CHAPTER ONE

Introduction

1.1. Background

Any remote sensing image, regardless of whether it is acquired by a multispectral scanner on board a satellite, photographic system in an aircraft, or any other platform, sensor combination, will have various geometric distortions (Levin, 1999).

This problem is inherent in remote sensing, as we attempt to accurately represent the three dimensional surface of the earth as a two dimensional image.

All remote sensing images are subject to some form of geometric distortion, depending on the manner in which the data are acquired. these errors may be due to a variety of factors including one or more of the following to name only a few:

- The perspective of the sensor potties.
- The motion of the scanning system.
- The motion and instability.
- The platform attitude, and velocity.
- The terrain relief, and
- The curvature and rotation of the earth.

1.2. Research problem

To some extant there is ambiguity concerning the use of ground control points for images georeferencing.

1.3. Research Objectives

- The main objectives of this study is to evaluate the accuracy of geometric correction of Aerial photograph , in addition to study the effect of distribution and densification of control points used in geometric correction.
- The study also investigates and compares the result obtained when increasing the number of control points, in addition to investigate the effect of the distribution of control points in the geometric correction.

1.4 .Previous studies

There are a variety of studies implemented to examine the geometric correction , Eiman Elhaj (2012) examined the effect of polynomial order on the adjustment of the satellite images and the result was that the first order polynomial equation is enough to adjust the satellite image.

Mutluoglu (2014) investigated the effect of the number of ground control points and distribution on adjustment of WorldView-2 Stereo images and concluded that the effect of distribution of control points was found to be more effective than the effect of number of the control points upon the adjustment results.

1.5. Structure of the Thesis

This thesis is organized into six chapters. The first chapter forms the introduction to the thesis and discusses the image geometric correction in addition to the research objective.

Chapter two provides general concepts of remote sensing, including the types of remote sensing, platforms, in addition to digital image processing in details.

Chapter three reports geometric correction in details. Data and methods have been discussed in chapter four in detailed.

Chapter five reports in detailed results and discussion of results .Conclusion and recommendations have been provided in chapter six.

CHAPTER TWO

Remote Sensing And Digital Image Processing

2.1. Introduction of remote sensing

Remote sensing can be broadly defined as the collection and interpretation of an object, area or event without being in physical contact with the object. Aircrafts and satellites are the common platforms for remote sensing of the earth and its natural resources. Aerial photographs in the visible portion of the electromagnetic wave length were the original form of remote sensing but technological developments has enabled the acquisition of information using other wave lengths including near infrared, thermal infrared and microwave. Collection of information using a large number of wave length bands is referred to as multispectral or hyper spectral data. The development and deployment of manned and unmanned satellites have enhanced the collection of remote sensing data and offered an inexpensive way to obtain information over large areas. The capacity of remote sensing expanded greatly over the last few years and remotely sensed data will be an essential tool in natural resource management (Sanderson, 2010).

also Remote sensing can be defined as the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation. While the science of remote sensing provides the instrument and theory to understand how object and phenomenon can be detected, the art of remote sensing provides useful information (Canada center for remote sensing tutorial).

2.2. Stages of Remote Sensing

1. Emission of electromagnetic radiation , or EMR(sun/self emission).
2. Transmission of energy from the source to the surface of the earth, as well as absorption and scattering.
3. Interaction of EMR with the earth surface: reflection and emission.
4. Transmission of energy from the surface to the remote sensor.
5. Sensor data output.
6. Data transmission, processing and analysis.

2.2.1. Electromagnetic Energy

The electromagnetic (EM) spectrum is the continuous rangs of electromagnetic radiation extending from gamma rays (highest frequency and shortest wave length) to radio wave (lowest frequency and longest wave length) and including visible light .figure (2.1) represents the electromagnetic spectrum.

The EM spectrum can be divided into seven different regions - gamma rays, ultraviolet, visible light, infrared, microwaves and radio waves

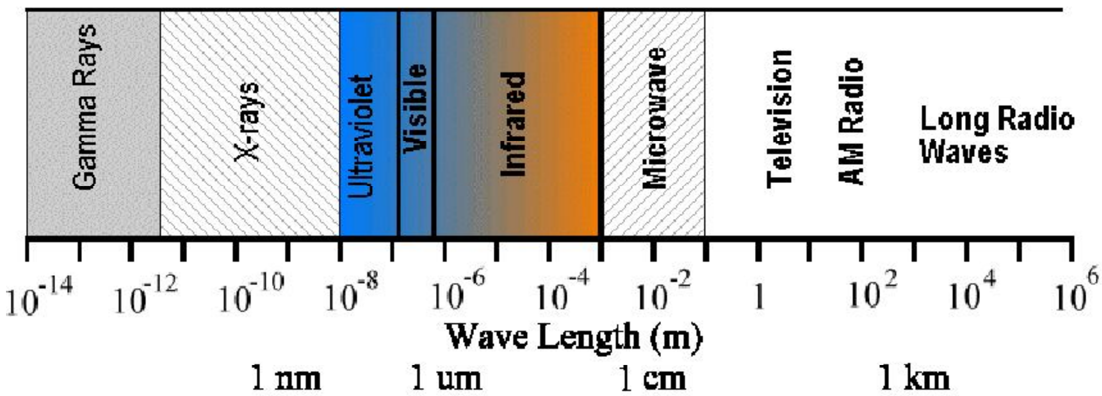

Figure (2.1) Electromagnetic Spectrum

Remote sensing involves the measurement of energy in many parts of the electromagnetic (EM) spectrum.

The major region of interest in satellite sensing are visible light, reflected and emitted infrared and micro wave regions. The measurement of this radiation takes place in what is known as spectral band.

A spectral band is defined as discrete interval of the EM spectrum, for example, the wave length range of 0.4µm to 0.7 µm (µm=micrometers or 10^{-6})is one spectral band. Satellite sensors have been designed to measure responses within particular a spectral band to enable the discrimination of the major earth surface materials .

Scientists will choose a particular spectral band for data collection depending on what they wish to examine.

The design of satellite sensors is based on the absorption characteristics of the Earth surface materials across all the measurable part in the (EM) spectrum (Sanderson, 2010).

2.2.2. Reflection and Absorption

When radiation of the sun reaches the surface of the earth, some of the energy at specific wave lengths is absorbed and the rest of the energy is reflected by the surface material.

The only two the exceptions to this situation are if the surface of body is a perfect reflector or true black body. The occurrence of this surface in the natural world is very rare.

In the visible region of the (EM) spectrum, the feature we describe as the color of the object is the visible light that is not absorbed by that object.

In the case of green leaf, for example, the blue and red wavelengths are absorbed by the leaf, while the green wavelength is reflected and detected by our eyes.

