AUTOMATIC DETECTION OF LINEAMENTS

FROM LANDSAT IMAGES IN UNITED ARAB EMIRATE (UAE)

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ABSTARCT

Lineaments play tremendous role for preliminary exploration for characterization of geologic structure, oil exploration and ground water storages. Lineament identifications from remotely sensed data are required standard procedures. This work utilized a new geomatical tool for lineament identification which based on automatic detection algorithms. Integration between Laplacian, edge detection and Canny algorithms with different kernel window sizes is main component of new geomatical tool. The examination area is in mountainous areas of United Arab Emirate. The results show that: Canny algorithm with kernel window size of 3 x 3 pixels and line provides highly precisely lineaments information compared to Laplacian algorithm. Integration between Canny and edge detection algorithms illustrated highly accurate level within RMSE of ± 2 m.

1. INTRODUCTION

Particularly, geological studies are requiring standard methods and procedures to acquire precisely information. However, traditional methods might be difficult to use due to highly earth complex topography. Regarding the previous prospective, the advantage of satellite remote sensing in its application to geology is the wide coverage over the area of interest,

where much accurate and useful information such as structural patterns and spectral features can be extracted from the imagery. Yet, abundance of geological features are not be fully understood. Lineaments are considered the bulk geological features which are still unclear in spite of they are useful for geological analysis in oil exploration. In this sense, the lineament extraction is very important for the application of remote sensing to geology. However the real meaning of lineament is still vague. Lineaments should be discriminated from other line features that are not due to geological structures. In this context, the lineament extraction should be carefully interpreted by geologists. Visual interpretation is imperfect method for liniment extractions from satellite data. Thus researchers and scientists have developed computer packages to acquire precisely liniment features from remotely sensed data.

In referring to Katsuaki et al., (1995); Moore et al., (1998); Walsh (2000) liniment information extractions in satellite images can be divided broadly into three categories: (i) lineament enhancement and lineament extraction for characterization of geologic structure;(ii) image classification to perform geologic mapping or to locate spectrally anomalous zones attributable to mineralization (Mostafa et al., 1995; Süzen and Toprak 1998); and (iii) superposition of satellite images and multiple data such as geological, geochemical, and geophysical data in a geographical information system (Novak and Soulakellis 2000; Semere and Ghebreab 2006). Furthermore, remote sensing data assimilation in real time could be a bulk tool for geological features extraction and mapping. In this context, several investigations currently underway on the assimilation of both passive and active remotely sensed data into automatic detection of significant geological features i.e. liniments. Edge automatic detection algorithms such as Laplacian, Sobel, and Canny are the major geomatica tool for liniment investigation in remotely sensed data. In this study there is integration of different automatic detection algorithms to develop a new approach for liniment detection and mapping.

Approximately 90 % of United Arab Emirate (UAE) is experiencing scarcely of underground water. In fact, highly complex topography features exist in eastern side of UAE which contains huge numbers of liniments and fractures. The discontinuities of groundwater, rainfall recharge and salinity intrusions are recurred due to liniments and fractures. Furthermore, lineaments play an important role in structural controls of groundwater vertical and lateral flow along fault and bedding plans. In this context lineaments are located in the mountainous eastern part of UAE consists of fault zones, fractures influences ground water

recharge especially the area directly adjacent to Oman mountain. In addition, drainage lines in terms of water flow gradually changes direction from eastward to westward and northwest direction around the Bahays, Fayah and Mellihah mountains belt is due to existence of foredeep thrusting front fault zone which extends 75 Km parallel to Oman mountain from north AL Ain city to the north passing through the Al Fayah range Thus underground water discharge into in land sand dunes and Arabian gulf . In this manner, UEA economic might be influenced due to water shortages (Semere and Ghebreab 2006).

The aim of this study is to develop a geomatica tool for lineament feature automatic detection from remotely senses data. The main objectives are (i) to utilize LANDSAT ETM data for lineament extractions and mapping (ii) to determine proper band for mapping lineaments in Landsat data; and (iii) to develop automatic detection tool for lineament extractions;

