Registration of Satellite Images by Using the Linear Transformations

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ABSTRACT

The processes of rectification and registration that conducted at the satellite images of the most important steps in images interpretation and extract information for use in various applications of remote sensing. There are things that must be observed before entering into the details of the operation. There are a number of important factors that must be considered. Such as the illumination angle, Sun-Earth distance varies throughout the year. In addition to the effects of environmental, climatic and weather such as cloud, haze, dusty weather, cover for one of the dates, that affect the nature of the scene this requires effort and extra work for the interpretation of these satellite images after removing the mistakes in them when captured by the satellite. The first process applied to the satellite image is the Pre-Processing process, and which includes radiometric and geometric corrections.

In this paper, image to map registration method, of 1st order transform, has been performed to correct the SPOT image from geometric errors using geoimage of "UTM" projection. The total RMS error, which has been reached, was less than one meter,. The results were obtained using the ready program (ENVI).

Keywords: Image Pre-Processing, Geometric Correction, Map Projection, Image Transformation, Image Rectification, Image resampling

تصحيح الصور الفضائية باستخدام التحويلات الخطية

الخلاصة

تعتبر عملية التصحيح و التسجيل التي تجري على الصور الفضائية من اهم الخطوات فــي تفسـير الصور الفضائية واستخراج المعلومات للاستفادة منها في تطبيقات التحسس النائي المختلفة. هناك عــدة امور يجب مراعاتها قبل الدخول في تفاصيل العملية. هناك عدد من العوامل الهامة التي يجب مراعاتها مثل زاوية الإضاءة, اختلاف المسافة بين الارض والشمس على مدار السنة بالاضافة الى التـأثيرات البيئية والجوية والمناخية مثل الغيوم,الضباب, الجو المغبر التي تغطي احد التواريخ والتي تؤثر في طبيعة المشهد مما يتطلب جهدا وعملا اضافيا لتفسير تلك الصور الفضائية بعد تخليصها من الاخطاء الموجودة فيها عند التقاطها بواسطة الأقمار الصناعية, لذلك فأن أول عملية تطبق على الصورة الفضائية هي عملية المعالجة الاولية والتي تتضمن التصحيحات الهندسية والراديومترية .

في هذا البحث تم استخدام تقنية المتوالية من الدرجة الاولى وتم تصحيح الصورة هندسيا وفقا الـى صورة مصححة باستخدام مسقط الـ (UTM projection) اعتبرت كخارطة مرجعية. تم الحصول على نسبة خطأ اقل من واحد متر, وقد تم الحصول على النتائج باستخدام البرنامج الجاهز (ENVI).

INTRODUCTION

Digital image can be described as combination of discrete number (DN), arranged in matrix form (columns and rows), each (DN) called "pixel", associated with "brightness" of a relatively small area within a scene.

Mathematically a digital image can be represented as a function of two variables **f (x,y),** where **f**, denoted the value of (DN) in that position   **(x,y)**. The minimum (DN) value means no energy reflected or emitted from the scene, while maximum value "often (255) for 8-bit" image indicated the saturation energy received from the scene. In this work, we shall concert on satellite image in which the sensors is looking through the atmosphere at the earth's surface. This form of remote sensing actually began in the 1960s with a limited number of researchers, analyzing airborne multispectral scanner data and digitized aerial photographs, **[1]**.

IMAGE PRE-PROCESSING

Remote sensing system gathered data using many forms and techniques. In all these systems, there are numerous errors associated with gathered data. Therefore, it is usually necessary to preprocess the remotely sensed data priory to analyzing it in order to remove these errors. Errors can be divided into: [2]

First, "Internal", which are created by the sensor itself; in general internal errors are systematic, predictable, and stationary (constant). These errors can be determined from pre-launch or in-flight calibration measurement.

Second, "External", which are created by platform perturbations and the modulation of scene characteristics, which are variable in nature. These errors refers to many factors such as, Earth rotation, sensor orientation, exposure direction, etc.

