describe the geological features of the earth. From the statistical result analysis of this work depicts 80 % of micro lineaments are extracted by MBC method, 40% of macro lineaments are targeted by FCM algorithm and LI algorithm segments 54% of micro lineaments and also 40% of macro lineaments. MBC method detected a good number of micro lineaments but failed to map moderate and macro lineaments. FCM algorithm over-segments the lineaments which average the frequency of all classes of lineaments. Finally, LI algorithm targets the optimum number of lineaments and also results in the maximum total length of lineaments. Thus, the LI algorithm is found to be the most appropriate method for extracting lineaments from the given satellite image when compared with the other two methods examined here.

Keywords: Lineament, ASTER, Mask based Clustering, LI algorithm,

INTRODUCTION

Remote sensing and Geographical Information System [1] is widely used in various applications like civil engineering, urban planning, geology, hydrogeology, and tectonic studies, etc., conventionally, mapping of lineaments can be done either by automatic, or manual interpretation techniques. This kind of techniques examines the geomorphological features, tectonic features, rock patterns, drainage networks and vegetation patterns. Most of the existing works dealt with the lineaments extraction alone. In geology, features extracted from the lineaments like length and frequency are significant to solve the problems raised during pre-exploration activities. Crowded micro lineaments alone with the macro lines are the best place for minerals exploration. The Accuracy of lineament mapping is affected by several factors including the sensor characteristics, illumination effect, clouds, etc., Geophysical analysis [2, 3] is done to evaluate the groundwater potential, and the validation of the analysis is carried out with the topological map of the area. From the detailed survey of the literature, most of the tectonic lineaments are extracted using edge enhancement and segmentation techniques [4]. The resultant edge maps are further processed to know the statistical parameters of the lineaments. There are various image segmentation techniques available where the neighboring pixels with similar values are merged to form a segment [5]. However, this kind of segmentation results in either over-segmented region or under-segmented regions. Because of this, a new algorithm named Mask Based Clustering (MBC) is developed to cluster/segment the object of interest. Another method called lineament Identification algorithm is developed to extract and classify the lineaments from the input image, and also the performance of these two algorithms are compared with the existing methods (Hough transform and FCM) and portrays the performance evaluation chart with the resultant data. It can also be validated with the geological map of the study area. The following sections of this paper

MATERIALS USED

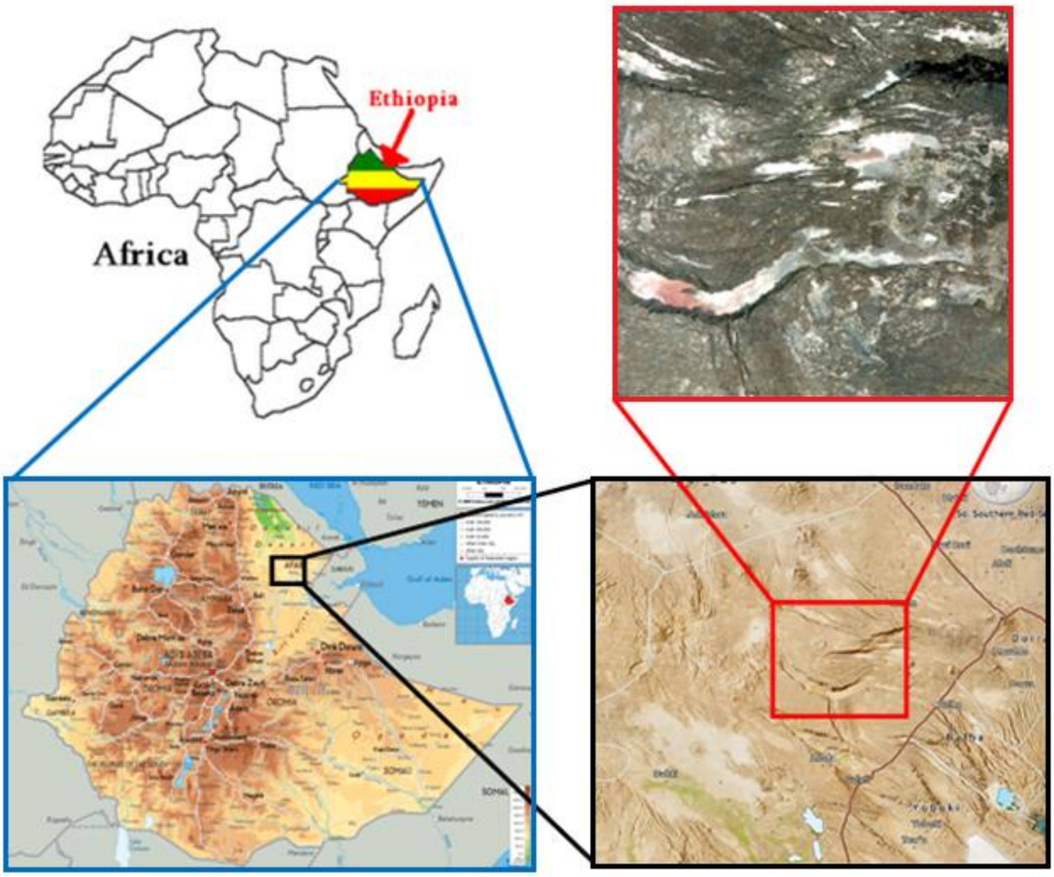
(i) ASTER Image Dataset

The successful launch of ASTER satellite contributes more towards the advancement of the remote sensing industry by providing excellent details of various spectral bands, more frequent revisits, low-cost image acquisition, and greater imaging flexibility.

