Sudan University of Science & Technology

College of Graduate Studies

DETECTION OF OBSTACLES AROUND KHARTOUM INTERNATIONAL AIRPORT USING DIGITAL ELEVATION MODEL (DEM)

اكتشاف العوائق حول مطار الخرطوم الدولي باستخدام نموذج الإرتفاع الرقمي

A Thesis Submitted for the Degree of Master of Science in Geodesy and GIS

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الآية

قال تعالى :

(خَلَقَ ٱلسَّمَـٰوَ ٰتِ وَٱلْأَرْضَ بِٱلْحَقِّ ۖ يُكَوِّرُ ٱلَّيْلَ عَلَى ٱلنَّهَارِ وَيُكَوِّرُ ٱلنَّهَارَ عَلَى ٱلَّيْلِ ۖ وَسَخَّرَ ٱلشَّمْسَ وَٱلْقَمَرَ ۖ كُلٌّ يَجْرِى لِأَجَلٍ مُّسَمًّى ۗ أَلَا هُوَ ٱلْعَزِيزُ ٱلْغَفَّـٰرُ)

صدق الله العظيم

سورة الزمر الآية ﴿٥﴾

Dedication

This dissertation is dedicated to my father’s soul,I pray that this research be his ongoing charity.

To whom I grew up with her advocacies,my mother.

To my brothers and sisters who have supported me.And to my friends.

Abstract

This study is oriented to extract the heights of buildings around the International Khartoum Airport and to detect any obstacles. Aerial photographs were used to extract these heights by creatig Digital Elevation Model (DEM). Data has been processed in two ways : using Ground Control Points (GCPs) and without measured GCPs depending on exterior orientation parameters.

The procedures adopted in this study are applied on aerial photographs in two different regions (Inner Horizental Surface and Outer Horizental Surface). Results of heights of extracted DEM in Inner Horizental Surface gave elevation of ground above the buildings. So these results are not acceptable.

Another aerial photographs in Outer Horizental Surface were processed, and results were logical. Then accuracy of DEM was checked with observed heights from feild using traditional survey methods. Buildings in images were compared in the field , two of them were choosed for checking heights in extracted DEM.

It was found that the maximum deviation between the phisical heights and computed one is 2.702 meter when using Ground Control Points (GCPs) and was 2.931 meter without collecting GCPs. This deviation is acceptable according to minimum clearence height (30.48 meter).

التجريده

تهدف هذه الدراسة لاكتشاف العوائق حول مطار الخرطوم الدولي وذلك باستخلاص نموذج الارتفاعات الرقمي من الصور الجويه لمعرفة ارتفاعات المباني حول مطار الخرطوم الدولي. تم معالجة الصور الجويه في مرحلتين : باستخدام نقاط ضبط ارضية مرة وبدون استخدامها مرة اخرى اعتمادا على عناصر التوجيه الخارجي.

تم تطبيق الإجراءات المعتمده في هذه الدراسه على الصور الحويه في نطاقين مختلفين (السطح الأفقي الداخلي والسطح الافقي الخارجي). أعطت نتائج إرتفاعات نموذج الإرتفاع الرقمي في السطح الافقي الداخلي ارتفاع الأرض اعلى من ارتفاع المباني. هذه النتائج غير مقبولة.

تم معالجة صور جوية في السطح الأفقي الخارجي وكانت النتائج منطقيه. تم التأكد من دقة نموذج الارتفاع الرقمي وذلك باستخدام طرق المساحة التقليدية. قورنت المباني في الصور الجويه مع المباني في الطبيعة، تم اختيار اثنان من المباني للتأكد من دقة إرتفاعات نموذج الإرتفاع الرقمي المستخلص.

وجد ان اعلى فرق في الارتفاع بين الارتفاع الحقيقي و المحسوب هو 2.702 متر وذلك باستخدام نقاط ضبط ارضية، وكانت 2.931 متر بدون استخدام نقاط الضبط الارضية. هذه القيم مقبولة نسبة لأدنى ارتفاع مسموح به للطائره (30.48 متر).

Acknowledgement

My thanks and appreciation to my breeder **Dr. Khalaflla Mohamed Badi** for his advices and cooperation with me.

