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Comparison of directional and non-directional filter techniques for lineament extraction using landsat-8 OLI to study active tectonics in parts of Northwestern HFT

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Abstract

Himalayan Frontal Thrust (HFT), states the present day physiographic and tectonic frontier amongst the Indian plate and the Himalayan orogeny. It illustrates seismically active faults and connected upliftment which represents a zone of active tectonics between the Siwalik Hills and the Indo-Gangetic Plain. In the foothills of Siwalik along HFT, numerous active fractures have caused several major and destructive earthquakes, it lies under seismic zone IV. The north-western part of Sub-Himalaya is a well-populated area like Chandigarh and small towns and villages near Pinjore dun. A moderate earthquake might produce extensive damages so, the mapping of such seismogenic areas are crucial for mitigation of seismic risk. Lineament mapping with remote sensing data by image processing techniques is a most useful method for the mapping of the structural and tectonic setting of the area. The lineaments are a very good geological and structural indicator to assess general and local trends of deformation and fracture zones in the rocks. Filtering is an image enhancement technique, which is used for edge enhancement of the image. In this work, a comparison of directional and non-directional filtering technique has been made to extract lineaments in parts of northwestern HFT adjacent Ghaggar river. In non-directional filter technique Laplacian filter is used for the linear feature analysis. The filter is a technique of altering/enhancing an image to emphasize certain features or suppress other features. The analysis is carried out by using band 6 of Landsat-8 data, which is automatically processed in LINE component of PCI Geomatica to extract the lineaments. Lineaments extracted by both filter techniques are verified from the,manually digitized geological map. The results observed that lineament extraction with directional filtering gives a better result than non-directional filter techniques.

Keywords: HFT, Landsat-8 OLI, directional filter, non-directional filter, PCI Geomatica.

Introduction

The Himalaya is seismically one of the most active terranes in the world[1]. Due to the collision of Indian and Eurasian plates, the ongoing tectonic activity along three major faults viz. MCT, MBT and HFT of Himalaya, often generate large and destructive earthquakes[2]. The major earthquakes and related hazards along these faults affect not only the Himalaya but also the adjacent alluvial plains. Himalayan Frontal Thrust (HFT) is a tectono-physiographic boundary in the Sub-Himalayan region which separates Siwaliks fromadjoiningIndo-Gangeticplain[3]. HFT represent sextant and southernmost major tectonic boundary between India and Himalayan orogeny[4,5]. The Sub-Himalayan zone is characterized by various deformational features like fault scarps, large active anticline structures, surface ruptures, and offsets which indicate that the Himalayan Frontal Thrust (HFT) is active[4-6]. Extensive fractured areas and associated upliftment along HFT signify a region of active tectonics among the Siwalik Hills and the Indo-Gangetic Plain[7]. The Himalayan foothills lie under seismic zone IV. A moderate earthquake may produce great destruction due to the high acquaintance of urbanization. So, the identification and characterization of such seismicity generating sources are vital for moderation of seismic risk. G. Philip et al. reported thatseveral active faults have generated major and great earthquakes in foothills of Siwalik along HFT[8-10]. Lineament mapping technique of remote sensing has been widely used to interpret the structure of active tectonic fault zones and monitor ground deformations[11]. Lineament mapping is an image-processing-based technique, where satellite data is processed for the extraction of linear features. During the data acquisition in satellite images, some of the unwanted information like noise is also recorded. This unwanted informationpresent in the data is removed by the several pre-processing techniques. The filteris a pre-processing technique used to enhance the quality of the image by removing noise and edge enhancement. The purpose of this work is to compare the directional and non-directional filter techniques for the tectonic lineament extraction and interpretation to know the structural and tectonic setting in parts of northwestern, HFT.

In non-directional filters, a Laplacian filter is used to produce a smoothing blur image, and to increase the contrast between bright and dark pixel for producing a sharpened image. The

directional filter is used in all four directions to enhance lineaments and smoothing the image in respective directions.

Materials and methods

Study area: The study area ranges from Abhipur to Bhoj Ponta along north western part of Himalayan Frontal Thrust. It falls between Lat 30°42'0"N - 30°58'0"N and long 76°40'0"E - 77°12'0"E, and covers the 40km square area. Ghaggar is the main river in this area. Geologically area can be divided in three zones Inner Siwalik range, Outer Siwalik range and, Piedmont zones.

