Utilizing Remote Sensing and Digital Image Processing to Delineate the Structural Features in the Eastern Part of the Dead Sea, Jordan

Eyad H.R. Fadda[1], Maher Kakish[2] and Nedal N. Al-Hanbali[3]

1) Surveying and Geomatics Eng. Dept., Al-Balqa Applied University, Al-Salt, 19117, Jordan, hakam96@hotmail.com (Corresponding Author).
2) Surveying and Geomatics Eng. Dept., Al-Balqa Applied University, Al-Salt, 19117, Jordan, maherkakish@yahoo.com
3) Surveying and Geomatics Eng. Dept., Al-Balqa Applied University, Al-Salt, 19117, Jordan, nhanbali@cyberia.jo

ABSTRACT

Digital image processing techniques were used for mapping structural features using a medium resolution image (ETM+) from Landsat 7. The aim of this study is to utilize remote sensed data and digital image processing techniques for updating the structural map in the north eastern part of the Dead Sea (Ma'in area), Jordan. The study area is becoming an important target for geological survey activities, mineral exploration and industrial investment. This area was chosen for conducting a study based on satellite imagery interpretation of Landsat Thematic Mapper (ETM+). A special attention has been given in this study to the textural analysis techniques and the methods of image enhancements of Landsat (ETM+) images. As a result, a new lineament map was produced that represents the subsurface geological features and structures using visual interpretation and digital image processing by utilizing different enhancement techniques. A map showing the old structural features at a sub-regional scale has been produced together with a map showing the new structural features as interpreted from Thematic Mapper images.

KEYWORDS: Remote Sensing, Mapping, Digital Image Processing, Eastern Part of the Dead Sea, Jordan.

INTRODUCTION

The northern boundary of study area is about 35 km south of Amman. The area lies between (35 30'-35 45') longitudinal, (31 30'-31 45') latitudinal, (197.6-221.4m E and 100.7-128.5 N) on the Palestine belt grid and occupies an area of about 465 km².

The objectives of this study were to detect the faults on the satellite image, detect the faults on the geological map, compare the observed faults on the satellite image and the geological map, and finally detect the drainage system on the satellite images from Landsat 7 ETM+ image, which was employed in this study. A subset was done on the study area using PCI software to obtain Ma'in area at a scale of 1:50,000 that matches the geological map of the study area at a scale of 1:50,000. Textural analysis utilizing high-pass filter and directional edge enhancement was done to obtain the lineaments, fracture and structural map.

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TOPOGRAPHY AND GEOMORPHOLOGIC SETTING

The Jordan Valley Region

The Jordan Valley is part of the Great Rift Valley, which extends from Turkey to Eastern Africa. The Jordan Valley was created by land sinking and at the same time, the rising of the land to the east. After the valley was

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created, waters from the north and east formed a great lake in the region called Samra Lake. Water was also supplied to Samra Lake by the aquifers that were revealed when the land in the Valley sank. Bedrock was also exposed at this time. While the rivers that fed Samra Lake flowed, they brought with them mineral-rich rock and sand from the mountains from which they came. During the Pleistocene period, a generally dry time, Samra Lake separated into three smaller lakes: Al-Hula, Tiberias and the Dead Sea. The land lying in between these lakes was found to be very rich in minerals as a result of the rivers bringing the rock and sand from the mountains above. After the separation of the three lakes, the Jordan River found its way to the Dead Sea through what is known as the Badlands (Lartet, 1869).

The Eastern Heights

The Eastern Heights extends from Yarmouk River in the North to Aqaba in the south. Tectonic movements created this area giving it its distinct hills and valleys. When the southern mountains were formed, the layers of granite became apparent.

GEOLOGICAL SETTING

Four major fault trends dominate the area. These are E-W-trending Wadi Zarqa Ma'in and Wadi Atum Fault zones, the N-S trending Zara Fault, the NE trending Faults and the NNE-SSW trending Dead Sea Fault zone (Rift).