Iam greatful as well to **Engineer Salah Alhaj and Teacher Sami Awad** who tried hard with me to complete the reasearch to the extent required.

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Abbreviations

CASA	Civil Aviation Safety Authority
DEM	Digital Elevation Model
GCP	Ground Control Point
ICAO	International Civil Aviation Orgnization
LIDAR	Light Detection and Ranging
LPS	Lieca Photogrammetry Suit
OFZ	Obstacle-Free Zone
OLS	Obstacle Limitation Surface

CHAPTER ONE

INTRODUCTION

1.1 Introduction :

Obstacles are objects that affect the safety of flight. These objects are penetrate Obstacle Limitation Surface. Obstacle Limitation Surfaces (OLS) define the volume of airspace that should ideally be kept free from obstacles, each surface has maximum height for object. In this researsh Digital Elevation Model extracted from aerial photographs were used to detect objects that penetrate OLS.

1.2 Problem Statement :

The problem of this research includes:

- Time consuming to collect obstacles around airport.
- High cost for collecting these obstacles.
- There are not regular interval periods to descover any new obstacle.
- Reporting information about obstacle may be missed or omitted.

1.3 The Main Objectives of Research :

The objectives of this research are summerized in the following:

- Check obstacle's archives around airport for renew and updating.
- Monitoring of the urban growth around airport.
- Controlling of height around airport.
- Monitoring the implementing aeronautical plans.

1.4 Previous Studies

Many studies were made to observe obstacles around airports using different methods.

The RealScape/Airport system which depends on aerial photographs to collect obstacles for several airports in Japan over 4000 square kilometers in area(Airport Obstacle Extraction By Aerial Photograph Stereo Matching ,2009).

Another researsh about compairing three different techniques such as adaptive Automatic Terrain Extraction (ATE), traditional ATE available through Leica Photogrammetric Suite (LPS) and automated terrain extraction available through Orthoengine by extracted DSM from settelite image of Bhopal city in India (DSM extraction and evaluation from Cartosat-1 stereo data for Bhopal city, Madhya Pradesh, 2014).

1.5 Structure of the Thesis

This research contains six chapters, chapter one is introduction of the research it contains problem statement and objectives of the study. Chapters two discuses introduction of photogrammetry and software that has been used. Chapter three forms Digital Elevation Model (definition and sources). Obstacle Limitation Surface and Control of obstacles were introduced in chapter four. In chapter five steps to extract DEM and define obstacle have been explained. Chapter six is about results and discussion. Chapter seven contains conclusions and recomendations of research.

CHAPTER TWO

DIGITAL PHOTOGRAMMETRY

2.1 Introduction

Photogrammetry is the "art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena" (American Society of Photogrammetry,1980).

The traditional, and largest, application of photogrammetry is to extract topographic information from aerial photographs. Photogrammetric techniques have also been applied to process satellite images and close-range images in order to acquire topographic or non-topographic information of objects.

In analog photogrammetry, topographic maps were produced using, optical or mechanical instruments to extract three-dimensional geometry from two overlapping photographs.

The computer replaced some expensive optical and mechanical components in analytical photogrammetry. Outputs of analytical photogrammetry can be topographic maps, but also it can be digital products, such as digital maps and Digital Elevation Models (DEMs).

Digital photogrammetry is photogrammetry applied to digital images that are stored and processed on a computer. Digital images can be scanned from photographs or directly captured by digital cameras. The output products are in digital form, such as digital maps, DEMs, and digital orthoimages. With the development of digital photogrammetry, photogrammetric techniques could be integrated into remote sensing and GIS.

2.2 Coordinate Systems

Conceptually, photogrammetry involves establishing the relationship between the camera or sensor used to capture the imagery, the imagery itself, and the ground. In order to understand and define this relationship, each of the three variables associated with the relationship must be defined with respect to image space coordinate system (Lieca Photogrammetry Suite - Project Manager-user's guide, February 2008).

2.2.1 Pixel Coordinate System

The file coordinates of a digital image are defined in a pixel coordinate system. A pixel coordinate system is usually a coordinate system with its origin in the upper-left corner of the image, the x-axis pointing to the right, the y-axis pointing downward, and the units in pixels.