Image restoration is usually implemented to correct these distortion, to remove degradation, and to reduce noise introduced during the image process **[2]**.

The use of digital satellite image data for a spatial database requires several preprocessing procedures. These procedures include, radiometric correction, geometric correction. The goal of digital image preprocessing is to increase both the accuracy and the interpretability of the digital data during the image processing phase. Geometric correction involves the reorientation of the image data to selected parameters. This includes the selection of a map projection system and the co-registration of satellite image data with other data layers that may be used in a GIS (geographic information system). This will allow for accurate spatial assessments and measurements of the data generated from the satellite imagery **[3]**.

RADIOMETRIC CORRECTION

Before launching the sensors on board satellite, many calibration processes and data corrections have to be adopted to reduce the radiometric distortion as possible. These processes involve determining the relationship between the individual detector; i.e. output and input scene radiance, and to correct the data for any detector malfunctions or distortion. Almost, all remote sensing imagery has to be corrected due to radiometric distortion in the Earth received main station, before distributing the data for the user, **[4]**.

The primary reasons for applying radiometric corrections to the digital remotely sensed data are to achieve consistency in relative image brightness and absolute quantification of brightness values. Relative correspondence of image brightness magnitudes may be desired for pixels: (1) within a single image (e.g., orbit segment or image frame), (2) between images (e.g. adjacent, overlapping frames), (3) between spectral band images, and (4) between image dates. The key

here is that brightness value inconsistencies caused by the sensor and environmental noise factors listed above are balanced or "normalized" across and between image coverage and spectral bands. The other principal objective is the retrieval of surface energy properties such as spectral reflectance, Albedo or surface temperature, which requires absolute radiometric processing, **[5]**.

GEOMETRIC CORRECTION

Remotely sensed data usually contain both systematic and non-systematic geometric distortions, which are, refer to projection and physical properties of sensor **[6].**

The term registration or rectification is also used to describe geometric transformation,**[7]**.

The image registration is considered as an essential and important task in any remote sensing analysis. In order to remove geometric errors, a number of correction techniques have been developed. These techniques can be divided into two categories according to**[8]**; systematic distortion correction, and dynamic distortion correction.

Distortions that are systematic do not vary significantly in magnitude or direction for specific sensor. The removal of dynamic distortion require detailed information from the image and area **(ground control points GCPs)**, which are used to establish a relationship between the ground and image. The (GCPs) data can be gathered from a wide variety of sources, including map aerial photograph, field survey, and Global Positioning System **(GPS)**. In the present work, the evaluation of the geometric correction for the image has been done. The result was obtained using (ENVI, GCPs editor facilities, image to map registration) to correct image from dynamic distortion and to reach a Total Root Mean Square Error (RMS) less than 1 meter for the two images. **[5]**.

SOURCE OF GEOMETRIC ERRORS [5]
1- Earth rotation effects

Earth rotating in tangential velocity about 463 m / sec at the equator, while the sensor scan the terrain. This effect shifts the ground swath being scanned, producing along- track scale distortion.

2- Panoramic distortion or wide field of view

For a given scanner, the **(IFOV)** is constant, that means a constant pixel size. But in scanning process, the pixel size at the end of scan line is larger than the pixel size at the nadir view.

3- Earth curvature

For satellite sensor, the assumption that the earth can be adequately represented as a flat surface is incorrect. The major problem is that; the inclination of the surface makes the area viewed for given (IFOV) larger than it would be if no curvature existed.

4- Scan skew

The forward motion of the satellite causes this error during the time required for each mirror sweep. The ground swath is not normal to the ground track but it is slightly skewed, producing cross-truck geometric distortion.

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5- Mirrors Scan velocity

The scanning rate of a sensor is usually not constant during a given scan, producing along-scan geometric distortion.

6- Satellite velocity

As satellite velocity change, the ground track covered by successive mirror scan change, this will produce along-track scale distortion.

