Automatic Mapping of Lineaments Using Shaded Relief Images Derived from Digital Elevation Model (DEM) in Kurdistan, northeast Iraq

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Abstract

Lineament is one of the most important features showing subsurface elements or structural weakness such as faults and is usually extracted by visual analysis of enhanced image data. A different expert may extract different segments through a visual approach. To detect lineaments under the same conditions, this paper proposes a data processing approach on the automatically extraction shaded Relief image from digital elevation model (DEM).

The present study is the first study that used digital elevation model with GIS application in the study area to extract Lineaments and classified lineaments into positive and negative according to its relation with the drainage pattern system of the study area.

Keywords

Digital Elevation Model (DEM), Positive Lineament, Negative Lineament, shaded Relief, Drainage pattern.
Introduction

DEM is a numerical surface that stores elevation information for specific locations on a natural terrain. DEMs exist in two distinctive types: Grid or TIN (triangulated irregular network).

A DEM in grid format stores elevations in a regular array, very much like a raster image comprised of pixels (Figure 1). A TIN stores elevations at irregularly distributed points and connects these points with triangles. Hence, the triangles follow the terrains surface more or less closely. Since TINs are more complicated to deal with, simpler relief shading programs generally use grids instead of TINs.

Figure 1: Digital elevation model of the study area.
With both kinds of elevations models one can interpolate elevation values for positions where such values don't exist in the model. This allows software applications to compute shaded relief images at arbitrary resolutions. In addition to the elevation, other characteristics of the terrain can be extracted from a digital elevation model. For relief shading, the most important characteristics are two angles: aspect and slope. Slope is the maximum steepness at a particular location. Aspect is the horizontal direction of this maximum steepness (www.reliefshading.com).

**Study Area**

The study area is situated in the north eastern part of Erbil city, Kurdistan between Latitudes 36°09'22.5", 36° 41' 15" N and Longitudes 44°09'22.5", 44°46'52.5" E (Figure 2).

According to the modified geological map (Figure 3) from Sissakian (1997), the rocks in the study area divided into four groups as follows:

1- Tertiary (Bai Hassan, Mukdadiyah, Injana, Fatha, Pilaspi, Avanah, Gercus, Khurmala and Kolosh) Formations.

2- Cretaceous (Tanjero, Shiranish, Aqra-Bekhme, Qamchuqa, Balambo, Garagu and Sarmord) Formations.

3- Jurassic (Chia Gara, Barsarin, Naokelekan, Sargalu, Sehkanian and Sarki) Formations.

4- Triassic (Baluti and Kura China) Formations.
Geological setting

Kurdistan is situated to the north eastern boundary of the Arabian plate. The Zagros fold-thrust belt covers most of Iraqi Kurdistan Region; it contains fold structures with Cretaceous limestone outcropping in the anticlinal cores and Tertiary limestone and clastic on its flanks (Jassim and Buday, 2006) (Figure 3). The geologic setting of Kurdistan foothills is basically an extension of the continental shelf deposits that occur beneath the Arabian Gulf and Arabian Peninsula (Stevanovic & Markovic, 2003).

This fold-thrust belt copses by the continuing active collision of the Arabian plate with the continental blocks of Central Iran (Ahmadhadi et al., 2007); but had a main event during Alpine Orogeny in the Late Miocene-Pliocene orogenic phase (Hessami et al., 2001). The Alpine orogeny caused the folding and extensive fracturing in the Zagros belt (Ameen, 1992). There are three major tectonic zones which developed in Kurdistan: 1) the Foothill Zone; 2) the High Folded Zone; and 3) the Imbricated Zone (Jassim and Buday, 2006). The Zagros fold-thrust belt involve gigantic anticlinal traps, with fracturing producing well connected reservoirs (Beydoun et al., 1992).

Figure 2: Location map of the study area.
Figure 3: Geological Map of study area (Modified from Sissakian, 1997).
Data processing

DEM can be obtained from various sources: SRTM (90 x 90m global DEM), ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), Japan, 30 x 30 m or manually by interpolation, in the present study we used ASTER DEM for getting shaded relief maps. In order to identify linear topographic features from the DEM, eight shaded relief images were generated. The first step is the production of eight separate shaded relief images with light sources coming from eight different directions. The first shaded relief image created had a solar azimuth (sun angle) of 0°, and a solar elevation of 30°. An ambient light setting of 0.20 was used, which produces a good contrast. The ambient light setting is simply a scaling factor in the Imagine Topographic program (Erdas, 1998). The other seven shaded relief images were created with seven contrasting illumination directions 45°, 90°, 135°, 180°, 225°, 270°, and 315° (Figure 4). The second step is to combine four shaded relief images to produce one shaded relief image, for this purpose, the combinations of the four shaded relief maps are computed by using GIS overlay technique, where the first four shaded relief images are overlaid to produce one image with multi-illumination directions (0°, 45°, 90°, and 135°) and the second overlay is to produce one image with multi-illumination directions (180°, 225°, 270°, and 315°) (Figure 5-A and 5-B). Finally, those two images have been used for automatic lineaments extraction over the study area (Abdullah et al., 2010).
Figure 4: Eight shaded relief images derived from DEM with illumination directions (sun azimuth), $0^\circ$, $45^\circ$, $90^\circ$, $135^\circ$, $180^\circ$, $225^\circ$, $270^\circ$, and $315^\circ$ and a solar elevation of $30^\circ$. An ambient light setting of 0.20
Cross operations:

Performs an overlay of two raster maps, Pixels on the same positions in both maps are compared, After converting both lineament maps and Drainage pattern map of study area into raster format (figure.6) and These combinations shown in a cross table (Table 1).