2. STUDY AREA

The study area is located in Sharjah Emirate about 70 Km from Sharjah city. It is considered in the alluvium plain for central area of UAE and covers an Area of 1800 Km^2 (60 km x 30 km) within boundaries of latitude 25º 00'N - 25º.20'N and 55º.50'E- 56º 10' E (Figure 1). The northern part of UAE (Plates 1 and 2) is composed of the Oman mountains and the marginal hills extends from the base of the mountains and (alluvium plain) to the south western sand dunes. Land geomorphology is consisted of structural form, fluvial, and Aeolian forms(sand dunes). According to JIACA (1997) structural form is broad of the Oman mountains and Jabal Fayah which are folded structure due collusion of oceanic crust and Arabian plate (continental plate). Furthermore, the mountain is raised higher than 400m above sea level and exhibit parallel ridges and high–tilted beds. Many valleys are cut down the mountains, forming narrow clefts and there are also intermittent basins caused by differential erosion. In addition, the Valley bases are formed small caves.
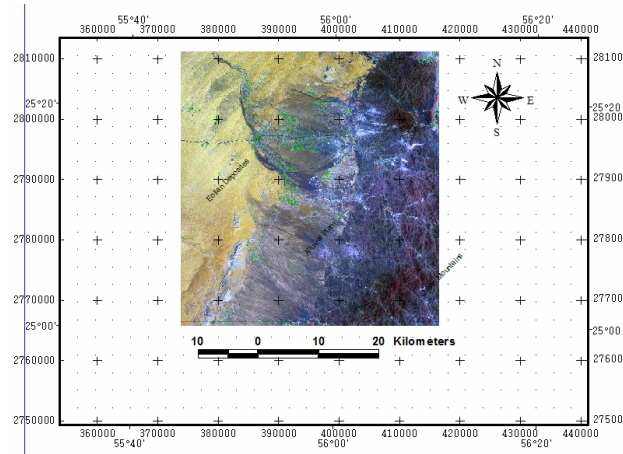
Figure 1 Location of Study Area

Plate 1 Geological Fault Feature on Oman Mountain

Plate 2 Dune Forms on Oman Mountain Base

The fluvial forms are consisted of streams channels which are flowed from Oman mountains have and spread out into several braided channels at the base of the mountains from the Bahada and Playa plains. Stream channels have been diverted to the southwest and they deposited silt in the tongue –shaped playa plain which lies between the dunes. Referring to JIACA (1997) Aeolian forms are extended westwards from the Bahada plain,

where liner dunes run towards north-southwest in parallel branching pattern. Their relative heights are more than 50 meters. Nevertheless, the heights are decreased towards the southeast due to a decrease in sand supply and erosion caused by water occasionally flowing from the Oman mountains. Moreover, some of the linear dunes are quite complex due to the development of rows of star dunes along the top of their axes. Additionally, inter dunes areas are covered by fluvial material which are laid down in the playas formed at the margins of the Bahadas plain near the coastline. The dunes changes their forms to low flats of marine origin and their components are also dominated by bioclastics and quartz sands.

3. METHODOLOGY

3.1 Data Set

In study, there are two sort of data have been used. First is satellite data which is involved LANDSAT Enhanced Thematic Mapper (ETM) image with pixel resolution of 30m Second is ancillary data which are contained digital topographic, geological maps, well loggs and finally ground water data. These data are obtained from UAE ministry of agricultures and UAE University, Department of Geology, respectively. Furthermore, ancillary data such as topography map of scale 1: 25,000.00 used to generate Digital Elevation Model (DEM) of selected area.

3.2 Lineament Extraction Procedures

This section describes the procedures have been used to extract lineaments and drainage pattern from LANDSAT ETM satellite images. In this context, image enhancement contrast, stretching and linear enhancement were applied to acquire an excellent visualization. In addition, automatic detection algorithm such as Soble, Laplace, and Canny are performed to acquire excellent accuracy of lineament extraction.. The flow chart of these procedures is shown in Figure 2. Two procedures have involved to extract lineaments from LANDSAT ETM data. First is automatic detection by using automatic edge detection algorithm such as Laplace, Soble and Canny algorithms. Prior to implementations of automatic edge detection processing, LANDSAT ETM data are enhanced and then geometrically corrected. Second is manual digitizing of lineaments are visualized after performing appropriate image enhancement tool**.**