In remote sensing, a detector measures the electromagnetic (EM) radiation that is reflected back from the Earth’s surface material (Sanderson, 2010).

This measurement can help to distinguish the type of absorption over different wave length.

The reflectance of radiation from one type of surface material, such as soil, varies over the range of wave lengths in the EM spectrum .This is known as the spectral signature of the material.

All Earth surface features, including minerals, vegetation, dry soil, water, and snow have unique spectral reflectance signatures (Sanderson, 2010).

2.2.3. Sensors and Platforms

2.2.3.1. Sensors

A sensor is a device that measures and records electromagnetic energy . sensors can be divided in two groups :

passive sensors depend on an external source of energy, usually the sun. The most common passive sensor is the photographic camera.

Active sensor have their own source of energy, an example would be a radar . These sensors send out a signal and measure the amount reflected back.

Active sensors are more controlled because they do not depend upon varying illumination condition (Sanderson, 2010).

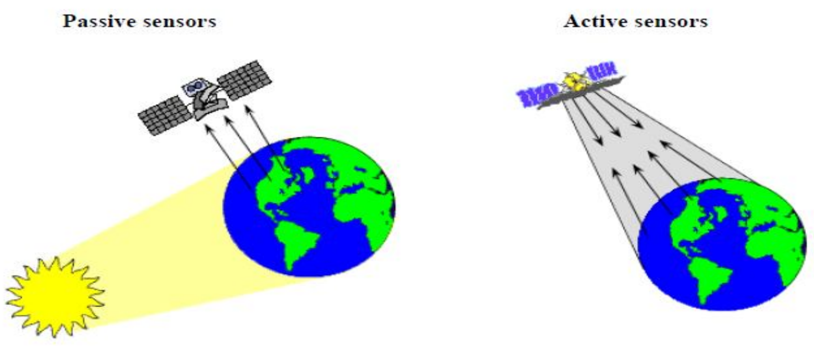

Figure (2.2) Passive and Active Sensors

2.2.3.2. Platforms

Aerial platforms are primarily stable wing aircrafts , although helicopters are occasionally used. Aircrafts are often used to collect very detailed photographs and facilitate the collection of data over virtually any portion of the Earth's surface at any time (Leven, 1999).

2.2.4. Transmission, Reception and Processing

The energy recorded by the sensor has to be the transmitted, often in electronic form to a receiving and processing station where data are processed.

2.2.5. Interpretation and Analysis

The processed image is interpreted visually and or digitally or electronically to extract information about the target which was illuminated.

2.2.6. Application

The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information or assist in solving a particular problem (Sanderson, 2010).

2.3. Digital Image

Electromagnetic energy may be detected either photographically or electronically. The photographic process uses chemical reaction on the surface of light –sensitive film to detect and record energy variations . It is important to distinguish between the terms images and photographs in remote sensing.

An image refers to any pictorial representation, regardless of what wavelength or remote sensing device has been used to detect and record the electromagnetic energy (Leven, 1999).

A photograph refers specifically to images that have been detected as well as recorded on photographic film. Photos are normally recorded over the wavelength range from 0.3µm to 0.9 µm (the visible and reflected infrared) .

According to these definitions, it is clear that all photographs are images, but not all images are photographs. Therefore, unless we are talking specifically about an image recorded photographically, the term image will be used.

A photograph could also be represented and displayed in digital format by subdividing the image into small equal –sized divisions and representing the brightness of each area with a numeric value or digital number. Figure (2.3) represents a digital image.

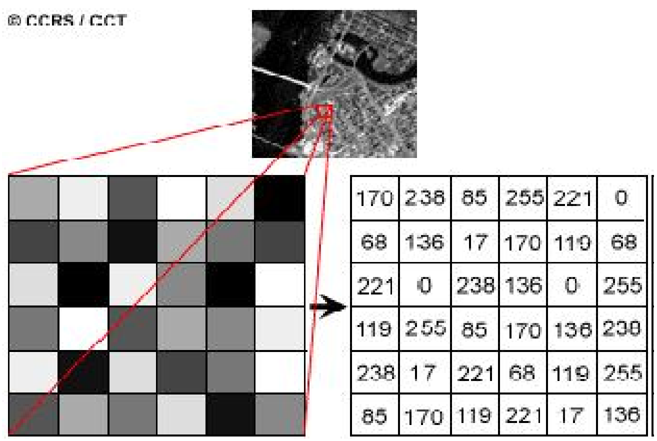

Figure (2.3) Digital Image

The photograph was scanned and subdivided into pixels with each pixels assigned a digital number representing its relative brightness.

The computer displays each digital value as different brightness levels (Levin, 1999).

2.4. Digital Image Processing

In today's world of advanced technology where most remote sensing data are recorded in digital format, virtually all image interpretation and analysis involves some element of digital processing.

Digital Image Processing may involve numerous procedures including formatting and correcting the data, digital enhancement to facilitate better visual interpretation or even automated classification of targets and features entirely by computer (Levin,1999).

In order to process remote sensing imagery digitally, the data must be recorded and available in a digital form suitable for storage on a computer tape or disk.

Obviously, the other requirement for digital image processing is a computer system.. Several commercially available software system have been developed specifically for remote sensing. Image processing functions available in image analysis systems can be categorized into the following four categories :

- Preprocessing.
- Image enhancement.
- Image transformation.
- Image classification and analysis.

2.4.1. Preprocessing

This function involves operations that are normally required prior to the main data analysis and extraction of information, and are generally grouped as radiometric or geometric corrections .

2.4.1.1. Radiometric Correction

Radiometric correction includes correcting the data for sensor irregularities and unwanted data such as atmospheric noise, and converting the emitted radiation measured by the sensor.

2.4.1.2. Geometric Correction

Geometric correction includes correcting for geometric distortions due to sensor _ earth geometry variation, and converting the data to real world coordinates (e.g. latitude and longitude) on the earth's surface.

2.4.2. Image Enhancement

Image enhancement is solely to improve the appearance of the imagery to assist in visual interpretation and analysis. Examples of enhancement functions include contrast stretching to increase the tonal distinction between the various features in a scene, and specific spatial patterns in an image (Levin, 1999).

2.4.3. Image Transformation

Image transformation is an operation similar in concept to those for image enhancement. However, unlike image enhancement operations which are normally applied only to a single channel of data at a time, image transformation usually involves combined processing of data composed of multiple spectral bands.

Arithmetic operations (i.e. subtraction addition, multiplication, division) are performed to combine and transform the original bands into “new” image which better displays or highlights certain features in the scene.