ASTER is an Advanced Spaceborne Thermal Emission and Reflection Radiometer; a multispectral imager which covers a broad spectral region of the electromagnetic spectrum from the Visible Near Infra Red (VNIR) to the Thermal Infra Red (TIR). It can accurately map lithologic and mineralogical units on the surface. Regarding the dataset, the images are collected from the NASA website, and it is freely available to the researchers.

(ii) Study Area

The Afar depression [6, 7] is the region located near the East African Rift in Ethiopia, Africa. It is one of the lowest altitude locations on earth. This Afar is slowly being moved up every year. It contains most of the basaltic lava. This place has the significance in the field of geology to know the formation of the earth since only the mid-ocean ridge can be studied on the land surface. The ASTER sensor captured this image on March 2002 which covers 3500 sq.kms.



[Fig.1] Location map of the Study area – Afar Depression, Ethiopia, Africa

METHODS USED

(i) Hough transform

Hough transform is the basic and commonly used method to detect the lines from the high-resolution image. It is reliable and computationally efficient in extracting line segments from an edge image. It is based on accumulator cells [8] which record all possible shapes passing through each extracted edge point. In this technique, the image is binarized with the help of thresholding method [9]. Every point in the image at an angle θ and distance d from the origin of the line gives the density of the point along the line segment. While detecting lines from the image, it doesn't provide any information regarding length and end points of the extracted lines. It is essential to know the length and end points of the lines in the geological context.

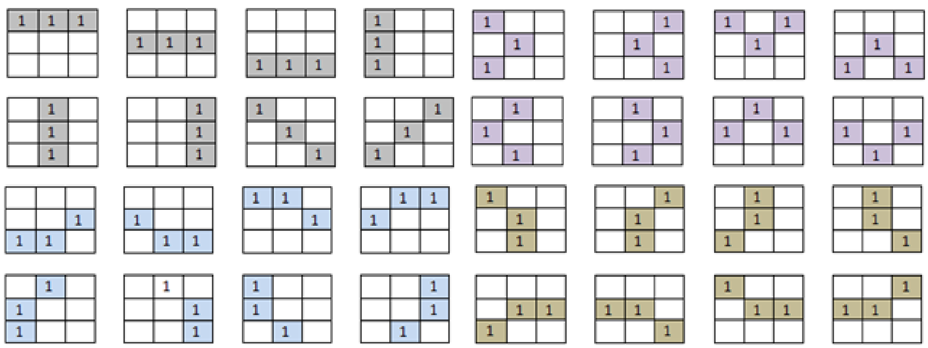
(i) Fuzzy C Means clustering

Fuzzy c means algorithm [10] is a combination of fuzzy algorithm and clustering algorithm. It is one of the dyanmic image segmentation algorithms based on clustering of objects of interest in the input image [11]. It performs clustering by recursively searching the set of fuzzy clusters [12, 13], and it's corresponding cluster centers which show the exact structure of the group. Two types of clusters (high-density and low-density regions) of irregular shape need to be extracted. An adaptive algorithm seeks the direction of maximum scatters which is independent of the dimension of the linear varieties.

(ii) Mask based Clustering

Retrieving geologic lineaments such as faults, fractures, folds from the ASTER satellite image is difficult since the Multispectral image contains various colors, so that, the lineaments can be represented in the form of vector masks. A vector mask is a resolution independent path that embeds the contents of the image. Building and applying Mask for clustering is done by the following steps

1. Build image masks with specific data values including the data ignore values; this can be any combination of input to define a mask.



[Fig.2] 32 Combinations of 3x3 Masks

2. Determine the size of the mask (3x3) and set the minimum and maximum value of pixels and set the finite values for the pixels of the mask. Pixel range of the mask is based on the pixels that are in the data range of Input Image.
3. Divide the mask into four parts using Discrete Wavelet Transform (DWT) based on the image attribute to get better intensity
4. Mask Data Values: Build a mask that includes all the pixels for which the data ignore values occurs in all bands (a logical OR operation). Mask Data Ignore Values: Build a mask that includes all pixels which have a NULL value as Data Ignore Value on all bands (a logical OR operation).
5. Cluster the image by embedding the mask image with the input image. Set the mask value in the input image to group similar areas (checking the pixel values of the mask with the pixel values of the input image).