3.2.1 Histogram Equalization

Following Gonzalez and Woods (1992) histogram equalization is applied to LANDSAT ETM image to obtain high quality image visualization. An image histogram is an analytic tool used to measure the amplitude distribution of pixels within an image. For example, a histogram can be used to provide a count of the number of pixels at amplitude 0, the number at amplitude 1, and so on. By analyzing the distribution of pixel amplitudes, you can gain some information about the visual appearance of an image. A high-contrast image contains a wide distribution of pixel counts covering the entire amplitude range. A low contrast image has most of the pixel amplitudes congregated in a relatively narrow range (Gonzalez and Woods 1992).
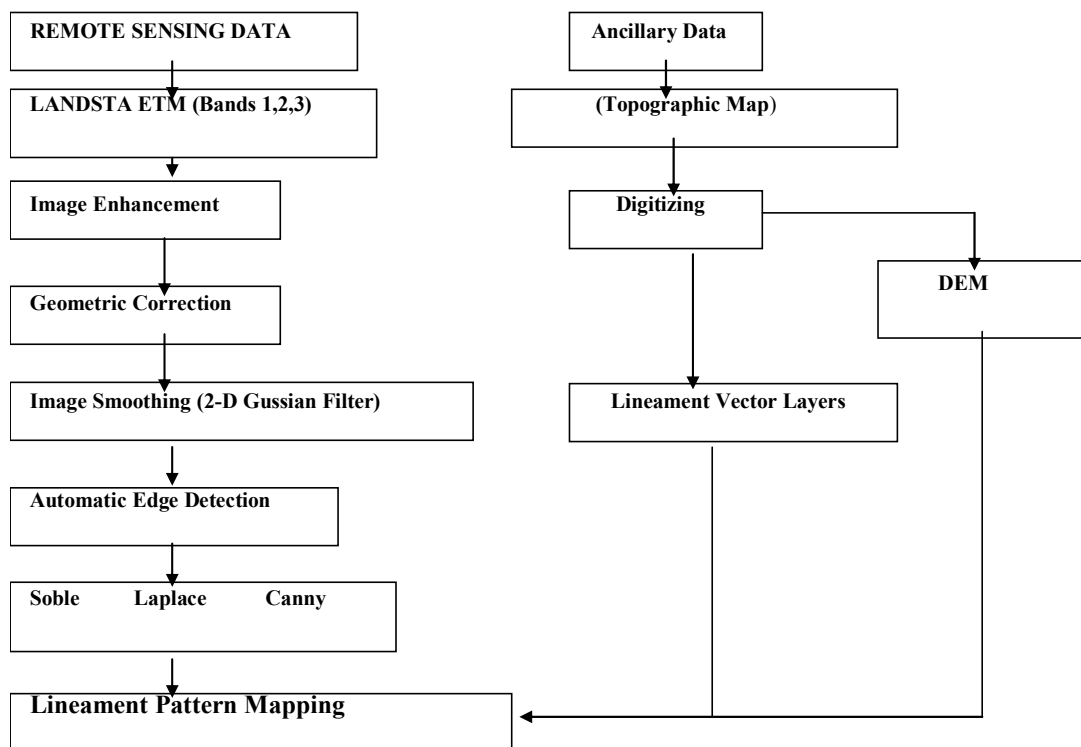
Figure 2 Flow Chart of Procedures are Used for Lineament Patterns Mapping

3.2.2 Automatic Edge Detection

Three automatic edge detection algorithms have been implemented to remote sensing data in this study. Two methods are used to perform automatic edge detection which are involved gradient and Laplacian. The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. In contrast, the Laplacian method searches for zero crossings in the second derivative of the image to find edges. An edge has the one-dimensional shape of a ramp and calculating the derivative of the image can highlight its location.

3.2.2.1 Sobel Operator

This study utilized Sobel operator which made up pair of 3×3 convolution kernels as shown in Figure 3.

Figure 3 Soble Operator Kernel

These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input LANDSAT ETM data, to produce gradient components in raw and lines of image (call these *Gx* and *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. Following Gonzalez and Woods (1992) the gradient magnitude is given by:

$$|G| = \sqrt{Gx^2 + Gy^2}$$

(1.0)

3.2.2.2 Laplacian of Gaussian:

According to Gonzalez and Woods (1992), the Laplacian is a 2-D isotropic measure of the 2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection. The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian Smoothing filter in order to reduce its sensitivity to noise. The operator normally takes a single graylevel image as input and produces another gray-level image as output.

Following Davies (1990) Gonzalez and . Woods (1992) , Laplacian *L(x,y)* of an image with pixel intensity values *I(x,y)* is given by:

$$L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}$$

(2.0)

Since the input LANDSAT ETM image is represented as a set of discrete pixels, we have to find a discrete convolution kernel that can approximate the second derivatives in the definition of the Laplacian. Three commonly used small kernels are shown in Figure 4.