Data, Software and Methodology: The research endeavors are accomplished by utilizing Landsat-8 OLI/TIRS data (resolution 30m), path/row (147/39), attained in April 2017. The data transmit two Earth-monitoring sensors, the Operational Land Imager (OLI) and the Thermal Infra Red Scanner (TIRS). Both sensors are operating in different electromagnetic ranges, OLI functions in the visible, NIR and SWIR range and TIRS functions in the thermal infrared range of the electromagnetic spectrum (EMS). In Landsat-8 OLI there are 11 bands whereas Landsat-7 ETM + have only 9 bands. The major variance between Landsat-7 and Landsat-8 is that OLI has two new wavebands; band 1 is in the ultra-blue portion of the EMS for water (coastal/aerosol) studies, while band 9 is in the atmospheric absorption window for better discrimination of cumulus and cirrus clouds. In thermal range ETM has a singleband, it splits into 2 bands in TIRS (bands 10 and 11), which provides greater potential for geological studies based on variation in thermal emissivity of rocks. The main geological implication of the differences of both the data is that the lithological and structural discrimination will be better with OLI because of the narrower bandwidths. The adopted methodology of the work is given in Figure-2.

The Landsat 8 data were processed in ENVI 5.3 and filtered image of band 6 was generated by using directional and non-directional (Laplacian) module of ENVI. Lineaments were extracted automatically with LINE module of PCI Geomatica software and Rockworks software was used for the rose diagram.

Data Processing: Landsat-8 OLI data was processed in various software to achieve the objective. Lands at image of the study area was geometrically co-registered with scanned Topo sheet Map of the study area (scale 1:50,000) and then pan-sharpened to get higher spatial resolution image. In this study two techniques are involved; the first one is edge enhancement (filtering) and second automatic lineament extraction. Edges in the images are linear features like rivers, roads, railway lines, canals, faults, folds, ridges, and valleys. Sometimes the edges/linear features are difficult to identify either due to the poor quality of the image or due to narrow linear features. Such a poor-quality image and narrow linear features in the image can be improved using suitable edge enhancement filtering techniques. Edge enhancement processes (directional and non-directional filtering) are performed in ENVI 5.3 software and lineament was extracted with the help of LINE module of PCI Geomatica. Directional and Laplacian (non-directional) filter tool of Geomorphology and convolution module in ENVI software was used for the edge enhancement. After edge enhancement, the filtered image was imported in Geomatica software for the extraction of linear features. The quality and quantity of extracted lineaments are depending on some elective constraints (RADI, GTHR, LTHR, FTHR, ATHR, DTHR)[12]. RADI (Filter radius): This constraint states the range of the edge detection filter and also regulates the smaller details of the image. The value of RADI ranges from 0 to 8192. GTHR (Gradient threshold): is the threshold to obtaining a binary image through the least gradient level for a pixel of an edge, the parameter value ranges from 0 to 255. LTHR (Length threshold): Stipulates the smallest length of the curve (in pixels) to be measured as lineament. FTHR (Line fitting error threshold): is the threshold for the maximum error (in pixels) acceptable in fitting a polyline to a pixel curve. A smallvalue of FTHR gives good fitting but small sections in the polyline. ATHR (Angular difference threshold): is the threshold for the maximum angle (in degrees) among sections of a polyline. This is the maximum angle among two trajectories to be connected. The value varies from 0 to 90. DTHR (Distance linking threshold): This is the smallest distance (in pixels) among the endpoints of two trajectories to be linked[13].