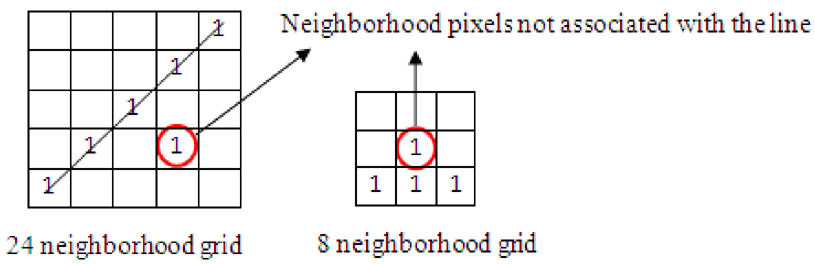
(iii) Regional level lineament extraction

It is termed as the process of dividing the image into non-overlapping equal sized blocks of size m x m. Initially, the entire image is considered as a single block, and then computes m/2 x m/2 square regions for micro level extraction of lineaments. After that, lines are segmented in each sub block. Finally, these blocks are merged to form a whole image. If the block size differs, then the merging process stops and further merging is not possible. It can be done to identify the micro lineaments in the local area.

(iv) Lineament Identification (LI) Algorithm

Most of the existing methods [14] are deal with extracting lineaments on a global scale. Those methods are not focusing on micro lineaments and stockworks; where the probability of occurrence of minerals is very high. For that, a new algorithm is proposed to target all kinds of lineaments (micro, moderate, and macro lineaments) projected at different angles.

1. Scatter matrix is created to check the contribution of a pixel to form a line. Eight neighborhood grid and Twenty Four neighborhood grid is used to find the spatial relationship between the pixels.

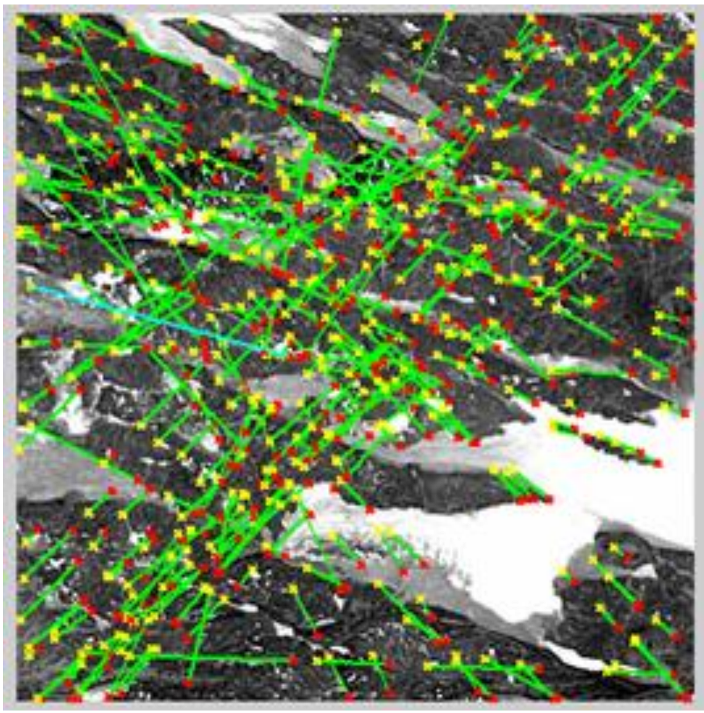


[Fig.3] 24 Neighborhood grid and 8 neighborhood grid

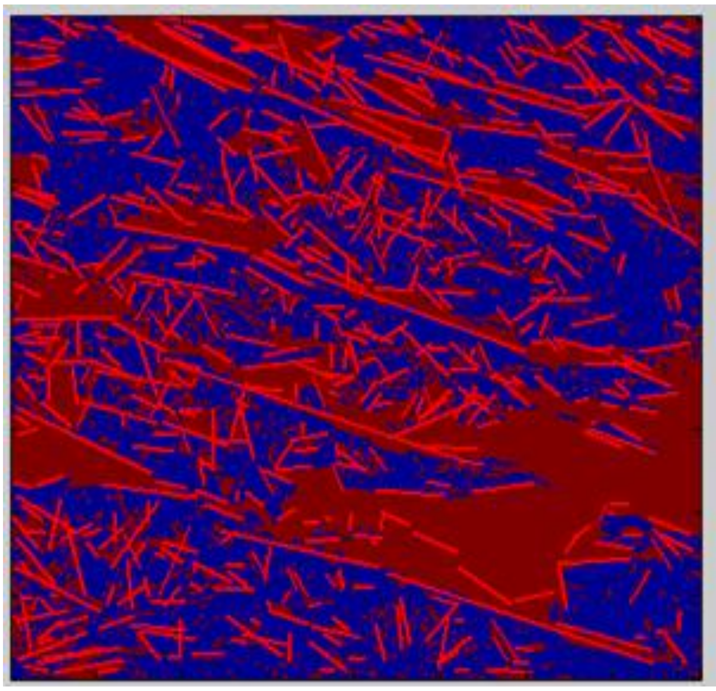
2. The lineament lengths and the number of lineaments are calculated using Euclidean distance measure.
3. After that, lineaments are classified based on its length. It is labeled as micro, moderate and macro lineaments and also the separate color code is applied to differentiate it easily.
4. In this method, micro level lineaments are extracted from the image by splitting the image into grids. Extracted lineaments may lie on more than one grid. It can be joined during the grid merging process.
5. To map the stockworks, set the cross point pixel as the cumulative successive difference between the pair of an adjacent pixel belonging to 8 neighborhood grid.