0	1	0
1	−4	1
0	1	0

1	1	1
1	−8	1
1	1	1

−1	2	−1
2	−4	2
−1	2	−1

Figure 4 Three commonly Used Discrete Approximations to the Laplacian Algorithm.

3.2.2.3 Canny Edge Detection Algorithm

Third edge detection algorithm has performed to enhanced LANDSAT ETM image is Canny algorithm. According to Gonzalez and Woods (1992), three criteria are used to improve edge detection. The first and most obvious is low error rate. It is important that edges occurring in images should not be missed and that there be NO responses to non-edges. The second criterion is that the edge points be well localized. In other words, the distance between the edge pixels as found by the detector and the actual edge is to be at a minimum. A third criterion is to have only one response to a single edge. This was implemented because the first 2 were not substantial enough to completely eliminate the possibility of multiple responses to an edge (Davies 1990).

Based on these criteria, the canny edge detector first smoothes the image to eliminate and noise. It then finds the image gradient to highlight regions with high spatial derivatives. The algorithm then tracks along these regions and suppresses any pixel that is not at the maximum (non-maximum suppression). The gradient array is now further reduced by hysteresis. Hysteresis is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two thresholds and if the magnitude is below the first threshold, it is set to zero (made a nonedge). If the magnitude is above the high threshold, it is made an edge. And if the magnitude is between the 2 thresholds, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above threshold. In order to implement the canny edge detector algorithm, a series of steps must be followed. The first step is to filter out any noise in the original image before trying to locate and detect any edges. In fact, the Gaussian filter can be computed using a simple mask, it is used exclusively in the Canny algorithm. Once a suitable mask has been calculated, the Gaussian smoothing can be performed using standard convolution methods.

4. RESULTS AND DISCUSSION

Comparison between Laplacian, Sobel and Canny algorithms is shown in Figure 5. Canny algorithm provided an excellent automatic detection of lineament pattern compared to Laplacian and Sobel algorithms. In fact, Canny algorithm is able to extract linear features from image (Figure 5c) as it produces thresholding hysteresis which allowed any pixel in an edge list to have greater gradient values than threshold. This procedure classes the edge pixel as valid edge point. On other words, any pixels connected to valid edge points that have a gradient value above the lower threshold value are classes as edge points which can be presented as vector layers (Mostafa and Bishta 2005). Seven joint sets are observed in the eastward of study area (Oman mountain)including a sub-horizontal to gentle dipping set that is present in almost all rock units and other six steeply dipping joint sets (Figure 6) these trends have significant effects on groundwater flow regime. The major orientations of the steeply dipping joint sets are NW–SE, N–S, NE–SW,ENE–WSW, NNE–SSW , WNW–ESE. and The WNW– ESE joint set. The NNE–SSW joint set is the second least frequent and it is restricted to the foliated metamorphic rocks along and south of DIBBA fault zone. . Other joint sets with NW–SE parallel to HAMM fault zones, N–S, NE–SW and ENE– WSW orientations are characteristic of most rock types. On the other hand FAYAH range NNE-SSW trending has been significant effect by shear stress deformed thrust fold cut by strike slip and normal faults into three mountains .however the crest of

folds (mountains) have high frequency of regular fractures and escarpments mainly W-E,NNE-SSW,NNW-SSE. The spacing of joint sets varies within a single rock unit even in the same locality as well as between different rock units and in crest folding in FAYAH range and the area adjacent to Oman mountains.In general, the closest spacing is observed in the NNW–SSE and NNE-SSW trending joint sets that parallel and under effect of shear.

(a)

(b)