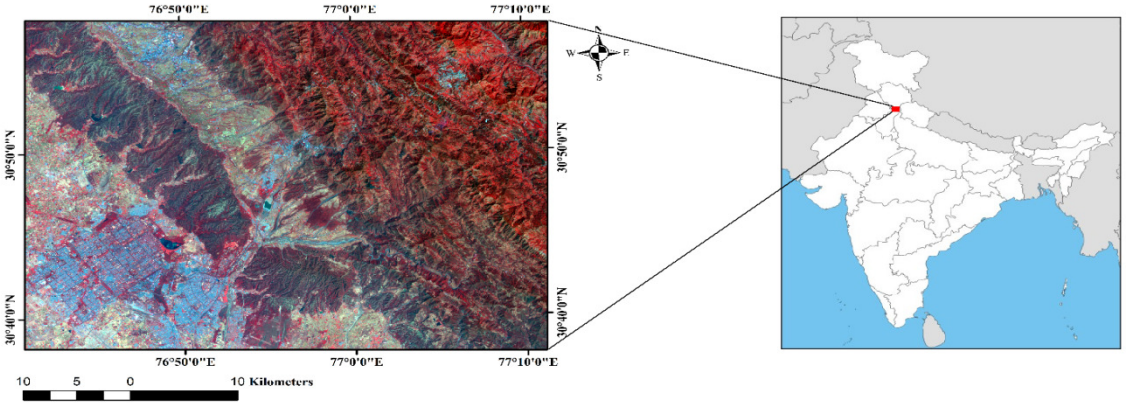

Figure-1: Landsat-8 OLI image displays the location of the study area.

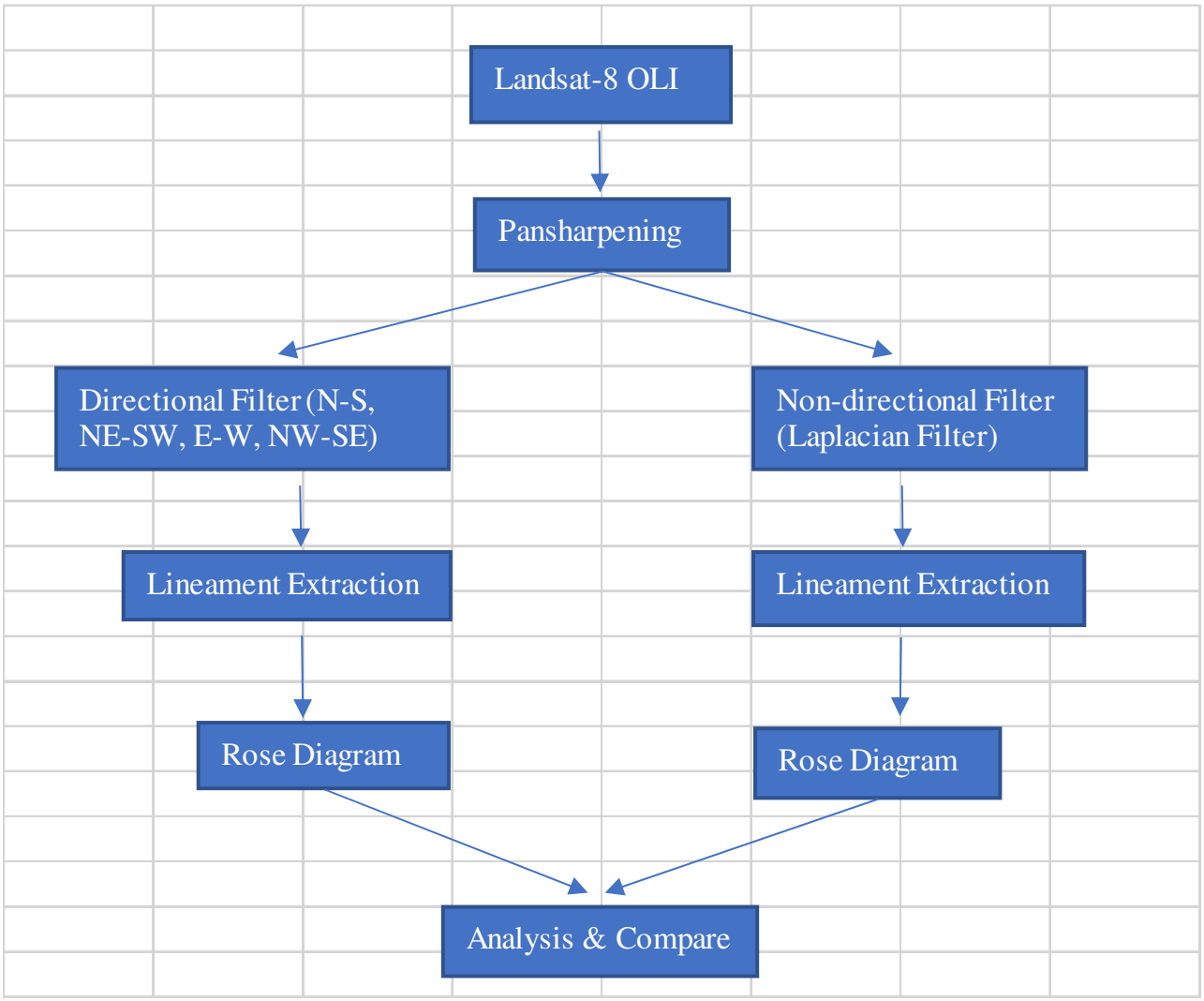

Figure-2: Flowchart of the Methodology.