The main fault movement was late Tertiary in age but the rift probably reflects renewed movements along an ancient weak zone initiated in the late proterozoic. Geological investigations in Jordan and Palestine commenced in the mid-19th century; a comprehensive bibliography of early work is given in (Burdon, 1959) and (Bender, 1974). Notable among the early works are the publications by (Freund et al., 1970), (Picard, 1943) and (Quennel, 1951).

The first geological map covering the area was produced by (Blake, 1936) at 1:1,000,000 scale, for the whole of East Jordan. More recently, the geological surveying of (Quennel, 1951) was published; a 1:500,000 geological map in 1951. This work formed the basis of a compilation of 1:250,000 for the region immediately east of the Rift Valley.

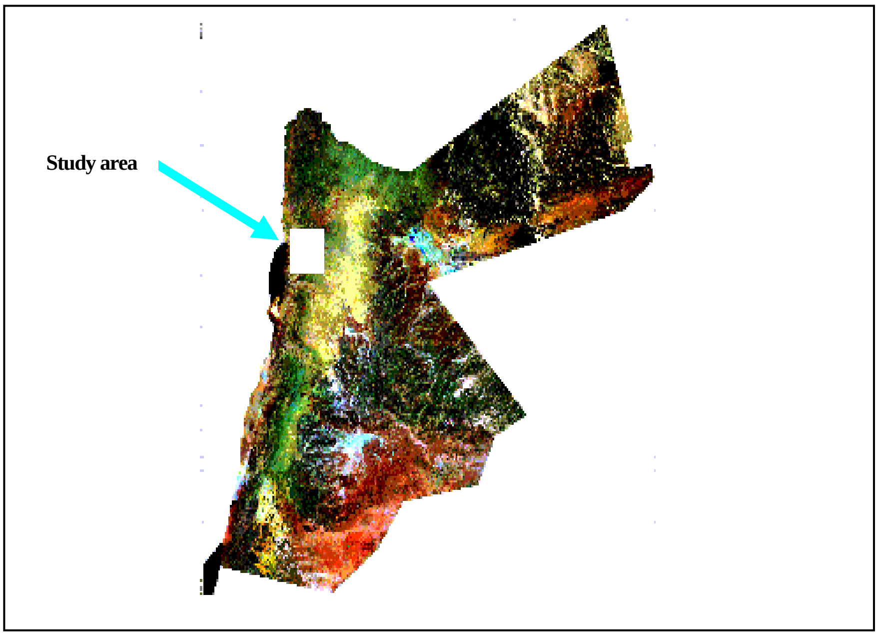

Figure 1: Location Map of the Study Area.

Figure 2: Landsat 7 ETM+ Image.

Figure 3: Geological Map (1:50000).

REMOTE SENSING

Light is a particular type of electromagnetic radiation that can be seen and sensed by the human eye, but this energy exists at a wide range of wavelengths. The micron is the basic unit for measuring the wavelength of electromagnetic waves. The spectrum of waves is divided into sections based on wavelength. The shortest waves are gamma rays, which have wavelengths of 10-6 microns or less. The longest waves are radio waves, which have wavelengths of many kilometers. The range of visible light consists of the narrow portion of the spectrum, from 0.4 microns (blue) to 0.7 microns (red) (Lillesand and Kiefer, 2000).

Satellite Imagery

Using LANDSAT 7 ETM+ data in geology helps in mapping major geologic features, revising geologic maps, recognizing and classifying certain rock types, delineating unconsolidated rocks and soils, mapping volcanic surface deposits, mapping geologic landforms, identifying indicators of mineral and petroleum resources, determining regional geologic structures, producing geomorphic maps and mapping impact craters.