(c)
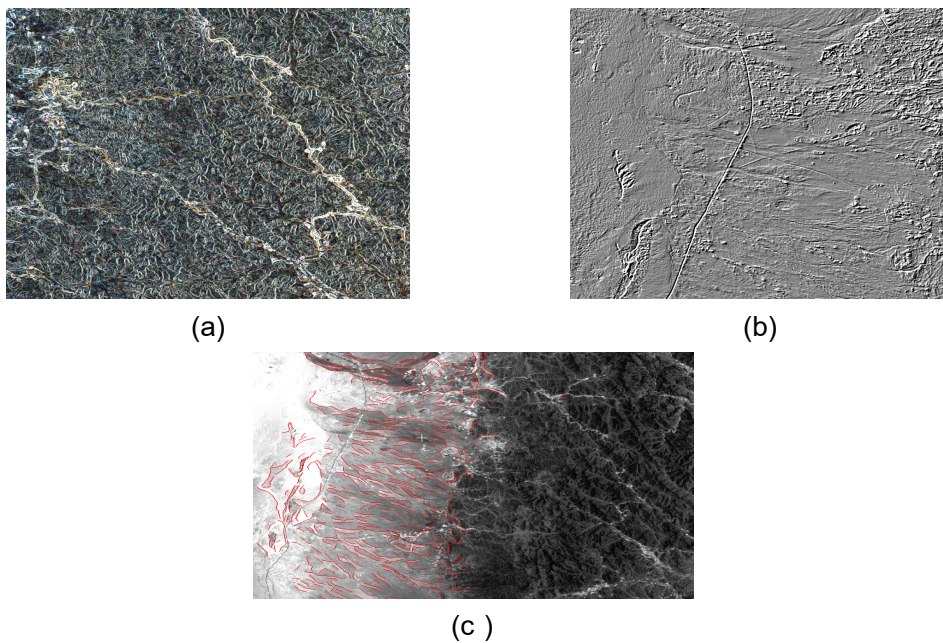
Figure 5 Results of (a) Laplacian , (b) Sobel and (c) Canny Algorithms
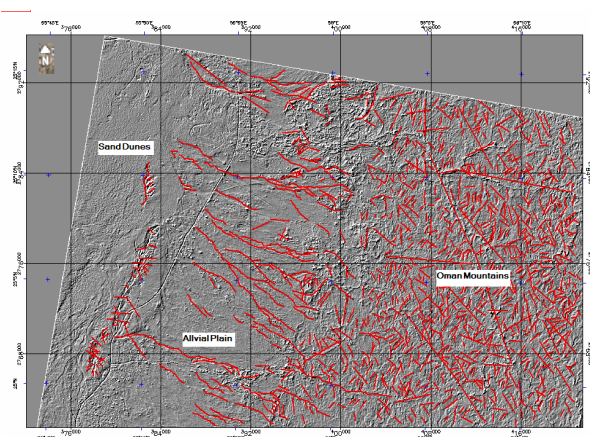
Figure 6 Results of Joint Pattern

Figure 7 shows DEM variation over the study area. DEM varies between 200 to 1000 m. Maximum elevation is found in north-east direction of UAE. The high density of lineaments are found in north-west direction in Alluvial plan (Figure 8). It is clear that area adjacent to the mountainous area from Manamh (northward), Flili village in the (southward) has high density of lineaments due to the westward compressive force between the oceanic crust and Arabian plate ,such as fractures and faults and drainage pattern that running in the buried fault plains (filled weathered materials coming from Oman mountains).
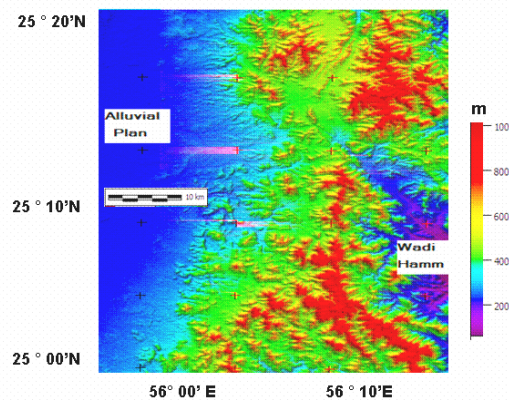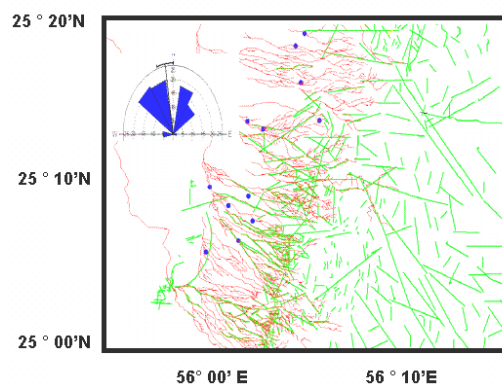

Figure 7 Study Area DEM

Figure 8 Density Map of Lineament Pattern and their Rose Diagram

5. CONCLUSION

It can be said that composite LANDSAT ETM band 1 to band 4 can be used to map the spatial lineament variations. It has been demonstrated that Canny algorithm is appropriate algorithm for automatic lineaments mapping. Integration between Canny algorithm and DEM could be used as an excellent tool to understand variation of lineament density. In fact high

lineament densities are found on steeper slope of DEM which located in northern-west of UAE.

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