2.4.4. Classification and Analysis Operations

Classification of images is used to digitally identify and classify pixels in the data. Classification is usually performed on multichannel dataset and this process assigns each pixel in an image to a particular class or theme based on statistical characteristics of the pixel value. There are a variety of approaches followed to perform digital classification

In a supervised classification the analyst identifies in the imagery homogeneous representative samples of the different surface cover types (information classes) of in tersest .These samples are referred to as training area.

This selection of appropriate training areas is based on the analysts familiarity with the geographical cover type present in the image .This analyst “supervizes” the categorization of a set of specific classes. Unsupervised classification is in essence the reverse, the spectral classes are grouped first, based solely on the numerical information in the data, and are then matched by the analyst to information classes (if possible) . information classes (if possible) .

Programs , called clustering algorithms are used to determine the natural (statistical) groupings or structures in the data. Usually, the analyst specifies how many groups or clusters are to be looked for in the data. Unsupervised classification is not completely without human intervention.

However, it does not start with a predetermined types of classes as in a supervised classification.

CHAPTER THREE

Geometric Correction

3.1. Introduction

Image data commonly need to be rectified to a standard projection and datum . rectification is procedure that distorts the grid of image pixels onto a know projection and datum . the goal in rectification is to create a faithful representation of the scene in terms of position and radiance . Rectification is performed when the data are un projected needs to be reprojected , or when geometric correction are necessary .if the analysis does not require the data to be compared or overlain onto other data , correction and projection not be necessary . The distortions may be due to several factors, including: the perspective of the sensor optics; the motion of the scanning system; the motion of the platform; the platform altitude, attitude, and velocity, the terrain relief, and the curvature and rotation of the Earth. Geometric corrections are intended to compensate for these distortions so that the geometric representation of the imagery will be as close as possible to the real world. Many of these variations are systematic or predictable in nature and can be accounted for by accurate modeling of the sensor and platform motion and the geometric relationship of the platform with the Earth. Other unsystematic or random errors cannot be modeled and corrected in this way. Therefore, geometric registration of the imagery to a known ground coordinate system must be performed. Satellite images can be acquired at different processing levels regarding their geometric quality (Levin, 1999).

It would be wonderful if every remotely sensed image contained data that were already in their proper geometric x, y location. This would allow each image to be used as if it were a map (Jensen. 2005) Unfortunately; this is not the case the geometric distortion should be removed so those individual picture elements (pixels) are in their proper plan metric (x, y) map locations.

This allows remote sensing -derived information to be integrated with other thematic information in Geographic Information System (GIS) or Spatial Decision Support (SDSS). Geometrically corrected imagery can be used to extract accurate distances, areas and directions (bearings) information (Jensen, 2005).

3.2. Systematic Errors

1- Scan Skew: Caused by the forward motion of the platform 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-scan geometric distortion .

2- Mirror-Scan Velocity Variance: The mirror scanning rate is usually not constant across a given scan, producing along-scan geometric distortion.

3- Panoramic Distortion: The ground area imaged is proportional to the tangent of the scan angle rather than to the angle itself. Because data are sampled at regular intervals, this produces along-scan distortion

4- Platform Velocity: If the speed of the platform changes, the ground track covered by successive mirror scans changes, producing along-track scale distortion.

5- Earth Rotation: Earth rotates as the sensor scans the terrain. This results in a shift of the ground swath being scanned, causing along-scan distortion.

6- Perspective: For some applications it is desirable to have images represent the projection of points on Earth on a plane tangent to Earth with all projection lines normal to the plan (Jensen. 2005).

3.3. Non systematic Errors

1- Altitude Variance: If the sensor platform departs from its normal altitude or the terrain increases in elevation, this produces changes in scale

2- Platform Attitude: One sensor system axis is usually maintained normal to the Earth's surface and the other parallel to the spacecraft's direction of travel. If the sensor departs from this attitude, geometric distortion results.

3.4. Types of Geometric Correction

The geometric correction procedures often used for most commercially available remote sensor data (e.g., from spot image Inc, digital globe Inc; space imaging, Inc) already have much of the systematic errors removed. Unless otherwise processed, however, the errors remain in the image making it non planmetric (i.e., the Scientists apply one of the following procedures to make the digital remote sensor data of value:

1- Image to map rectification

2- Image to image registration

3- Image rectification using ground control point

The general rule of thumb is to rectify remotely sensed data to a standard map projection whereby it may be used in conjunction.

Geometric correction can be done by one of the following procedures:

3.4.1. Image- to- Map Rectification

Image – to- map rectification is the process by which the geometry of an image is made planmetric. Whenever accurate area, direction and distance measurements are required, image-to-map geometric rectification should be performed.

It may not, however, remove all the distortion caused by topographic relief displacement in image. The image-to-map rectification process normally involves coinciding GCP image pixels coordinates (row and column) with their map coordinate counterparts (e.g., meters northing and eating in universal transverse Mercator map projection) (Jensen, 2005).

3.4.2. Image-to- Image Registration

Image-to-image registration is the translation and rotation alignment process by which two images of like geometry and of the same geographic location are positioned coincident with respect to one another so that corresponding elements of the same ground area appear in the same place on the registered image.

This type of geometric correction is used when it is not necessary to have each pixel assigned unique x, y coordinates in a map projection. For example, we might want to make a cursory examination of two images obtained on different dates to see if any change has taken place. While it is possible to rectify both of the images to a standard map projection and evaluate them (image-to-map rectification), this may not be necessary to simply identify the change that has taken place between the two images (Jensen, 2005).

3.4.3. Image Rectification using Ground Control Points

The purpose of image rectification is to correct geometric errors of distorted image completely or partially. Geometrically rectified images can be used to extract distance, polygon , area and direction information with certain accuracy (Lee, et al ,2012).

The parametric and non- parametric approaches are the two main approaches used for image rectification according to pie, parametric approach is based on the modeling of the occurrence of the distortion.

Commonly , the characteristics, position and attitude of imaging sensors are used to update the parameters in parametric approach . However , in some cases the imaging parameters are difficult to obtain and are not disclosed by providers due to the purpose of commercial technology protection .

While for non-parametric approach, it is usually implemented in geographic information system (GIS) and remote sensing software. Non- parametric approach uses a set of ground control points (GCPs) as reference points and with an appropriate mathematical function to generate transformation approximation without considering the imaging mechanisms that caused the distortion (Lee, et al, 2012).

Besides that, non- parametric approach with GCPs has been claimed to rectify the variation caused by attitude inconsistencies of aircraft.