After lineament extraction from Geomatica the format of extracted lineaments was converted to shapefile. Further, this shape file was exported to the ArcGIS software for the splitting of lineament by using specialist tools. Split lineaments were imported in Rockworks software to generate the rose diagram for azimuth-frequency analysis of the lineaments.

Results and discussion

Edge Enhancement: Edge enhancement was done by using a filtering technique, it enhances the quality of the image in selected arrays of the pixels. Filtering is an extensively adapted technique of image enhancement it reduces the noise and more sharpen them[14]. For image filtration, two types of digital filters were used i.e.: i. Directional filter, ii. Non-directional filter.

Directional filter enhances the linear features which are oriented in the specific direction (oriented in N45E) whereas non-directional filter enhances all linear features oriented indifferent directions.

Directional filter: Directional filter enhances the edges or linear features in a particular direction (N-S, NE-SW, E-W, NW-SE). The direction is specified in degrees with respect to North in which the edges are to be enhanced. In directional filtering, we had taken two kernels of 3x3 pixel size (stated as left and right kernels). The kernel of 3x3 is moved on the whole image and each pixel of the image are multiplied by the kernel coefficients. The obtained filter masks (nine pixels) value are added up for every kernel distinctly. The value added up for the left kernel is multiplied by Sin(A) and the right kernel is multiplied by Cos(A) respectively, where A is the angle quantified. The resulting value of left and right kernels are summed up to obtain the value of the directional filter.

If the alignment of linear features is in the NE orientation direction the directional filter will be negative and if the features are aligned in the NW direction it will be positive. Directional gradient filters detect and enhance edges / linear features in a definite orientation direction (Figure-3).

Non-directional filter: Laplacian Filter: Laplacian filter is a non-directional filter used to enhance edges or linear features of all directions. It is based on the additional three-dimensional derivatives of the pixels. In the Laplacian filter, the size of the kernel located was a 3x3 array of original pixels. Every pixel of the image is multiplied by the original kernel value, the obtained nine kernel value is combined with the central pixel value of the 3x3 array. This number substituted the digital number (DN) of the central pixel and the process is repeated for every pixel of the input image. Laplacian filter enhances linear features of all the directions except the direction of the movement of the filter. Laplacian filter can detect minute tonal variations in the pixel values and hence enhances fine edges and linear features (Figure-4).