Also, many other distortion affected data geometry such as, sensor vibration, (3-D) sensor excises vibration, and the difference between sensor image index and map index for a given area **[5]**.

MAP PROJECTION

Before discussing our correction techniques (Image to Map Registration), it is convenient to discuss map projection in order to understand the procedure of the work. The main source of the environmental information is the topographic map. Map projection is a process of transforming location on the curved surface of the earth with the geodetic coordinates (φ, λ) (refereed to latitude, longitude) to planner map coordinates (X, Y). There are a number of different map projection methods used to fathering a sphere to a plane. All methods cause distortion to the surface, each map projection system compromise accuracy between certain properties, such as concentration of distance, angle, and area **[9].**

UNIVERSAL TRANSVERSE MERCATOR (UTM)

The idea of the transverse mercator projection has its roots in the 18th century, but it did not come into common usage until after World War II. It has become the most used because it allows precise measurements in meters to within 1 meter.

A mercator projection is a 'pseudocylindrical' conformal projection (it preserves shape). What you often see on poster-size maps of the world is an equatorial mercator projection that has relatively little distortion along the equator, but quite a bit of distortion toward the poles.

What a transverse mercator projection does, in effect, is orient the 'equator' north-south (through the poles), thus providing a north-south oriented swath of little distortion. By changing slightly the orientation of the cylinder onto which the map is projected, successive swaths of relatively undistorted regions can be created.

This is exactly what the UTM system does. Each of these swaths is called a UTM zone and is six degrees of longitude wide. The first zone begins at the International Date Line (180°, using the geographic coordinate system). The zones are numbered from west to east. The last zone (zone 60) begins at 174°E and extends to the International Date Line.

The zones are then further subdivided into an eastern and western half by drawing a line, representing a UTM, down the middle of the zone. This line is known as the 'central meridian' and is the only line within the zone that can be drawn between the poles and be perpendicular to the equator (in other words, it is the new 'equator' for the projection and suffers the least amount of distortion). For this reason, vertical grid lines in the UTM system are oriented parallel to the

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central meridian. The central meridian is also used in setting up the origin for the grid system. Figure (1)

Any point can then be described by its distance east of the origin (its 'easting' value). By definition the Central Meridian is assigned a false easting of 500,000 meters. Any easting value greater than 500,000 meters indicates a point east of the central meridian. Any easting value less than 500,000 meters indicates a point west of the central meridian. Distances (and locations) in the UTM system are measured in meters, and each UTM zone has its own origin for east-west measurements.

Many topographic maps published in recent years use the UTM coordinate system as the primary grids on the map. On older topographic maps published in the United States, UTM grids are shown along the edges of the map as small blue ticks. **[10]**.

In Iraq the basic map scale adopted from the arial master sheet is 1/ 25000, while the standard map scale for all Iraqi area is 1/ 100000. Our map projection is (UTM) Zone 37, 38, and 39 North; the Datum is Clarck 1880, or WGS84.

DATUM, SPHEROIDS AND ELLIPSOIDS

The precise determination of the latitude and longitude of a point over a broad area must take into account the actual shape of the Earth. To achieve the precision necessary for accurate location, the Earth can not be assumed to be sphere. Rather, the Earth shape more closely approximates an ellipsoid (Oblate Spheroid), flattened at the poles and bulging at the equator. Thus, the Earth shape, when cut through its polar axis approximates Ellipse. A Datum is standard representation of shape at offset for coordinates, which includes an ellipsoid on an origin. In fact, the Datum should be considered when working with geospatial data, since data with different Datum would not line up; i. e. the difference in distance measurement could be larger than kilometer **[11]**.

IMAGE TO MAP REGISTRATION TECHNIQUE

Registration of data is an important stage in the remotely sensing detection task. This important stage can be evaluated by using two major methods *(Image to Map & Image to Image techniques)*, In the present work, the first method was used with direct GCPs fitting and first order transformation polynomial to correct the image.