GCPs are points on the surface of the earth where both image coordinates and map coordinates can be identified. The aerial images could be rectified by generating the mapping transformation through the matching of control point from reference images and raw aerial images –generally, the process flow of aerial images rectification include GCPs detection and selection, corresponding GCPs matching, geometric transformation determination, rectification evaluation with residual error estimation and image resampling and interpolation as shown in figure (3.1) (Lee, et al, 2012).

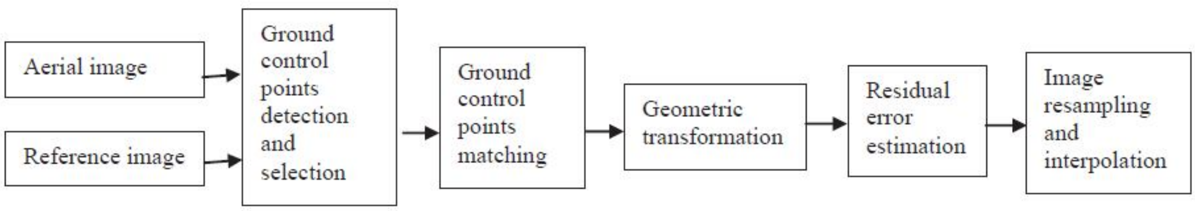

Figure (3.1) Process Flow of Aerial Image Rectification

The proper distribution of GCPs could be studied through the consideration of the possibilities that might exist in the aerial images and the geometric transformations used.

An evaluation of control points distribution is carried out to explore the effect of distribution patterns based on different distortions and commonly used geometric transformation (Lee, et al, 2012).

3.5 Polynomial Transformations

Polynomial equations are used to convert source file coordinates to rectified map coordinates. Depending upon the distortion in the imagery, the number of GCPs used, and their locations relative to one another, complex polynomial equations may be required to express the needed transformation. The degree of complexity of the polynomial is expressed as the order of the polynomial. The order is simply the highest exponent used in the polynomial.

The order of transformation is the order of the polynomial used in the transformation. ERDAS IMAGINE allows 1st- through nth-order transformations. Usually, 1st-order or 2nd-order transformations are used. However, if error in measurement is present, and it always is, to some degree, then greater accuracy may not be desirable.

A polynomial transformation may be more accurate for a control points, but less accurate on average (the image may suffer great distortions) (Levin, 1999).

The minimum number of selected GCPs depends on the polynomial order. The relations between The order of the polynomials; the minimum required number of GCPs; and number of coefficients of the used polynomials is given by the following equation: (lee, et al,2012)

$$N=(T+1)(T+2)/2 \tag{3.2}$$

Where:

N minimum number of GCPs

T order of the polynomial

M number of coefficients

3.6. Resampling

In order to actually geometrically correct the original distorted image, a procedure called resampling is used to determine the digital values to place in the new pixel locations of the corrected output image. The resampling process calculates the new pixel values from the original digital pixel values in the uncorrected image. There are three common methods for resampling: nearest neighbor, bilinear interpolation, and cubic convolution.

3.6.1 Nearest Neighbor

Nearest neighbor resampling uses the digital value from the pixel in the original image which is nearest to the new pixel location in the corrected image. Figure (3.2) represent the nearest neighbor resampling.

This is the simplest method and does not alter the original values, but may result in some pixel values being duplicated while others are lost. This method also tends to result in a disjointed or blocky image appearance (Levin, 1999).

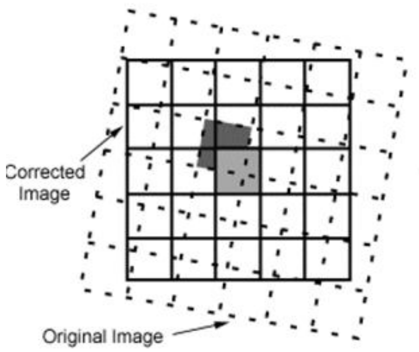

Figure (3.2) represents nearest neighbor resampling

3.6.2 Bilinear interpolation

Bilinear interpolation resampling takes a weighted average of four pixels in the original image nearest to the new pixel location. Figure (3.3) represents the bilinear interpolation resampling.

The averaging process alters the original pixel values and creates entirely new digital values in the output image. This may be undesirable if further processing and analysis, such as classification based on spectral response, is to be done. If this is the case, resampling may best be done after the classification process.

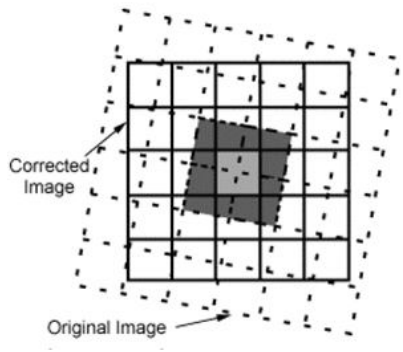

Figure (3.3) represents the bilinear interpolation resampling

3.6.3 Cubic Convolution

Cubic convolution resampling goes even further to calculate a distance weighted average of a block of sixteen pixels from the original image which surround the new output pixel location.

As with bilinear interpolation, this method results in completely new pixel values. However, these two methods both produce images which have a much sharper appearance and avoid the blocky appearance of the nearest neighbor method. Figure (3.4) represents cubic convolution (Levin, 1999).

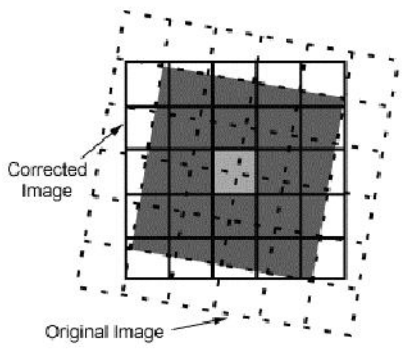

Figure (3.4) represents cubic convolution resampling

Chapter Four

Data And Methods

This research has been oriented to evaluate the effect of densification and Distribution of Control points in the Accuracy of Geometric Correction and how to enhance the accuracy by the best distribution of ground control points and reduce the number of ground control points when used for the geometric correction of datasets a situation which saves time, effort and money. The general steps adopted in this study are summarized in the flow chart displayed in figure (4.1) bellow.