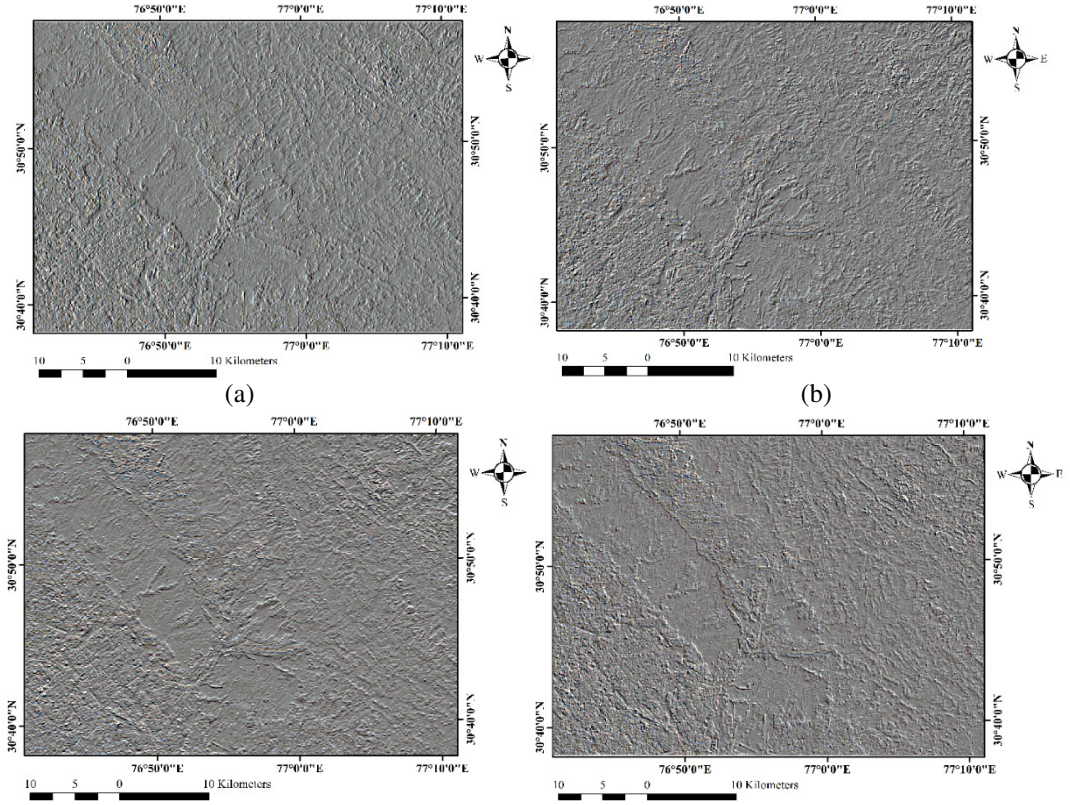

Figure-3: Directional filtered image (a) N-S orientation (b) NE-SW orientation (c) E-W orientation (d) NW-SE orientation.

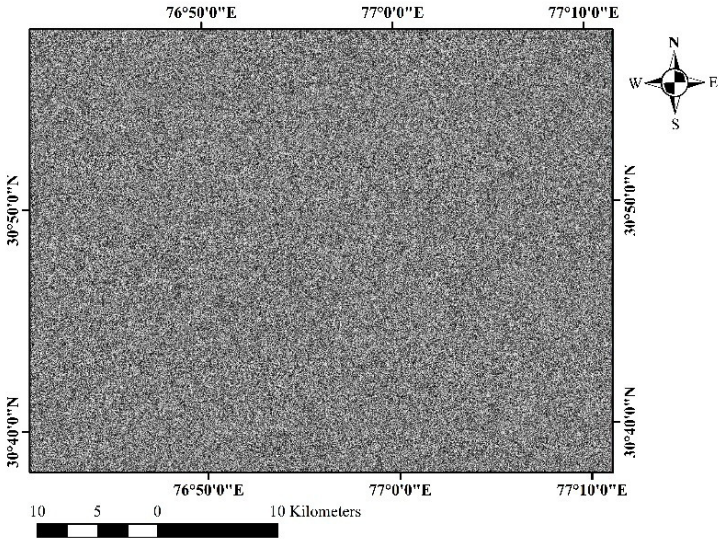

Figure-4: Non-directional (Laplacian) filter.

Automatic Lineament Extraction: The computer-based automatic method was used for lineament extraction of both directional and Laplacian filtered image. The quality and quantity of detected lineaments depend on the input parameters of the LINE module of PCI Geomatica. The procedure of Line module contains three phases: edge detection, thresholding, and curve extraction (A D 2013). This is a very fast and effective technique of lineament extraction, all lineament map generated is shown in Figure-5 and 6.