The Root Mean Square *(RMS)* error which being reached is less than 1 meter. In resampling process, rotation and rescaling the image to conifer with reference map was evaluated using the cubic convolution approach.

GROUND CONTROL POINTS SELECTION

The Ground Control Points (Ground Control Points, GCPs) is an important baseline data of Remote Sensing Image correction. The quantity, distribution and accuracy of GCPs play an important role in correcting Remote Sensing Image.

To achieve scientific selection of GCPs we should define the concept of "uniformly distribution". In fact, Because of the difference of terrain Location of GCPs and so on, the affected area of each GCPS is different. In order to make the selection of GCPs more scientific and build the relationship between the quantity and uniform distribution **[12]** .

Ground control points **(GCPs)** are features located in the input and reference images (in this work the reference image is ETM+ bands, 4, 5, & 7 geoimage was used, 14.25 meter in spatial resolution). The selection of GCPs was as sharp features such that, (main road intersects river boundary, railway line, or any feature that can distinguish it in the image and map). Each GCP has two coordinates system, first the coordinates of input image denoted by (X, Y) given in pixel unit, second the coordinates of map denoted by (E, N) given in meter unit.

In GCPs selection we should seek to get uniform distribution on an image to evaluate the best fitting of transformation matrix. To perform 1st order transformation, which is expressed by the equation of a plane, at least three GCPs are needed, but this number is too small to get best fitting. **[7]**

The minimum number of GCPs required to perform a transform of order (n) equals is given as, **[13]**.

$$Minimum\ No.\ of\ GCP = [(n + 1) * (n + 2)/2] \qquad \ldots (1)$$

TRANSFORMATION

The most commonly used rectification model uses polynomial equation, **[8]**. Depending on the number of GCPs, polynomials of different degree of complicity can be used. For a first-degree polynomial (linear), three points are required.

ENVI can process first-degree polynomial equation with n GCPs according to user interpretation. However, because locating GCPs is often imprecise, it is best to adopt extra points, i.e. twice the number of GCPs as coefficient. If so, the effect of bad points will reduce, **[7]**.

All rectification process was done by the ENVI version 4.5 software. This software has best G`CPs editor with multi type of transformation and resampling methods. As appears in table (2), number of GCPs used to correct the image was six. In fact, they were small number and the reason referred to transformation order and image resolution.

We have used 6 GCPs to rectify the image due to rotation, scaling, and scan skew.
The first order polynomial equations are given by:

$$X_o = a_o + a_1 x_{(in)} + a_2 y_{(in)}$$
$$Y_o = b_o + b_1 x_{(in)} + b_2 y_{(in)} \qquad \ldots (2)$$

Where:

X_o, Y_o are coordinates of reference image.

$x_{(in)}$, $y_{(in)}$ are coordinates of input image.

$\begin{vmatrix} a_o & a_1 & a_2 \\ b_o & b_1 & b_2 \end{vmatrix}$ Transformation matrix

In order to determine the coefficients of transformation matrix, we have substituted values of X_o, Y_o, $x_{(in)}$, $y_{(in)}$ coordinates from each GCP. Equation (1) deals with three GCPs only, while our task was to use n-GCPs and solve them to

evaluate 6-transformation coefficients matrix. These can be computed by using least mean square fitting. The least square solution for Q, P is given by:

$$P = (K^T K)^{-1} K^T A$$
$$Q = (K^T K)^{-1} K^T B \qquad \qquad \dots (3)$$

Where:

$$P = \begin{vmatrix} a_o \\ a_1 \\ a_2 \end{vmatrix} \quad Q = \begin{vmatrix} b_o \\ b_1 \\ b_2 \end{vmatrix} \text{Transformation matrix coefficients}$$

$$K = \begin{vmatrix} 1 & x_{(in)1} & y_{(in)1} \\ 1 & x_{(in)2} & y_{(in)2} \\ 1 & x_{(in)3} & y_{(in)3} \\ \vdots & \vdots & \vdots \\ 1 & x_{(in)n} & y_{(in)n} \end{vmatrix} \text{ The input image coordinates.}$$