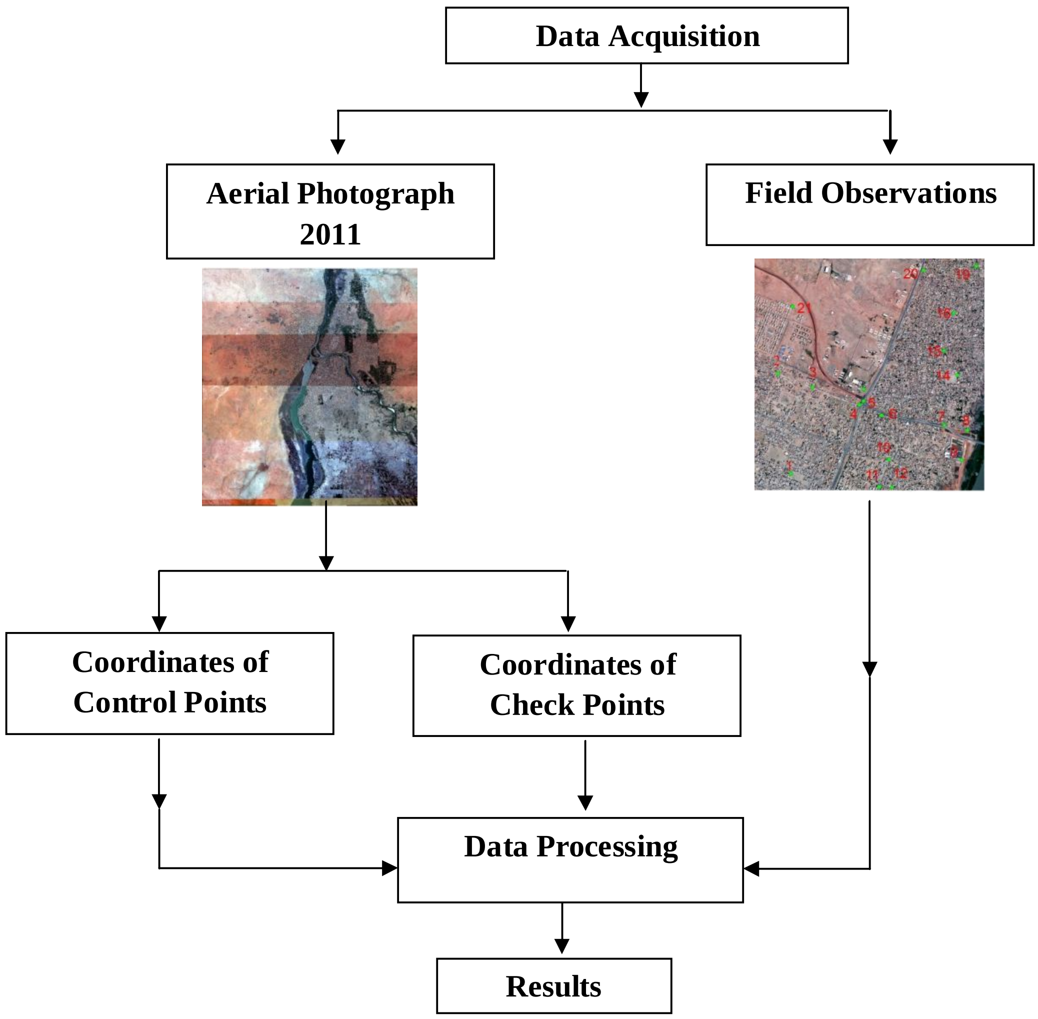

Figure (4.1) the Study Flow Chart

4.1. Study Area

The study area for this study is Sudan _ Khartoum State _ Karari Locality. Geographically, the study area is bounded by and approximately covers a total area of 8,935,159 m^2 longitudes (32° 30′ 10.0"E& 32° 31’ 45"E) and latitudes (15° 42′ 30" N & 15 ° 44′ 10" N).

Figures (4.2) and (4.3) represent the study area within Sudan map and the distribution of control points respectively.

Figure (4.2) Study Area within SUDAN Map

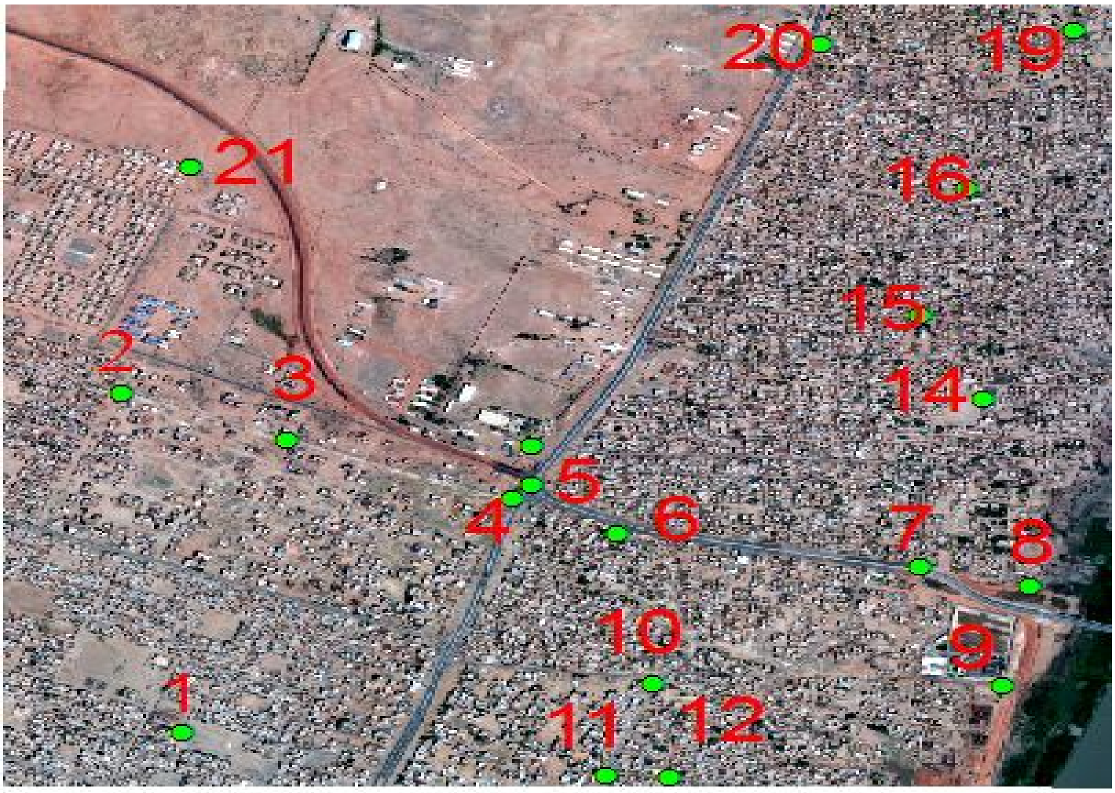

Figure (4.3) Study Area and Distribution of Control Points

4.2. Data Acquired and Sources

In order to examine the effect of distribution and densification of control points on the geometric correction, the following data were acquired:

Aerial photograph had been used as a primary source of spatial data with the following specifications:

Produced by: Sudanese Survey Authority.

Date of Photography: 2011.

Resolution: 0.5m

Datum: WGS84.