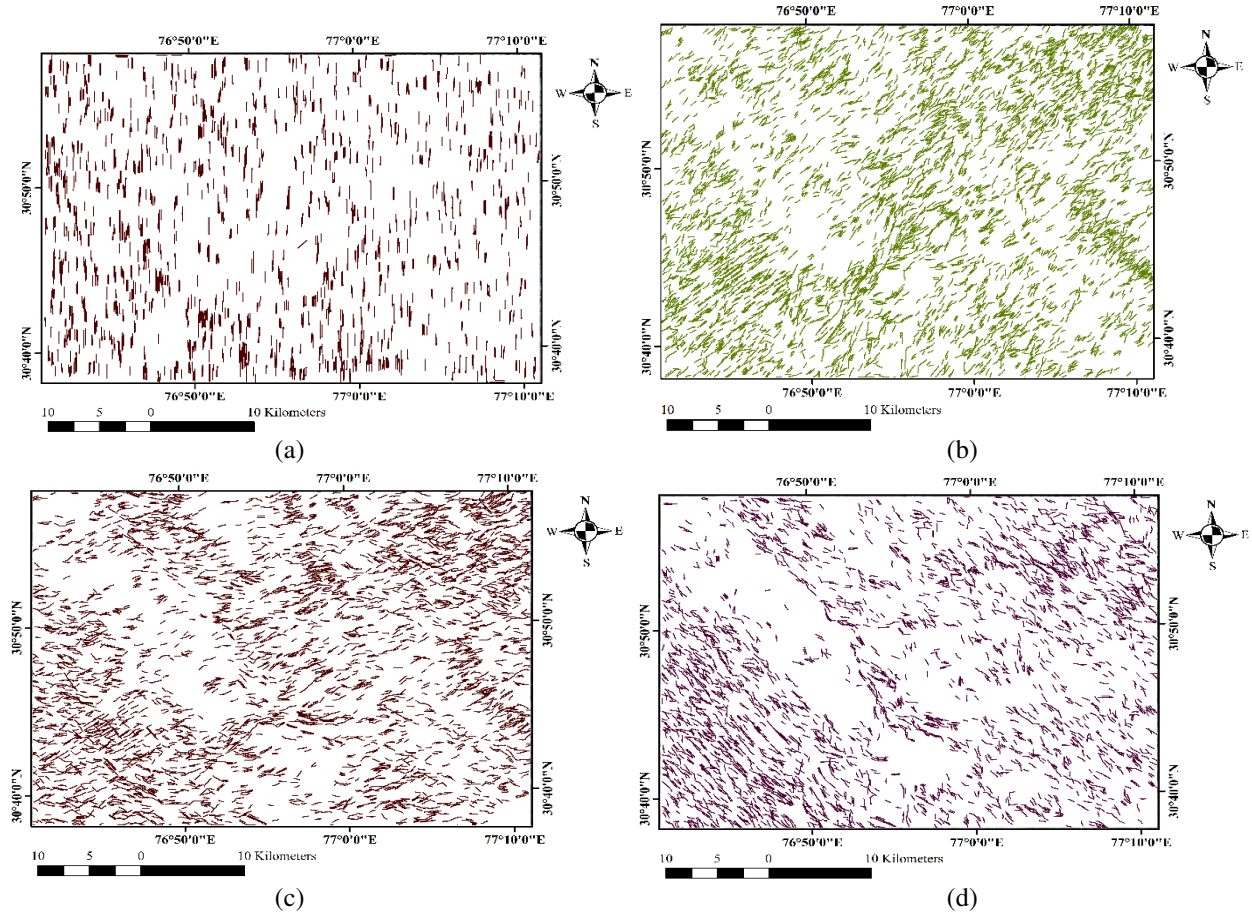

Figure-5: Representation of linear features oriented in a specific direction (a) N-S oriented lineaments (b) NE-SW oriented lineaments (c) E-W oriented lineaments (d) NW-SE oriented lineaments.

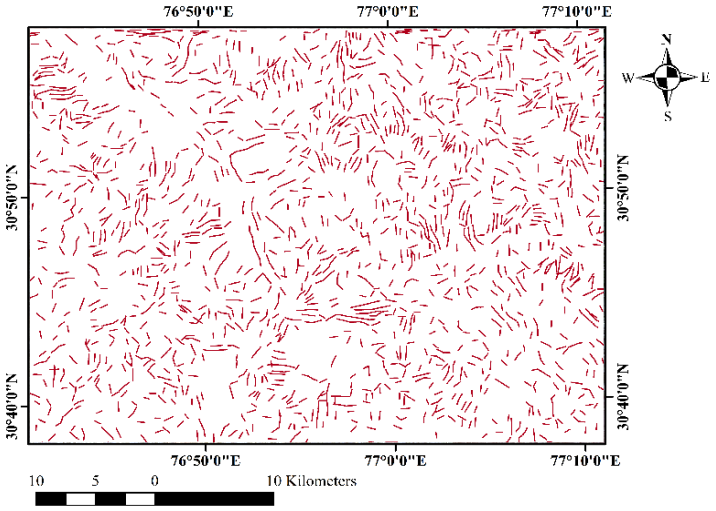

Figure-6: Non-directional linear features extracted from Laplacian filtered image.

Azimuth-frequency (Rose diagram) Analysis: The identified lineaments from the satellite images are subjected to azimuth-frequency analysis to highlight the main directions for the comparison of the structural orientation directions reported in the field. The azimuth-frequency analysis of extracted lineaments of the study area was done by the rose diagram. The digital processing of the satellite images using directional filters provides more detailed complementary structural information than the non-directional filters. The rose diagram of lineaments observed from directionally filtered image shows orientation directions NW-SE, NE-SW, E-W, and N-S (Figure-7), with the predominance of the first direction. However, the rose diagram of lineaments obtained from non-directional techniques (Figure-8), shows a predominant direction of lineaments are in NE-SW direction. This NE-SW direction of lineaments is due to drainage pattern interference in the study area.