Software (Geomatica 9.1)

Primary access to Geomatica 9.1 is through Geomatica Focus, an all-in-one tool that incorporates PCI Geomatics technologies for remote sensing, image processing map publishing, GIS and spatial analysis in one operating and viewing setting. Geomatica Focus offers a proficient and comprehensive tool for image rectification, data analysis and visualization, and it works easily with several geospatial data formats. The software Algorithm Librarian provides more than 300 practical algorithms, which are essential for data processing. The supported data processing functions embrace image filtering, image classification, data interpolation, spatial analysis and Digital Elevation Model (DEM) analysis by displaying algorithm results in the Focus view or saving them to an appropriate storage medium.

The OrthoEngine interface is a powerful photogrammetric tool designed to perform basic and advanced geometric corrections as well as geospatially mosaic remotely sensed imagery. Production of orthorectified or geometrically corrected images, DEMs, 3-D vectors and mosaics is simple and accurate. Furthermore, the interface can work with stereo imagery, view in 3-D and extract DEMs automatically.

The latest spatial analysis operations in Geomatica 9.1 provide useful tools for a wide range of GIS applications. Fundamental GIS tasks such as overlay, identify, assemble, derive, extract, store, manipulate, import, export and display geographical referenced vector and raster data can be performed without any difficulties.

DIGITAL IMAGE PROCESSING TECHNIQUES

Image processing operations can be roughly divided into three major categories; Image Compression, Image Enhancement and Restoration, and Measurement Extraction. Image compression is familiar to most people. It involves reducing the amount of memory needed to store a digital image. Image defects which could be caused by the digitization process or by faults in the imaging set-up (for example, bad lighting) can be corrected using Image Enhancement techniques. Once the image is in good condition, the measurement extraction operations can be used to obtain useful information from the image. Digital Image Processing involves the manipulation and interpretation of digital images with the aid of a computer.

Image Enhancement

The purpose of image enhancement is to render the images more interpretable, i.e. some features should become better visible, which generally occurs at the cost of some other features which may be relatively unimportant in that specific context.

Linear Contrast Stretching

Generally, the number of actually recorded intensity levels in a scene is rather low and the full dynamic range of the digital image (256 levels) is not utilized. So linear contrast stretching expanses the old grey range to occupy the full range of grey levels in the new scale. In this study, linear stretching was used to expand the entire maximum-minimum range in the DN's values. This allows greater contrast in the entire image.

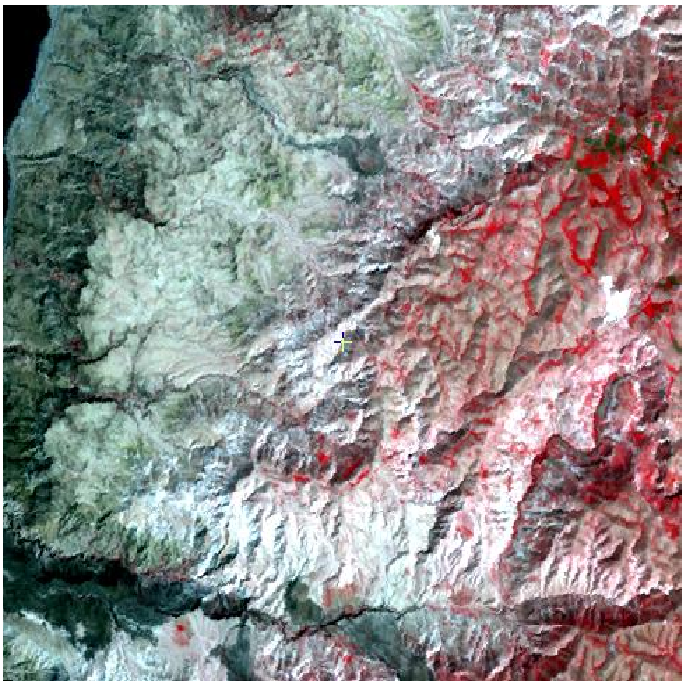

Figure (4): Linear Contrast Stretching.