Projection: UTM, Zone 36N.

*Geodetic Coordinates of Ground Control Points (GCPs)

Datum: WGS1984.

Projection: UTM, zone 36.

*Reference Control point

Datum: WGS1984.

Projection: UTM, zone 36.

E: 447936.15

N: 1738151.661

H: 393.463 (Ellipsoid Height).

Description: concrete control point.

Location: Sudanese Survey Authority.

Source: Sudanese National Survey Corporation.

4.3. Hardware and Software Used

In general, different types of hardware and software packages were used for this study :-

4.3.1. Hardware

i-GPS receiver.

ii-Two Trimble 5800 GPS (reference and rover)

4.3.2. Software

i-Trimble Geodetic office was used for coordinates processing

ii - ERDAS Imagine software was used for geometric correction process.

4.4. Field Observations

The reference GPS were set at the control point. The twenty one control points were observed by rover to be used to calculate the accuracy of coordinate of digital image after geometric correction. Tables (4.1) and (4.2) show the control points and check points respectively.

Table (4.1) Coordinates of Control Points

point	E(m)	N(m)
1	447018.871	1737063.056
2	446846.766	1738355.916
3	447300.528	1738193.287
4	447887.601	1737962.136
6	448196.581	1737816.926
7	449009.692	1737696.920
8	449320.994	1737612.696
9	449238.299	1737239.127
12	448331.023	1736889.845
13	449184.004	1738340.344
14	449011.072	1738651.093
16	449426.047	1739737.399
17	448741.259	1739688.195
18	447041.060	1739215.796

Table (4.2) Coordinates of Check Points

Point	E(m)	N(m)
5	447961.504	1738002.610
10	448289.977	1737248.815
11	448170.163	1736897.210
15	449134.438	1739134.217

4.5. Data Processing

Aerial photograph of the study area was displayed in ERDAS software viewer as shown in figure (4.4) below

Figure (4.4) Aerial Photograph of Study Area

4.5.1. Geometric Correction

In order to examine the accuracy of geometric correction by using coordinates of control points, two tests were carried out.

4.5.1.1 The Test (Distribution)

In this step, geometric correction using three control points distribution and three points clustered in order to examine the effect of distribution of control points on Geometric correction

4.5.1.1.1 Three Control Points Distribution

Figure (4.5) below represents the distribution of the three control points in addition to check point.

Figure (4.5) Three Control Points Distribution and Check Point

4.5.1.1.2. Three Control Points Cluster

Figure (4.6) represents the clustered control points used in geometric correction

Figure (4.6) Three Clustered Control Points and Check Point

4.5.1.1.3. Six Control Points in Line

Six control points located long a straight line were used in the geometric correction , figure (4.7)

Figure (4.7) Six Control Points in Line and Check Point

4.5.1.1.4 Six Distributed Control Points

Six control points were distributed also used to evaluate the geometric correction. Figure (4.8) represents the distribution of control points.

Figure (4.8) Six Control Points Distributed

4. 5.1.1.5 Ten Control Points Distribution

Ten control points were used in order to examine the effect of the number of control points on the geometric correction .

figure (4.9) represents the distribution of control points.

Figure (4.9) Ten Control Points Distribution and Check Point

CHAPTER FIVE

Result and discussions

5.1 Introduction

The main objective of this research is directed towards examining the effect of the distribution and densification of control points on the geometric correction.

This chapter presents the result of the geometric correction using three, six and ten control points, and also examines test in terms of the root mean square (RMS) and linear errors

5.2 Linear Errors

The differences between the actual ground coordinates of the check points (from GPS) and their measured coordinates (from corrected aerial photograph) were computed. The linear errors for any points were computed using the following equation:

Linear error = $\sqrt{\Delta E^2 + \Delta N^2}$. (5.1)

Where,

ΔE= measured coordinate –actual ground coordinate (GPS reading) (5.2)

ΔN =measured coordinate – actual ground coordinate (GPS reading) (5.3)

Tables (5.1) illustrates the results of the geometric correction when three distributed control points were used

Table (5.1) Difference in E and N coordinate and linear error correction when using three distributed control points

point	E(m) GPS	N(m) GPS	E(m) reading	N(m) reading	ΔE	ΔN	Linear error
5	447961.504	1738002.610	447962.18	1738001.37	-0.676	1.24	1.412
10	448289.977	1737248.815	448290.86	1737247.39	0.883	1.425	1.676
11	448170.163	1736897.210	448167.00	1736895.36	3.63	1.85	4.074
15	449134.438	1739134.217	449011.70	1738649.76	-0.628	1.333	1.474

The resultant image represented in figure (5.1)

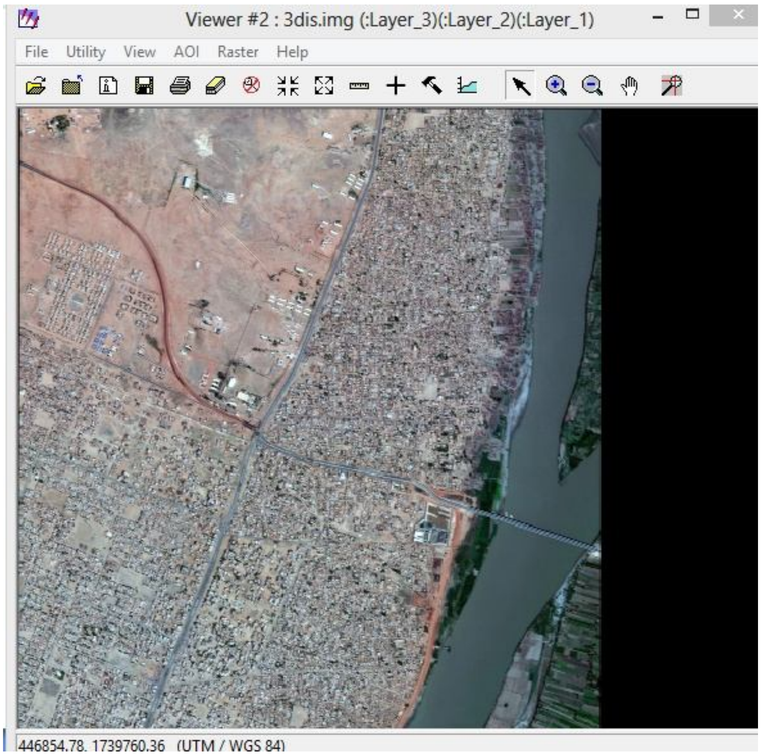

Figure (5.1) Result of Geometric Correction using Distributed Three Control Points

Tables (5.2) illustrates the results of the geometric correction using three clustered control points