2.2.2 Image Coordinate System

An image coordinate system or an image plane coordinate system is usually defined as a two-dimensional (2D) coordinate system occurring on the image plane with its origin at the image center. The origin of the image coordinate system is also referred to as the principal point. On aerial photographs, the principal point is defined as the intersection of opposite fiducial marks as illustrated by axes *x* and *y* in. Image coordinates are used to describe positions on the film plane. Image coordinate units are usually millimeters or microns.

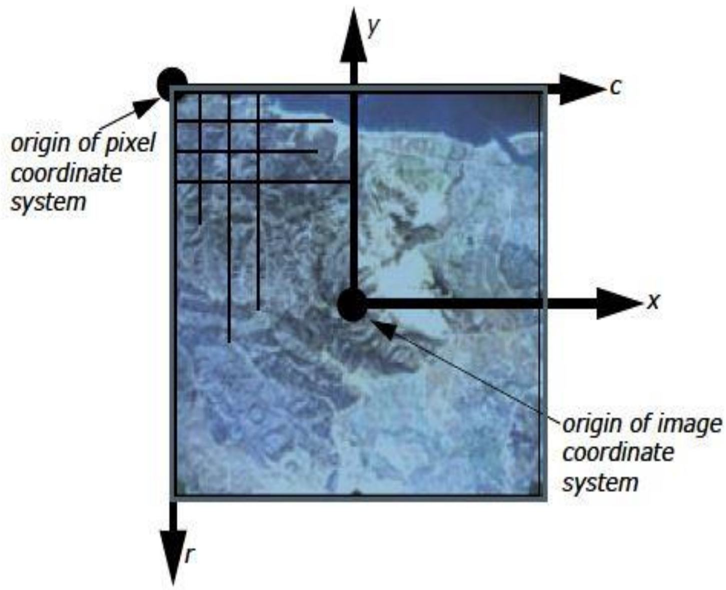


Figure (2.1): Pixel coordinates and image coordinates (Lieca Photogrammetry Suite - Project Manager-user's guide).

2.2.3 Image Space Coordinate System

An image space coordinate system is identical to an image coordinate system, except that it adds a third axis (z) to indicate elevation. The origin of the image space coordinate system is defined at the perspective center *S*. The perspective center is commonly the lens of the camera as it existed when the photograph was captured. Its x-axis and y-axis are parallel to the x-axis and y-axis in the image plane coordinate system. The z-axis is the optical axis, therefore the z value of an image point in the image space coordinate system is usually equal to the focal length of the camera (f). Image space coordinates are used to describe positions inside the camera and usually use units in millimeters or microns.

2.2.4 Ground Coordinate System

A ground coordinate system is usually defined as a 3D coordinate system that utilizes a known geographic map projection. Ground coordinates (X,Y,Z) are usually expressed in feet or meters. The Z value is elevation above mean sea level for a given vertical datum.

This coordinate system is referenced as ground coordinates (X,Y,Z).