Edge Enhancement

The edge enhancement is a typical local operation in which the DN-values at a particular pixel in the new image depend also on the DN-values at neighboring pixels in the old image. The high-frequency variations of DN-values correspond to local changes from pixel to pixel in an image. It is influenced mainly by terrain properties, vegetation and solar elevation. Thus, edge enhancement is basically a sharpening process whereby borders of objects are enhanced. Edge enhancement tries to bring out variations in DN values in neighboring pixels or high-frequency spatial changes, and is also called high-pass filtering or textural enhancement.

Textural Enhancement

Texture analysis is defined as the classification or segmentation of textural features with respect to the shape of a small element, density and direction of regularity. Texture is one of the important characteristics used to identify objects or regions of interest in an image. Unlike spectral features, which describe the average tonal variation in the various bands of an image, textural features contain information about the spatial distribution of tonal variations within a band. Textural analysis produces several output images in which the grey levels represent textural measures of the input image. These textural measures are derived from a grey level co-occurrence matrix or difference vector computed for each rectangular window of user specified dimensions and spatial relationships of the input image. The texture measure is put at the center of the window at the appropriate position in the output image. This technique was used to obtain a sharper image showing more details. The details could be related to differences in some fracture systems. It is also used to enhance linear systems, fractures and joints.

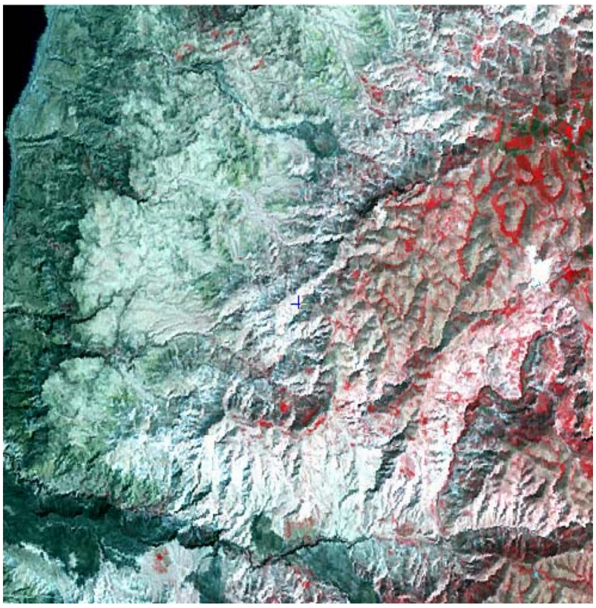

Figure (5): Sharping Edge Filter (FLSZ=7, 7).

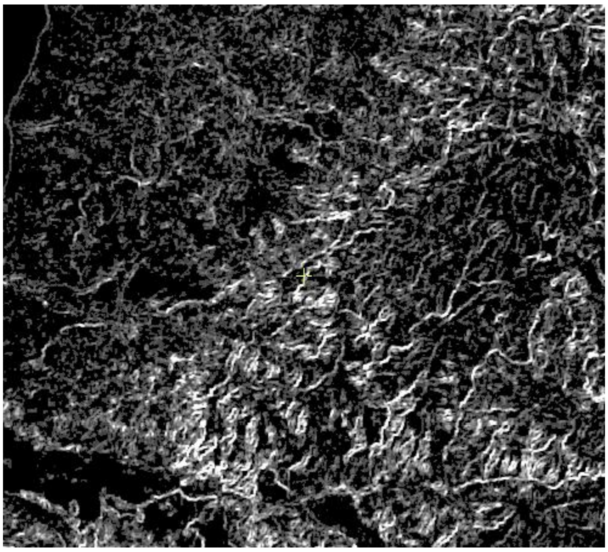

Figure (6): Textural Enhancement (FLSZ=3, 3).