Table (5.2) Difference in E and N coordinate and linear error using three clustered control points

point	E(m) GPS	N(m) GPS	E(m)	N(m)	ΔE	ΔN	Linear error
5	447961.504	1738002.610	447926.24	1738048.61	35.264	-46	57.962
10	448289.977	1737248.815	448258.61	1737285.45	31.367	-36.635	48.229
11	448170.163	1736897.210	448126.17	1736940.95	43.993	-43.74	62.037
15	449134.438	1739134.217	449022.32	1738647.26	-11.248	-145.09	145.525

Figure (5.2) shows the resultant image

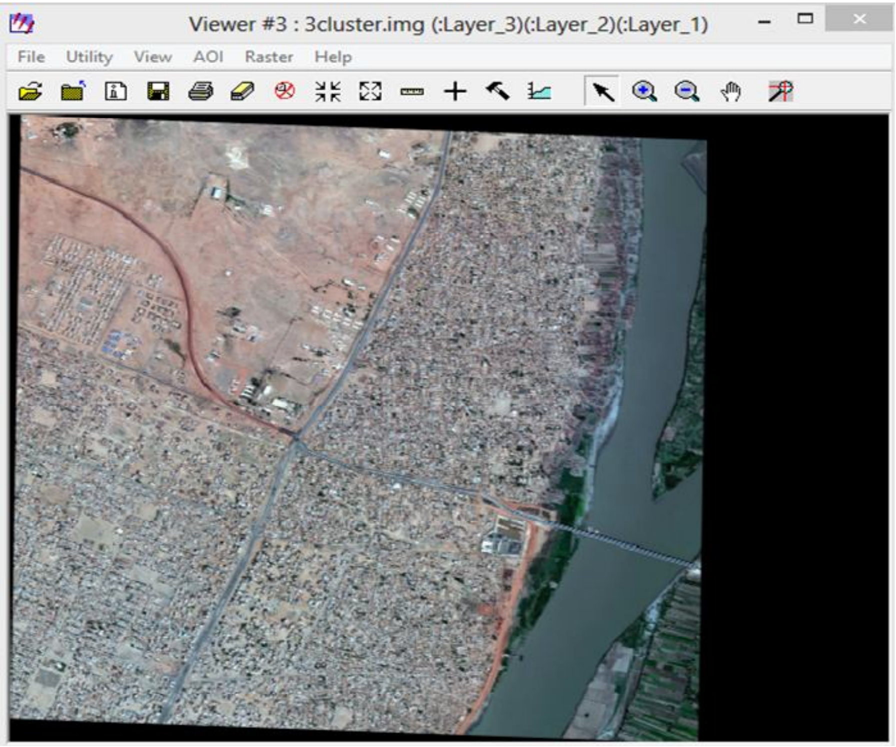

Figure (5.2) Result of Geometric Correction using Three Clustered Control Point

Tables (5.3) illustrates the results of the geometric correction using six distributed controls points

Table (5.3) Difference in E and N coordinate and linear error using six distributed control points

point	E(m) GPS	N(m) GPS	E(m)	N(m)	ΔE	ΔN	Linear error
5	447961.504	1738002.610	447961.07	1738002.41	0.434	0.2	0.478
10	448289.977	1737248.815	448290.99	1737241.85	-1.013	6.965	7.038
11	448170.163	1736897.210	448166.96	1736884.67	3.203	12.54	12.942
15	449134.438	1739134.217	449011.54	1738654.52	-0.468	-3.427	3.459