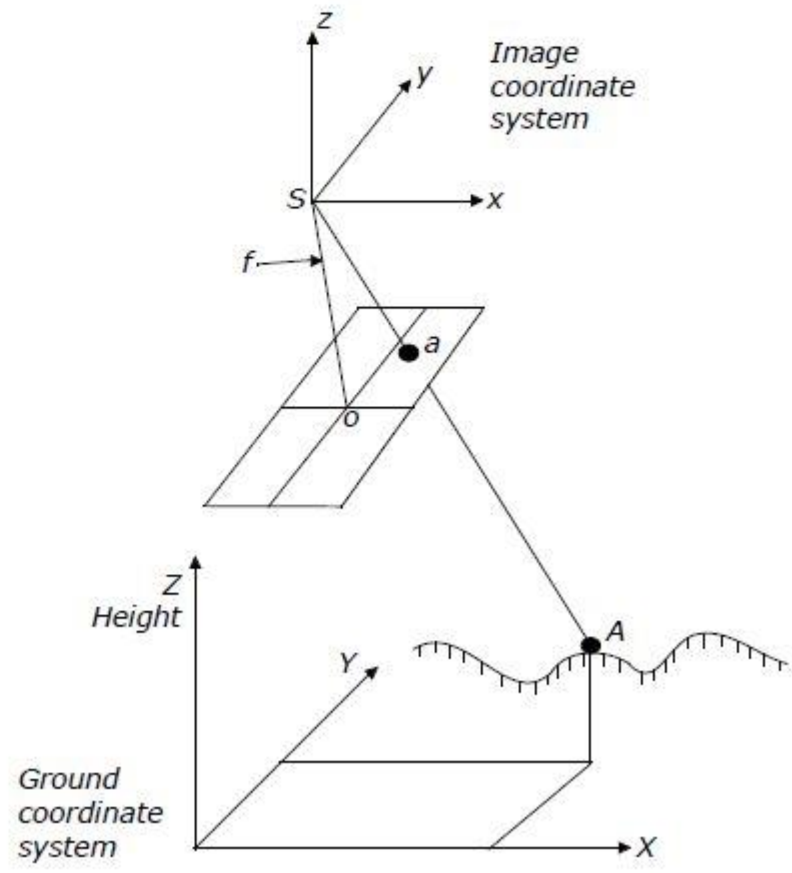


Figure (2.2): Image space and ground space coordinate system.

2.3 Orientation of Aerial Photographs

2.3.1 Interior Orientation

Interior orientation describes the internal geometry of a camera or sensor as it existed at the time of image capture. Interior orientation is primarily used to transform the image pixel coordinate system (x_0,y_0) to the image space coordinate system (x_0,y_0,z_0). The variables associated with the internal geometry of an image captured from an aerial camera are :

- Principal point.
- Focal length.
- Fiducial marks.

- Lens distortion.

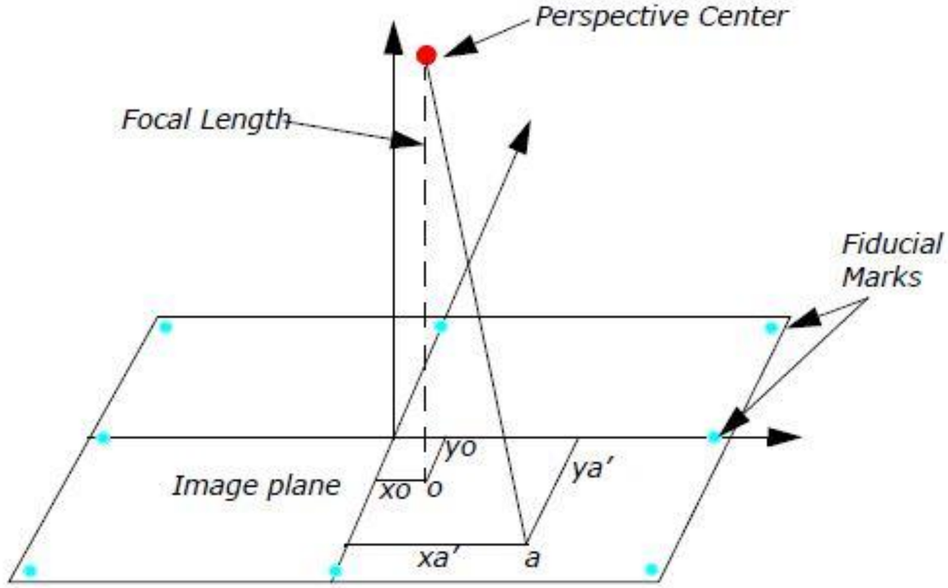


Figure (2.3): Internal geometry.

2.3.2 Exterior Orientation

Exterior orientation defines the position and angular orientation of the camera that captured an image. The elements of exterior orientation define the position and orientation of an image and the characteristics associated with an image at the time of exposure or capture. The elements of exterior orientation are positional elements and angular or rotational elements. Positional elements (Xo, Yo, and Zo) define the position of the perspective center (O) with respect to the ground space coordinate system (X, Y, and Z).

The angular or rotational elements define the relationship between the ground space coordinate system (X, Y, and Z) and the image space coordinate system (x, y, and z), these elements are: omega (ω) is a rotation about the photographic x-axis, phi (ϕ) is a rotation about the photographic y-axis and kappa (κ) kappa is a rotation about the photographic z-axis.