Table 1: The coincide number of lineaments with the drainage pattern of study area.

<table>
<thead>
<tr>
<th></th>
<th>Automatic lineaments map of Multi-directional light (0°, 45°, 90°, and 135°)</th>
<th>Automatic lineaments map of Multi-directional light (180°, 225°, 270°, and 315°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First order</td>
<td>152</td>
<td>126</td>
</tr>
<tr>
<td>Second order</td>
<td>48</td>
<td>47</td>
</tr>
<tr>
<td>Third order</td>
<td>31</td>
<td>21</td>
</tr>
<tr>
<td>Fourth order</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>253</td>
<td>212</td>
</tr>
</tbody>
</table>

Figure 5: Two shaded relief images created by combining different shaded relief images.
A: Combining four shaded relief images with sun angle of 0°, 45°, 90° and 135°.
B: Combining four shaded relief images with sun angle of 180°, 225°, 270° and 315°.
Figure 6: Automatic lineament maps of shaded relief images. A: Automatic lineament map of combining four shaded relief images with sun angle of 0°, 45°, 90° and 135°, B: Automatic lineament map of combining four shaded relief images with sun angle of 180°, 225°, 270° and 315° and C: Drainage pattern of study area.
**Lineament Extraction**

The lineament extraction algorithm of PCI Geomatica software consists of edge detection, thresholding and curve extraction steps (PCI Geomatica, 2001). These steps were carried out over two shaded relief images under the default parameters of the software.

Structural discontinuities in rocks most often result in linear morphological features along the intersection of fracture plane and land surface. Linear morphological expressions of fractures include: (1) linear valleys, (2) linear ridgelines and (3) linear slope breaks. The main geometric characteristics of a single linear line are orientation and length (continuity) and in case of curved line, curvature (Jordan and Csillag, 2003).

The directional analysis of the automatically extracted lineament maps have been done and the major trends of lineaments in the study area are NW-SE. Figure (7) and table (2) show the basic statistics of extracted lineaments.

Lineaments that carried out from shaded relief map with multi-illumination directions (0°, 45°, 90° and 135°) most coincided with the drainage pattern of study area according to the crossing maps between drainage pattern map and both lineament maps (Table 1) mostly resemble a negative system lines in the area. It is clearly to issue that, there is good relationship between these lineaments and drainage pattern system distribution especially with first and second river orders, on the other hand the extracted lineaments of shaded relief image with sun angle of (180°, 225°, 270°, and 315°) are mostly resemble a positive system lines in the area. The most important feature in the area is the presence of topographic relief pattern. It is clearly to issue that, there is good relationship between the lineament and topographic relief pattern distribution.
Automatic lineament map of Multi-directional light (0°, 45°, 90° and 135°) | Automatic lineament map of Multi-directional light (180°, 225°, 270°, and 315°)
---|---
**count** | 373 | 317
**Min. Length (m)** | 1588.6 | 1588.6
**Max. Length (m)** | 25736 | 28485
**Total Length (m)** | 1435004.8 | 1295375.4
**Standard deviation** | 3187.761357 | 3422.991279

![Rose Diagram](image)

Table 2: Basic statistics of the automatic lineament maps.
Lineaments have been used in many applications: petroleum, mineral exploration and water resource investigations generally lineaments are underlain by zones of localized weathering and increased permeability and porosity. Meanwhile, some researchers studied relationships between groundwater productivity and the number of lineament within specifically designated areas or lineament density rather than the lineament itself. Figure (8) shows the density of lineaments within the study area.

Figure 7: (A) Rose diagram of automatic lineament map of combining four shaded relief images with sun angle of 0°, 45°, 90° and 135°. (B) Rose diagram of automatic lineament map of combining four shaded relief images with sun angle of 180°, 225°, 270° and 315°.
Discussion and Conclusion

The present study is the first study that used automatic extraction for detecting lineaments in study area and classified lineaments into positive and negative according to its relation within drainage pattern of study area that derived from digital elevation model based on GIS software, the importance of this classification clearly shown in ground water exploration as it was known that lineaments could be useful as secondary porosity that increase recharging wells.

In other hand as shown in table (1), there is maximum relation between negative lineaments and first order stream in the study area. The directional analysis of the automatically extracted lineament maps have been done and the major trends of lineaments in the study area are NW-SE (Figure 7).
References


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