Figure (5.3) represents the resultant image

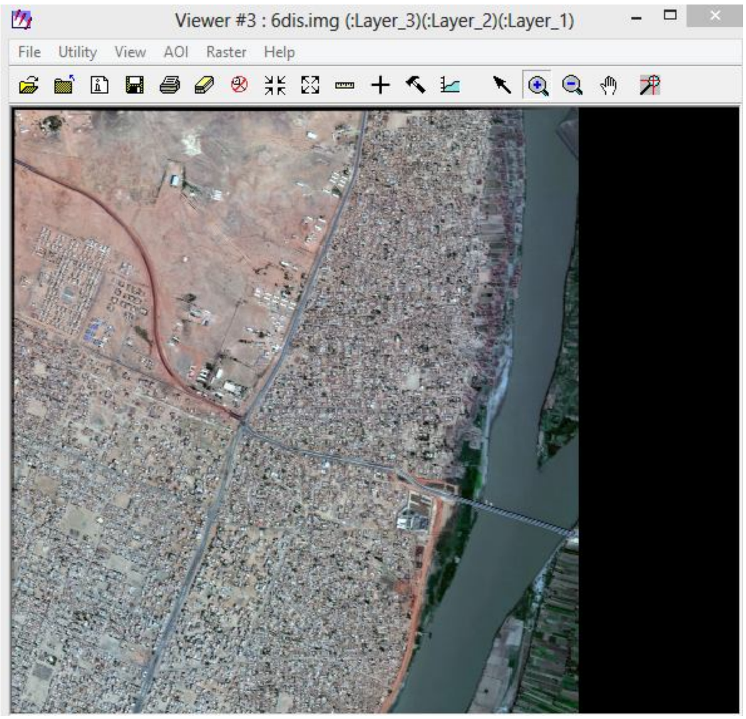

Figure (5.3) Result of Geometric Correction using Six Distributed Control Points

When six GCPs along a straight line, were used no corrected image was obtain

Figure (5.4) represents the resultant image

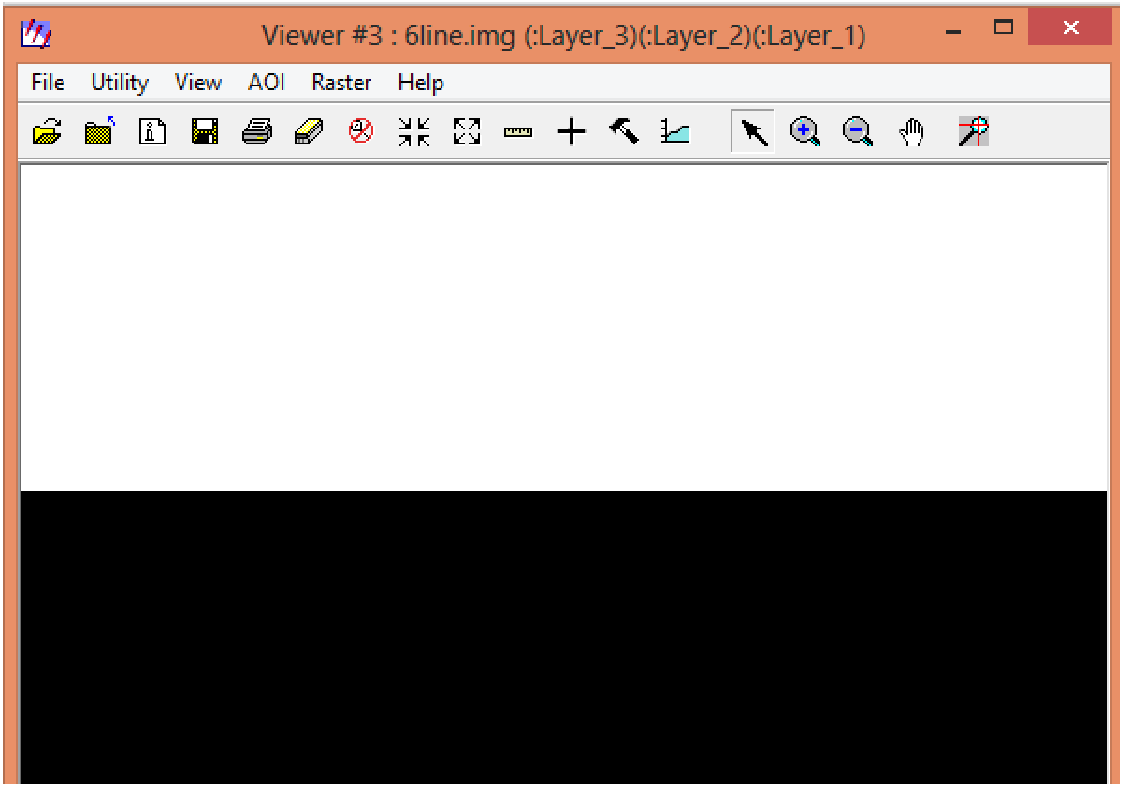

Figure (5.4) Result of Geometric Correction using Six Control Points Distributed along a straight Line

Tables (5.4) illustrates the results of the ten distributed control points for geometric correction

Table (5.4) Difference in E and N coordinate, and linear error using ten distribution control points for geometric correction.

point	E(m) GPS	N(m) GPS	E(m)	N(m)	ΔE	ΔN	Linear error
5	447961.504	1738002.610	447960.72	1738017.26	0.784	-14.65	14.671
10	448289.977	1737248.815	448291.96	1737255.51	-1.983	-6.695	6.983
11	448170.163	1736897.210	448168.40	1736898.25	1.763	-1.04	2.047
15	449134.438	1739134.217	449011.18	1738659.86	-0.108	-8.767	8.768

Figure (5.5) represented the resultant image

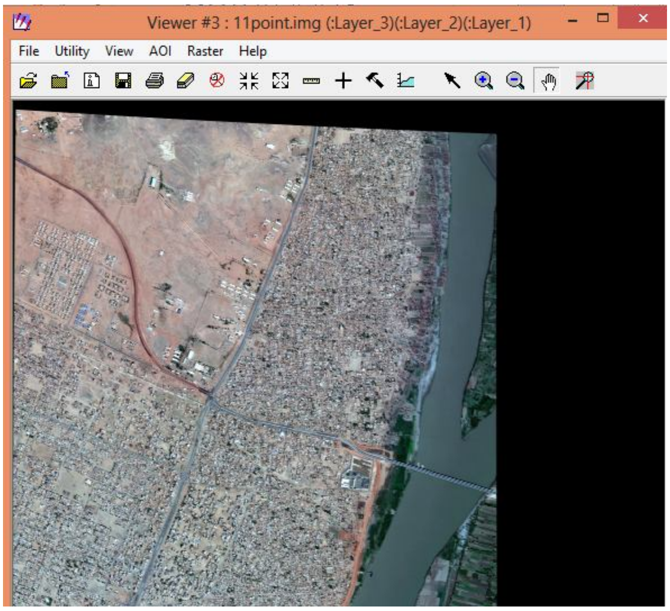

Figure (5.5) Result of Geometric Correction using Ten Distributed Control Point

5.3 Accuracy Evaluation

Root mean square errors for Easting and Northing coordinates were calculated for each order in the two tests. The equations used to calculate root mean square error are as follows:

$$\text{Root mean square error in } \Delta E = \sqrt{\frac{\sum \Delta E^2}{n}} \quad (5.1)$$

$$\text{Root mean square error in } \Delta N = \sqrt{\frac{\sum \Delta N^2}{n}} \quad (5.2)$$

Where,

ΔE = difference between measured coordinates and actual ground coordinate in easting.

ΔN = difference between measured coordinate and actual ground coordinate in northing.

n ≡ number of points.

To evaluate the accuracy of each test carried out, the root mean square errors were computed for the three orders of the polynomial equation as shown in table (5.5) and table (5.6) below.

Table (5.5) R.M.S.E in Easting & Northing for four images

Name	R.M.S.E in ΔE	R.M.S.E in ΔN
3clustered GCPs	4289.34	26422.419
3 distributed GCPs	14.808	8.768
6 distributed GCPs	11.693	217.547
10 distributed GCPs	7.667	337.387

Finally, the linear errors for the four products of the image were computed as shown in table (5.6) .The liner errors can be calculated using equation (5.3)

$$\text{Linear error} = \sqrt{\text{R.M.S.E in } \Delta E^2 + \text{R.M.S.E in } \Delta N^2} \quad (5.3)$$

Table (5.6) Linear Error for the Four Images**:**

images	**Linear error**
3clustered GCPs	175.2477072
3 distributed GCPs	5.164983253
6 distributed GCPs	5.722635657
10 distributed GCPs	5.600764493

Figure (5.6) Linear Error for the Four Images

CHAPTER SIX

Conclusion And Recommendation

6.1 Conclusion

The main conclusions obtained from the results and analysis of this research can be expressed as follows:-

- The bad location and bad distribution of the selected GCPs lead to increase in the average RMS error value of correction of an image.
- The effect of bad location of selected GCPs is more severe than that of bad distribution of selected GCPs on the correction accuracy.
- To obtain high accuracy of geometric correction of remote sensing aerial image, the location and distribution of selected GCPs should be taken into consideration as mentioned before.
- When the used GCPs were located in straight line , we did not obtain an image.
- Densification results showed that the number of GCPs used to adjust of the aerial images produce approximately the same results. Therefore, the use of three GCPs is sufficiently enough to adjust the aerial image, which will save time and effort.

6.2 Recommendations

The following recommendations are suggested for further studies in the same field:

- Using software such as: Arc GIS in all procedures of georeferenscing the distorted image to corrected image and compare the two results.
- Different distribution of Ground Control Points (GCPs) can be used to obtain result of geometric correction.
- Creation of a mathematical model for geometric correction.

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