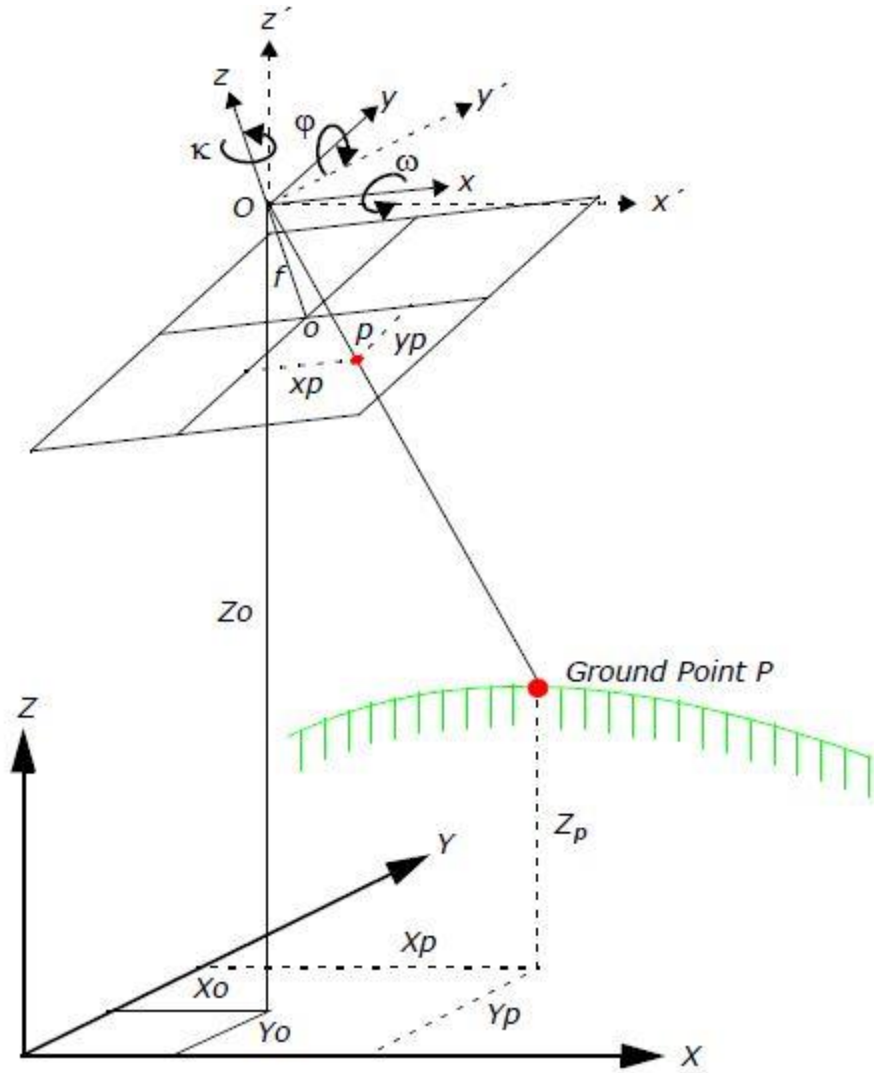


Figure (2.4): Elements of exterior orientation.

2.4 Aerial Triangulation

Block (aerial) triangulation, is the process of establishing a mathematical relationship between the images contained in a project, the camera (digital or film camera) or sensor model, and the ground. In Digital Elevation Model (DEM) extraction process the information resulting from triangulation is required as input. Lieca Photogrammetry Suite (LPS) Project Manager uses a technique known as bundle block adjustment for aerial triangulation which provides three primary functions (Lieca Photogrammetry Suite - Project Manager-user's guide, February 2008):

- The ability to determine the position and orientation of each image in a project as they existed at the time of photographic or image exposure. The resulting parameters are referred to as exterior orientation parameters.

- The ability to determine the ground coordinates of any tie points measured on the overlap areas of multiple images. The highly precise ground point determination of tie points is useful for generating GCPs from imagery in lieu of ground surveying techniques.

- The ability to distribute and minimize the errors associated with the imagery, image measurements, GCPs, and so forth. The bundle block adjustment processes information from an entire block of imagery in one simultaneous solution using statistical techniques to automatically identify, distribute and remove error.