Directional Edge Enhancement

This is done using a first derivative edge enhancement filter that selectively enhances image features having specific direction components (gradients). The sum of the directional filter kernel elements is zero. The result is that areas with uniform pixel values are zeroed in the output image, while those that are variable are presented as bright edges. This method was mainly used to detect the boundaries or lineaments in the study area.

STRUCTURAL MAPPING

The digitizing process was used to create two structural maps from the satellite image. The first one shows the faults that already existed in the published geological map. The second shows the new updated faults that did not exist in the geological map, Figures (7) and (8), respectively.

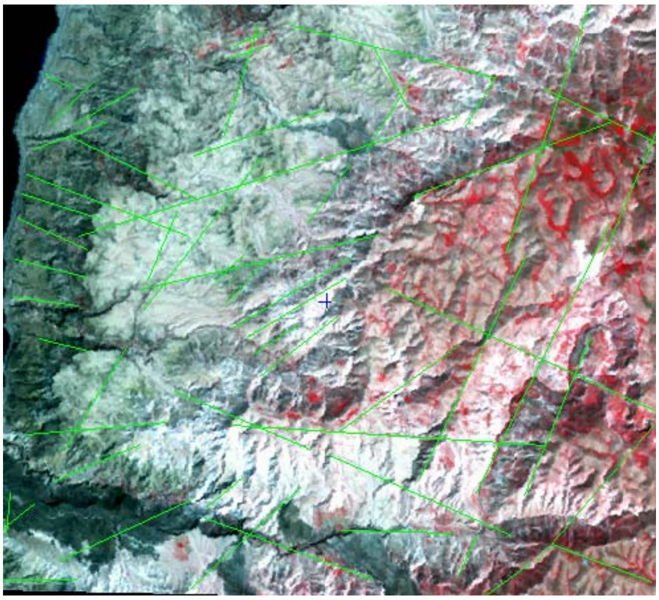

Figure (7): Image map showing faults that already existed in the published geological map.

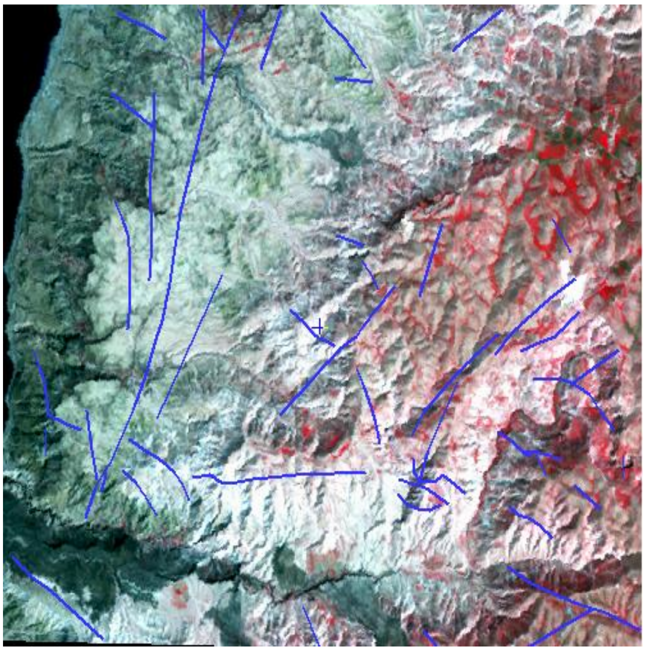

Figure (8): Image map showing new faults as delineated from the satellite image and that did not exist in the geological map.

CONCLOUSIONS

- Structural mapping is an important tool, that can be used for many purposes, such as faults.
- Landsat-7 (ETM+) images have the advantage of low cost and large area coverage; therefore structural mapping can be easy and quick.
- It has been found that digital image processing techniques have a direct and major role in a fast and accurate mapping.
- The structural map of Ma'in area was updated.
- Digital image processing techniques were used for structural mapping in Ma'in area.
- The resultants of this were two structural maps showing the faults that existed and the new faults that did not exist in the geological map.

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