RESULTS AND DISCUSSIONS

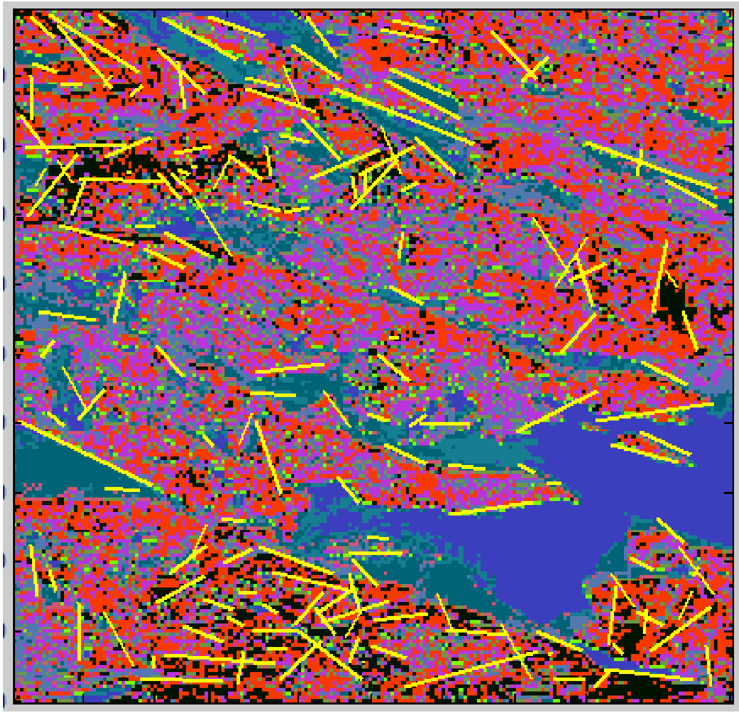
A group of four lineament extraction methods (Hough, MBC, FCM, and LI) is applied to an ASTER satellite image of Afar Depression, Ethiopia. Here, the results and its interpretations are discussed. From the qualitative and quantitative assessments of these three methods, LI algorithm performs better regarding an optimum number of lineaments which are extracted from the study area. As 54% of micro lineaments, 16% of moderate lineaments and 30% of macro lineaments are segmented which is superior concerning find stockworks. Stockworks is the area where the group of small lineaments along with the major fault line. MBC method results with the detection of 80% of micro lineaments, 8 % of moderate lineaments, and 12 % of macro lineaments. Even though it produces the highest contribution to micro lineaments, it lacks in identifying macro lineaments. To achieve the stockworks targeting goal, this result may not be useful since micro lineaments along with the major line are needed. Likewise, FCM method extracts 32% of micro lineaments, 29% of moderate lineaments, and 39% of macro lineaments. This process favors in detecting macro lineaments but fails to extract maximum possible micro lineaments. With this, Lineament Identification (LI) algorithm proposed in this work overcome these two issues and providing excellent results, and it is strongly recommended to target stockworks from the obtained results.



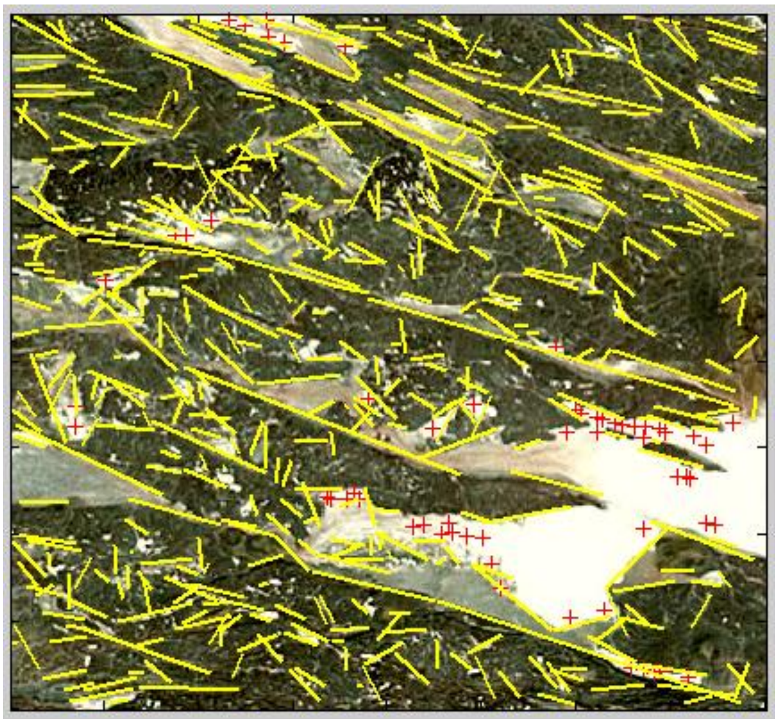
[Fig.4.a] Lineaments extracted using Hough Transform