And:

$$A = \begin{vmatrix} X_{01} \\ X_{02} \\ \vdots \\ X_{0n} \end{vmatrix} \quad B = \begin{vmatrix} Y_{01} \\ Y_{02} \\ \vdots \\ Y_{0n} \end{vmatrix} \text{GCPs coordinate in the reference image}$$

The error in the X, Y directions are then given as:

$$E_{error X} = E_{(reference s)} - X_{o \, (in \, meter)}$$
$$N_{error Y} = N_{(reference s)} - Y_{o \, (in \, meter)} \qquad \dots (4)$$

$$(RMS) = [(E_{erro X})^2 + (N_{erro Y})^2]^{0.5} \qquad \qquad \dots (5)$$

The reference map was ETM+ RGB (14.25 m resolution) geo- mosaic image, see, figure (2). The reference image-map characteristics can be given as in table, (1)

The (RMS) unit is meter. Table (2), shows all the GCPs coordinates, and errors,. After finding the transformation matrix, the input image takes new coordinates system due to references map. This will be accomplished by using equation (2) for all pixels within the image and find the sets of coordinates (X_o, Y_o) which represent the East and North of the (UTM) grid system in meter unit. As the order of the transform increases, the selection of GCPs from image will be more critical, so that the transformation will fail.

RESAMPLING

The final step in the rectification process is resampling**[8]**.

Image resampling may be defined as the reconstruction of a continuous function from observed sample points on a discrete input grid, followed by a sampling of the continuous function to a new discrete grid**.[14],[15]**

In practice, we have computed a mapping, or projection, between the input and output grid, then use interpolation to do the reconstruction and sampling **[16]**. Since the grid of pixel in the input image rarely matched the grid for the reference image / map, the pixels should be resampled so that a new data file for the output file can be calculated. One of the fundamental limitation of any resampling techniques is that the raster data can not be easily scaled, rotated, or distorted without the loss in information, **[8]**.

Consequently, the question of which resampling procedure most faithfully reproduces the information is an important one. The final evaluation of geometric errors are done during resampling process by the use of the new grid system, which is created according to reference image / map.

NEAREST NEIGHBOR

The simplest technique for assigning pixel values to the new grid is called nearest neighbor. This approach uses the input pixel value closet to output pixel location as the new value for the output image. The advantages of this approach are: (1) No change in the pixel values from the input data set to the output data set as no interpolation is performed. (2) The second advantage of this technique lays in its fast implantation, because this operation is an assignment and not computation this techniques is regarded as the faster resampling operation. The disadvantages are that: (1) The assignment process may duplicate some pixels while leaving out others. (2) Linear features often end up looking more jugged using this technique. See figure (3).**[8]**

The output georeferncing images according to the above GCPs are given in the following is figure; (4) illustrates the direct geo image results, where, figure (5) shows the final geo image.

CONCLUSIONS

1. The first order polynomial, used for geometric correction, has been found to be more efficient than implementing higher orders. This may be interpreted as a result of the available distinguished number of GCPs involved within the processed scene. It should be noted that; 1st order polynomial requires less number of GCPs, and, consequently, performed faster than higher orders. It should be kept in mind that; locating the GCPs accurately requires maps of large scale such as 1:25000 and high image resolution.

2. The image to map registration methods has been applied in order to extract the geo-image with total RMS error less than one meter.