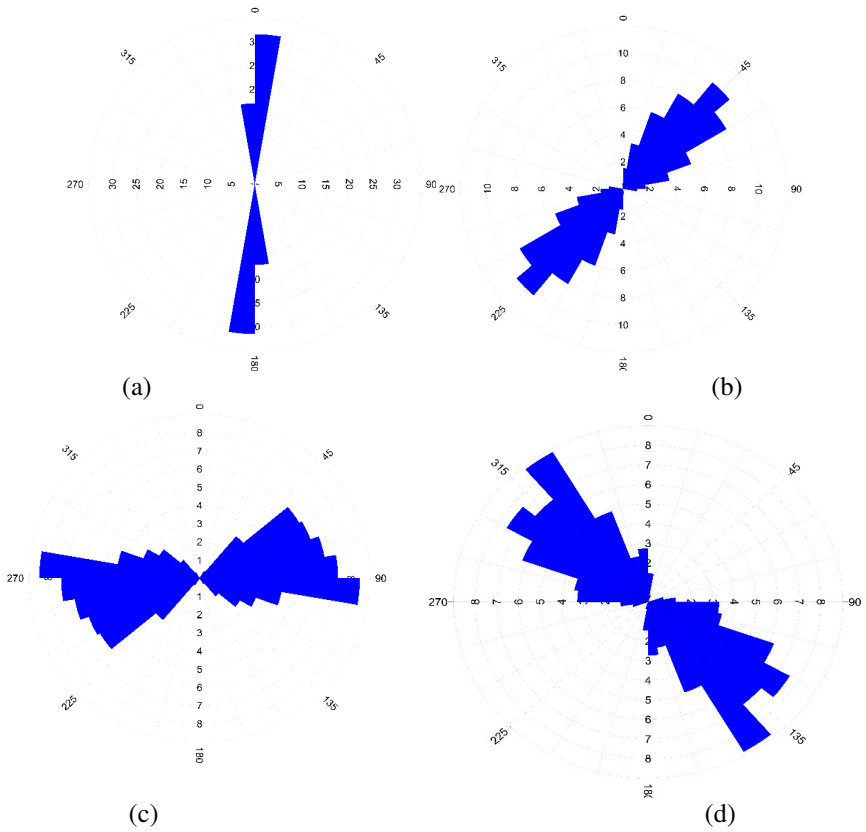

Figure-7: Azimuth-frequency diagram of directional lineaments (a) N-S (b) NE-SW (c) E-W (d) NW-SE.

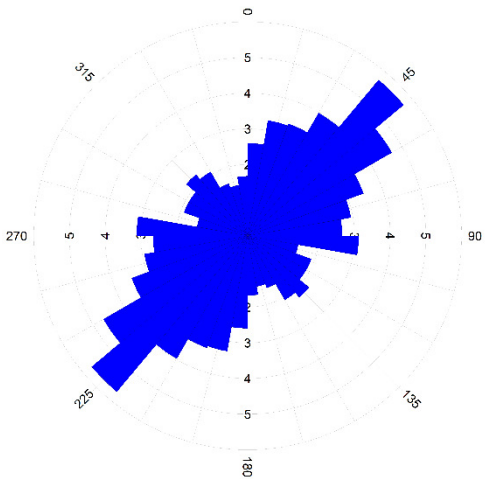

Figure-8: Azimuth-frequency diagram of non directional lineament.

The lineament mapping and rose diagram analysis reveals that the major trend of lineaments is in NW direction which shows the structural and tectonic setting of the area.

Conclusion

From the study, it is concluded that both directional and non-directional filtering technique of edge enhancement gives good result in the lineament mapping of the area. The lineament map and rose diagram analysis shows the majority of linear structures are in NW direction. Directional filtering technique has more relevance than non-directional, as it helps in the mapping of lineaments in a particular direction so it is easy to interpret the structural trend. Directional filtering technique gives a good result for local as well as regional scale lineament mapping. The non-directionaltechnique is good for regional scale analysis as it may create a problem on the local/large scale due to the interference of other linear features like drainage, roads etc.

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