[Fig.4.b] Lineaments extracted using FCM Method



[Fig.4.c] Lineaments extracted using Mask Based Clustering



[Fig.4.d] Lineaments extracted using LI Algorithm

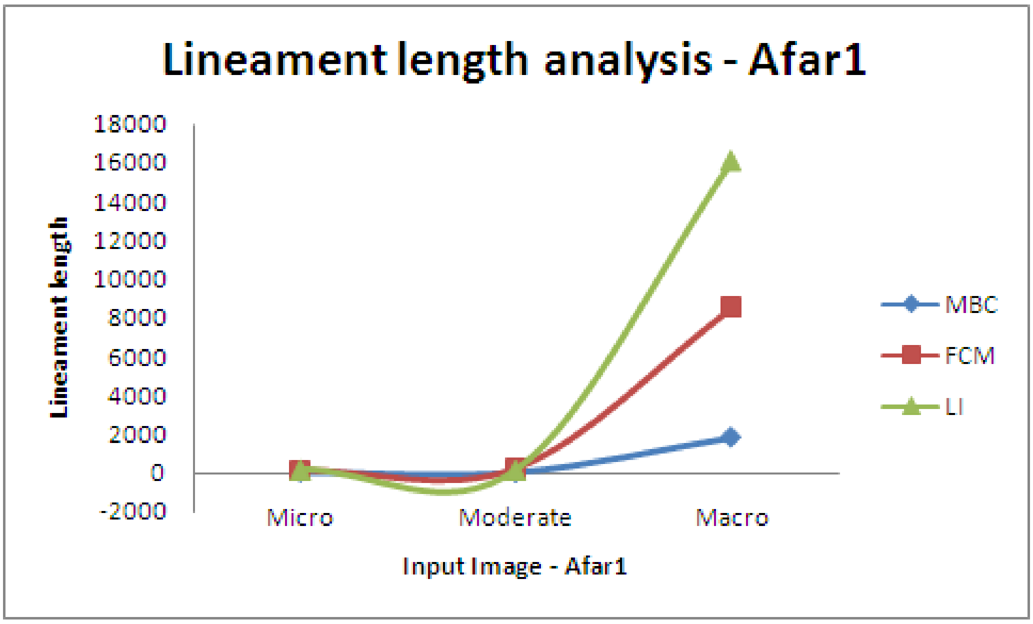
[Table.1] Resultant values of Lineament length analysis

AFAR1	Micro	Moderate	Macro
MBC	47.14	30.68	1852.35
FCM	144.82	253.65	8510.26
LIST	166.42	157.67	16105.6

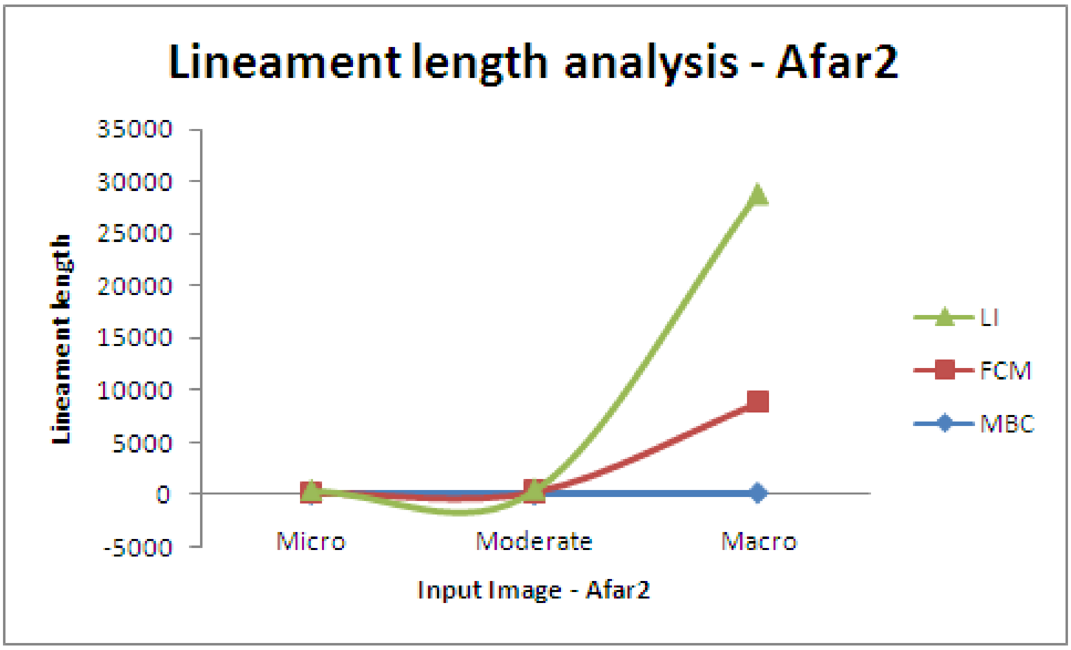
AFAR2	Micro	Moderate	Macro
MBC	42.25	19.53	167.74
FCM	143.44	271.47	8700.74
LI	184.56	181.86	20006.8