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Table (1) the Reference Image-Map Characteristics

Sensor	Landsat-7 ETM+
Bands	4, 5, &7
Projection	UTM
Datum	WGS84
Site	Baghdad-Iraq
Exposure Time	June 2003
Zone	38 North

Table (2) the Rectification Parameters

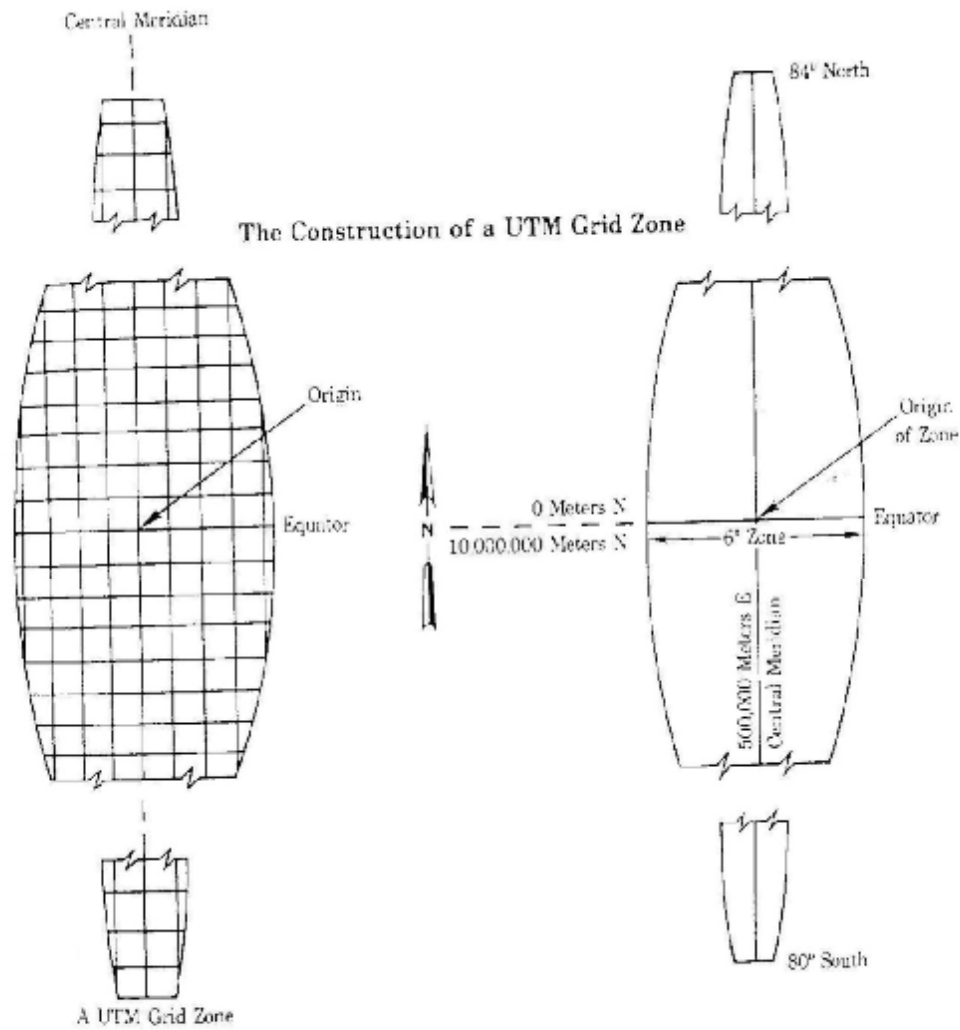| GCP #	Map Coordinates (m)		Image Coordinates (pixel)		Errors (m)		RMS Error (m)
	E	N	x	y	Belong x	Belong y	
1	444500	3683218	222.5	437	0.04	1.37	1.37
2	449145	3683900	554.5	400	-0.39	-0.96	1.04
3	443240	3685650	129.5	275	-0.43	-0.61	0.75
4	442700	3686838	88.5	194.5	0.29	-0.15	0.33
5	450590	3686600	653.5	221	0.32	0.53	0.62
6	443450	3678302	154	765	0.17	-0.18	0.25

Figure (1) The UTM Grid Zones.