AFAR3	Micro	Moderate	Macro
MBC	42.69	34.91	1621.55
FCM	150.7	259.57	5012.36
LI	178.77	184.83	10951.2

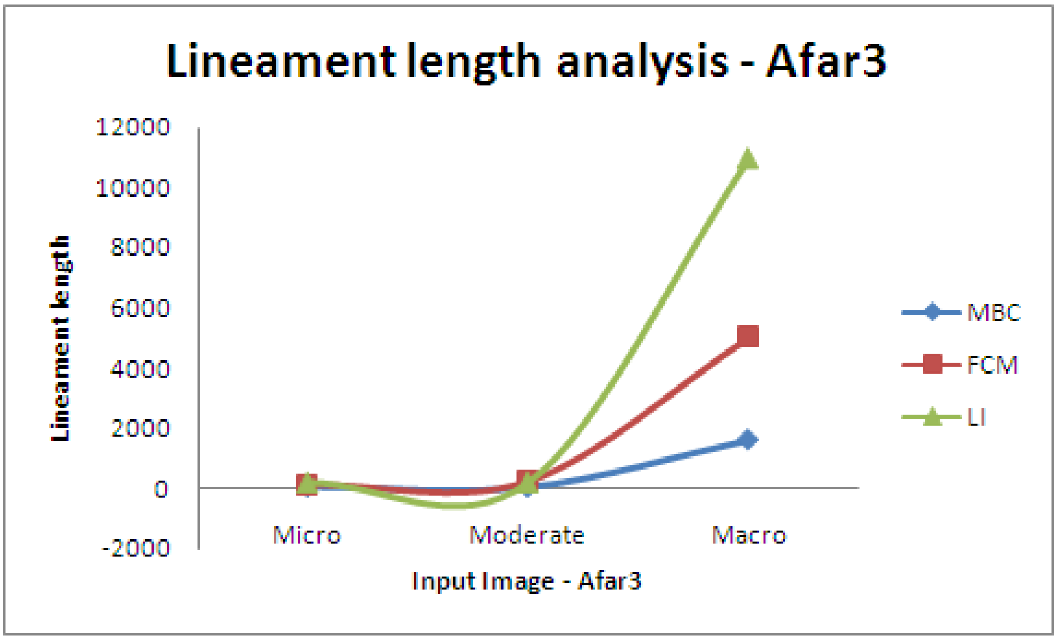
AFAR4	Micro	Moderate	Macro
MBC	75.52	41.5	249.48
FCM	175.88	347.2	4294.33
LI	237.45	242.9	5646.35



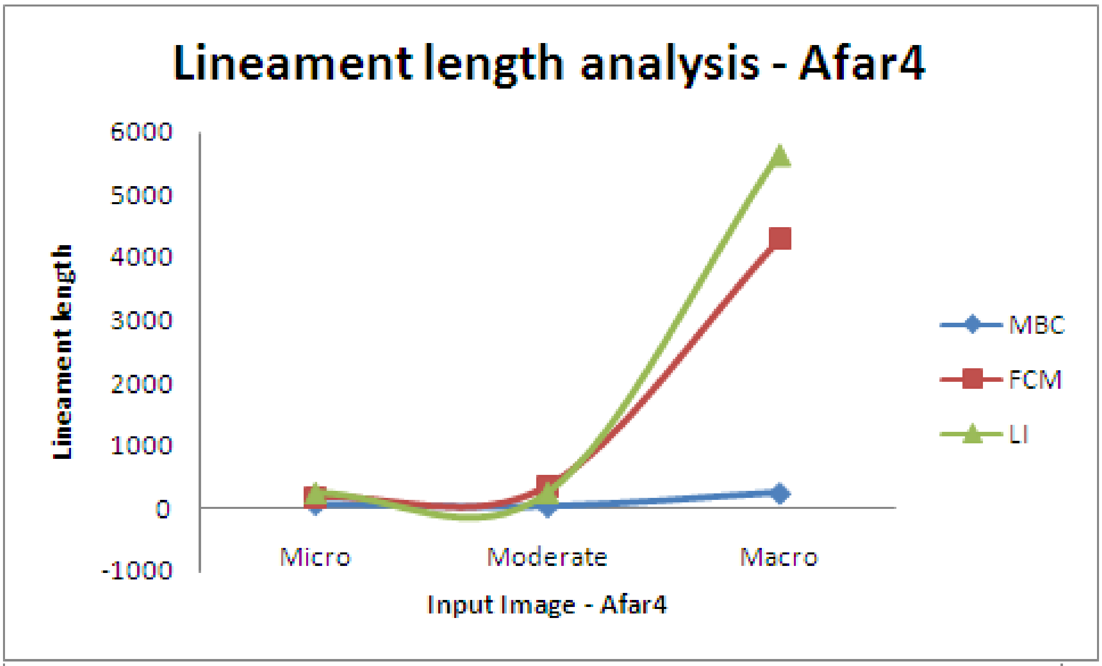
[Fig.5.a] Lineament Length analysis – Afar1 image



[Fig.5.b] Lineament Length analysis – Afar2 image



[Fig.5.c] Lineament Length analysis – Afar3 image

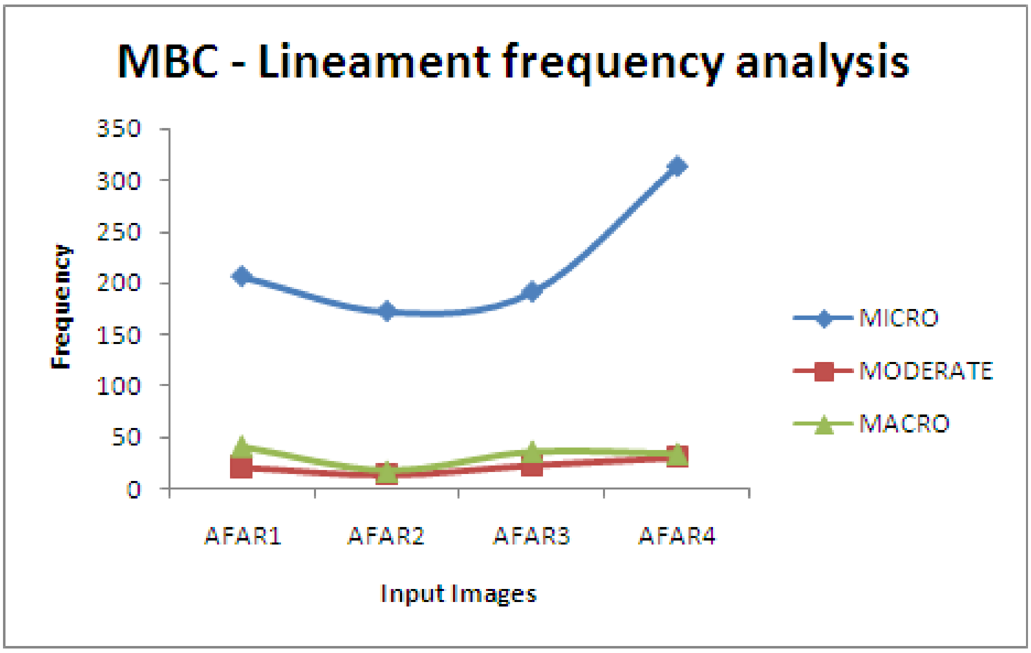


[Fig.5.d] Lineament Length analysis – Afar4 image

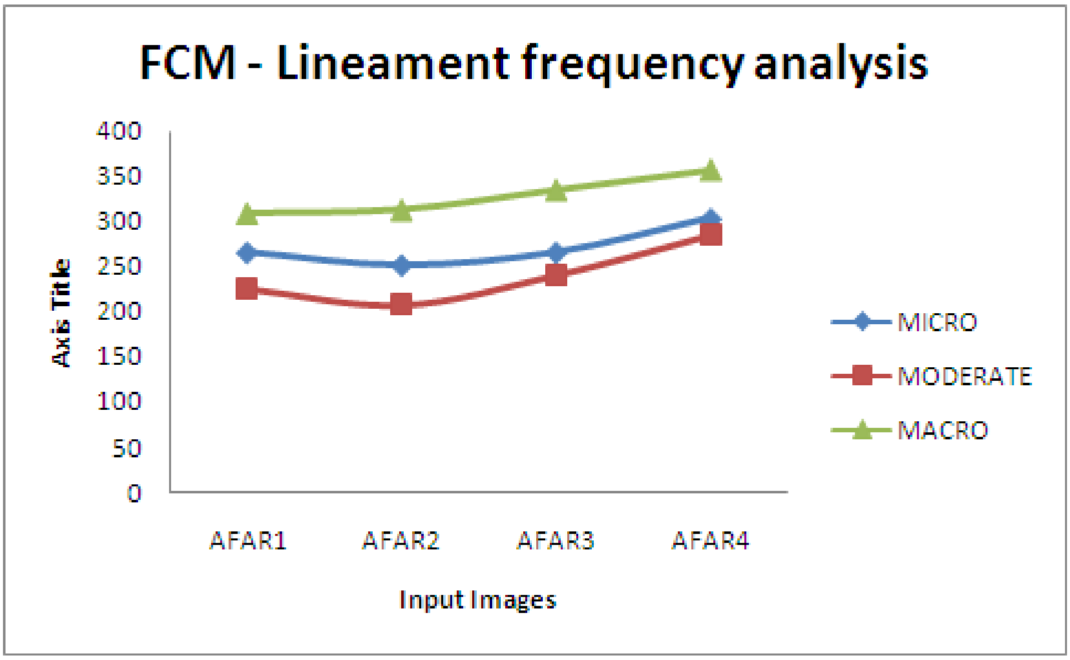
[Table.2] Resultant values of Lineament frequency analysis