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Figure (2) the Reference Image, ETM+ Multi Band, 14.25 m Resolution
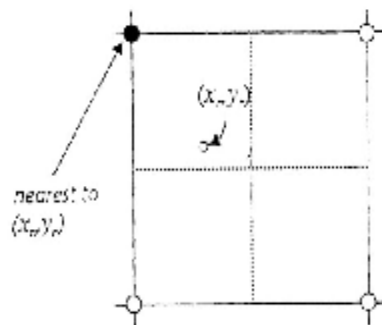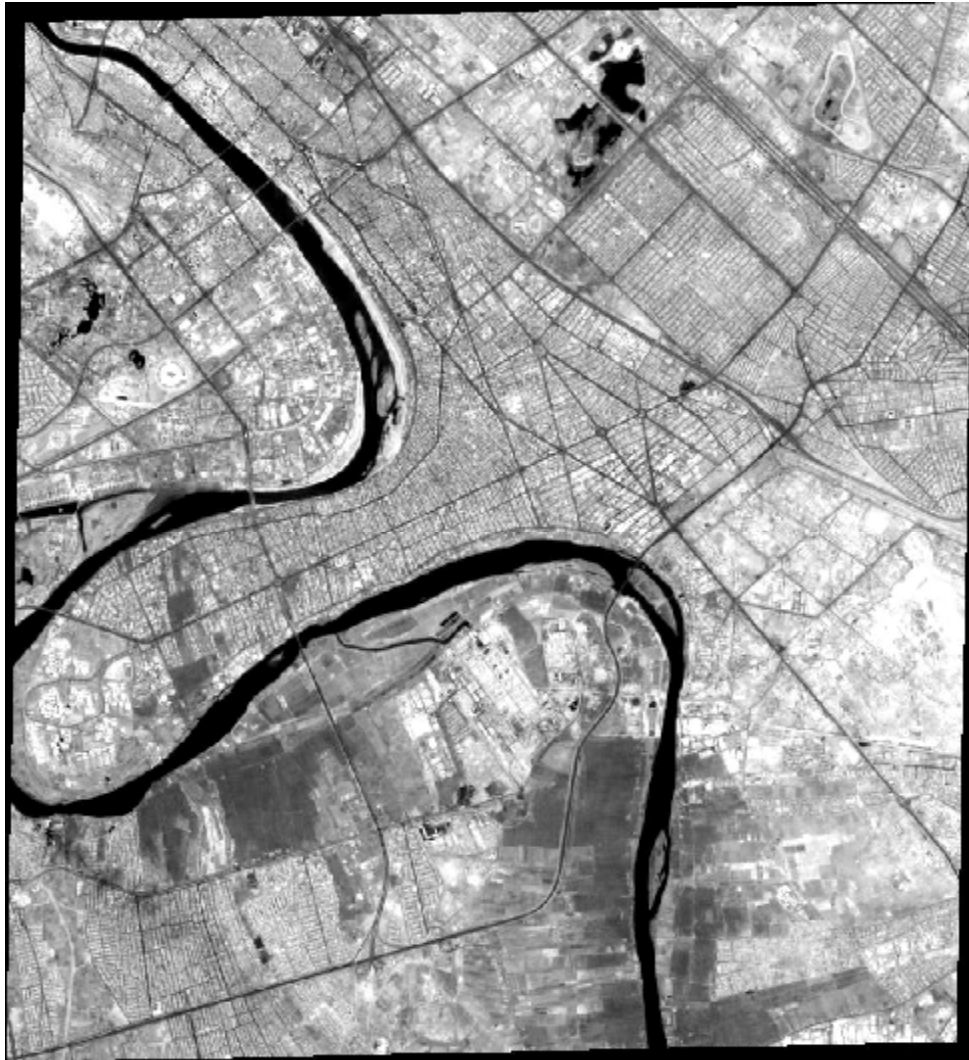