Lineament frequency table

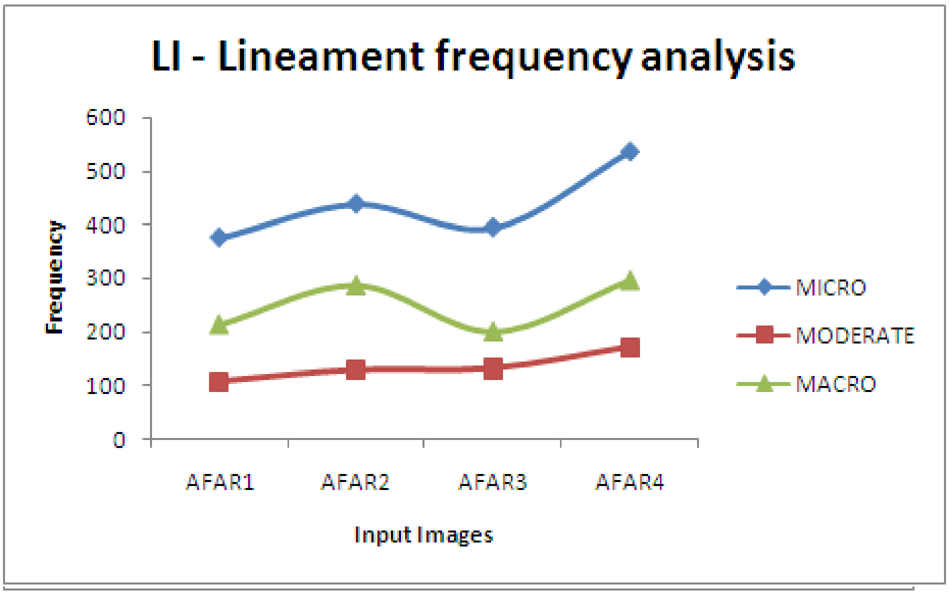
Mask based Clustering (MBC)				
Image	Micro	Moderate	Macro	Total
AFAR1	206	21	41	268
AFAR2	172	14	17	203
AFAR3	191	23	36	250
AFAR4	313	30	34	377
Fuzzy C Means Clustering (FCM)				
Image	Micro	Moderate	Macro	Total
AFAR1	266	226	309	801
AFAR2	252	208	313	773
AFAR3	266	241	335	842
AFAR4	303	285	357	945
Lineament Identification Algorithm (LI)				
	Micro	Moderate	Macro	
AFAR1	375	108	214	697
AFAR2	438	129	287	854
AFAR3	394	132	201	727
AFAR4	536	171	296	1003



[Fig.6.a] Lineament frequency analysis in MBC Method



[Fig.6.b] Lineament frequency analysis in FCM Method



[Fig.6.c] Lineament frequency analysis in LI Algorithm

CONCLUSION & FUTURE ENHANCEMENT

To narrow down the search area in the field of geological mining [15], identification of faults zones, fractures, and stockworks in the study area is essential. In view of this, applying lineament extraction algorithms in the ASTER satellite image is implemented to map the line segments which follow the terrain topography. It leads to the exact representation of geologic faults/fractures. The length and frequency measure of these lineaments play a vital role in mineralization. From these experiments, it has been observed that the appropriate representation of lineaments and the stockworks and its corresponding density maps play a very crucial role in the field of mineralization. Four methods are examined here. Out of these methods except Hough transform, all the other methods extract geologic lineaments to the certain extent. MBC algorithm concentrates on micro lineament, FCM algorithm focuses macro lineaments, and the LI algorithm extracts all the classes of lineaments effeciently. This result is validated with the help of Geologic survey map of Afar depression. Most of the micro lineaments extracted here are not specified on the Geologic map since it is in global scale level. LI algorithm is highly recommended to find the faults features on local scale. This will help to find stockworks. This can be improvised in the future to target stockworks.

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