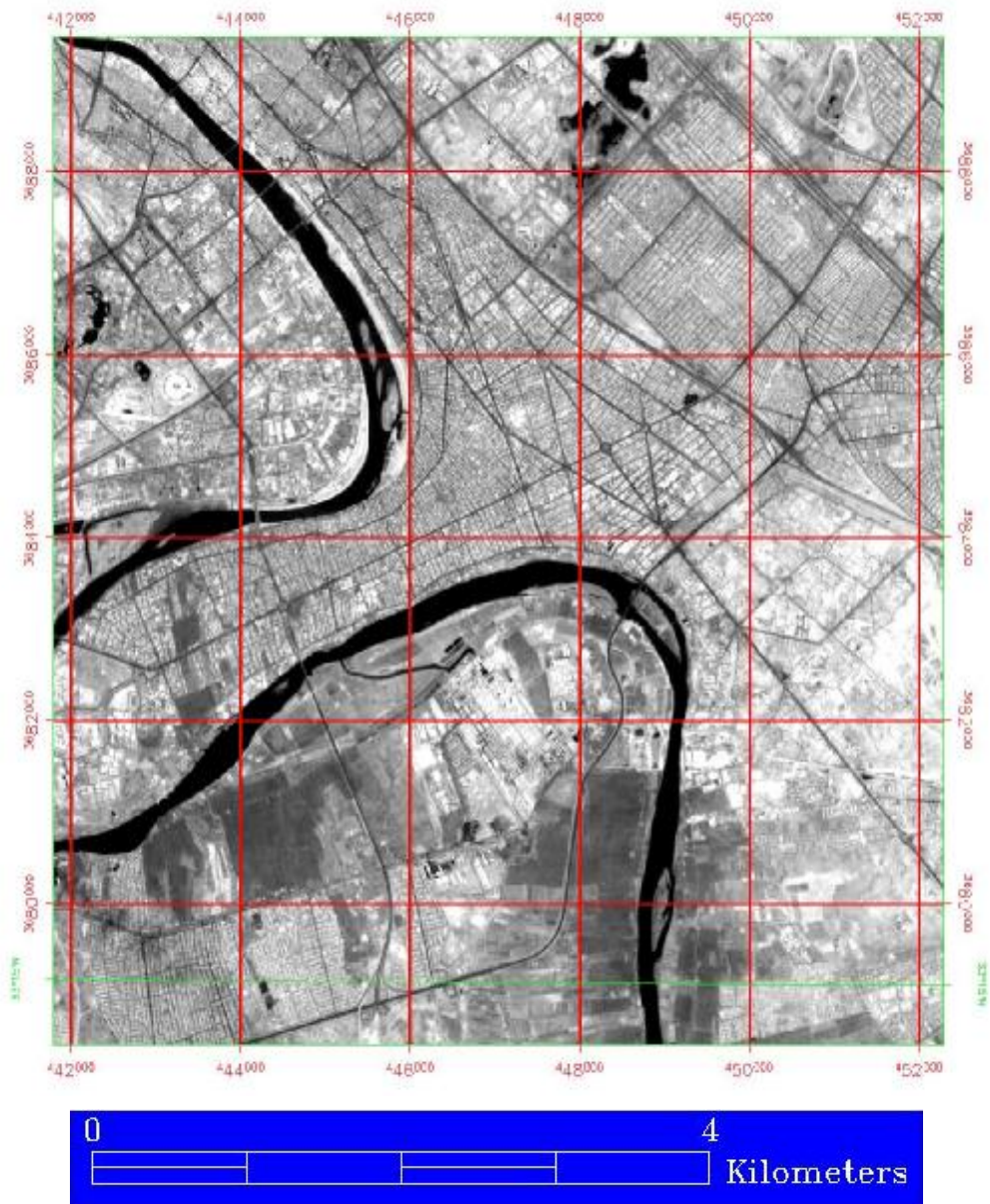

Figure (3) Nearest Neighbor Resampling

Figure (4) Direct Geo-Image Results

Figure (5) The Final Geo-Image

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