2.5 Lieca Photogrammetry Suite (LPS) Project Manager

LPS Project Manager reduces the cost and time associated with triangulating and orthorectifying aerial photography, satellite imagery, digital, and video camera imagery when collecting geographic informations. The product addresses issues and problems related to LPS:

- Collecting GCPs in the field or office.
- Measuring GCPs and tie points on multiple images.
- Performing quality control in order to verify the overall accuracy of the final product.
- Accommodating photography and satellite imagery from various camera and satellite sensor types, including standard aerial, digital, video, amateur 35 mm cameras (including terrestrial and oblique photography), and SPOT push broom sensors.
- Integrating data from airborne global positioning system (GPS) and other photogrammetric sources.
- Using photography scanned from desktop scanners.
- Triangulating multiple images automatically.

- Extracting DTMs automatically from imagery.

2.6 Lieca Photogrammetry Suite (LPS) Project Manager Functionality:

- LPS Project Manager allows you to easily model various camera and sensor types, referred to as sensor modeling. LPS Project Manager’s sensor modeling capabilities establish the internal characteristics (that is, geometry) associated with a specific camera or sensor, and correct for systematic error.
- LPS Project Manager allows you to model the position and orientation of a camera or sensor at the time of data collection, which dramatically improves the accuracy of the resulting orthoimages.
- LPS Project Manager automatically measures the image positions of ground feature points appearing on multiple images, which is referred to as automatic tie point collection. Once the image positions of the tie points are established, the corresponding ground coordinates can be determined using aerial triangulation techniques. (If many tie points were automatically collected, a rough DEM can be interpolated using the tie points as mass points).
- LPS Project Manager gives you the flexibility to orthorectify images from a variety of camera and satellite sensor types. Additionally, it allows you to process multiple orthos sequentially.

CHAPTER THREE

DIGITAL ELEVATION MODEL

(DEM)

3.1 Definition

A digital elevation model (DEM) is a three diementional (3-D) representation of the terrain's surface, created from elevation data. There are two types of DEMs, digital terrain model (DTM) and digital surface model (DSM).

DTM represent the bare ground surface excluding any man-made features.

DSMs represent the earth's surface including all objects on it.

DEM store continuously varying variables such as elevation, groundwater depth or soil thickness.

3.2 Sources of Digital Elevation Model

DEMs are made via the following techniques:

3.2.1 Ground Surveying

The earth's surface can be represented by surveying and recording 3-D information (X,Y and Z) of discrete points (spot heights). These points are used to interpolate a 3D surface of the specific area of interest.

3.2.2 Traditional Photogrammetry

Analog and analytical stereo plotters have been used extensively to extract 3-D mass points from stereopairs. The left and right photographs associated with a stereopair are first oriented within a stereo plotter. The operator then manually collects 3-D mass points or contour lines one stereopair at a time. The placement and distribution of 3-D mass points depends on the operator's discretion.The output can be recorded digitally or on hardcopy paper (for future digitization). The 3D points are then used to interpolate a 3D surface.Traditional photogrammetric techniques are highly accurate, but time consuming while also requiring high level expertise.

3.2.3 Digital Stereo Plotters

Similar to the traditional stereo plotters, digital stereo plotters digitally record 3-D mass points into a file for subsequent interpolation into a 3-D surface. For example, Stereo Analyst allows for the collection of 3-D mass points. The 3D mass points (stored as an ESRI 3-D Shape file) can be interpolated to create a 3-D surface.Semiautomated approaches can be used to place the 3D floating cursor on the terrain during collection.

DEM can also be made by Digitized Topographic Maps, Radar and Light Detection and Ranging (LIDAR).

CHAPTER FOUR

OBSTACLES OF FLIGHT

4.1 Obstacles:

Obstacles are all fixed (whether temporary or permanent) and mobile objects, or parts thereof, that are located on an area intended for the surface movement of aircraft, or extend above a defined surface intended to protect aircraft in flight, or stand outside those defined surfaces and that have been assessed as being a hazard to air navigation.

4.2 Obstacle Limitation Surfaces (OLS):

The purpose of the OLS is to define the volume of airspace that should ideally be kept free from obstacles in order to minimize the dangers presented by obstacles to aircraft. The OLS provided for the control of obstacles includes: (ICAO Document 9137 - Airport Service Manual Part 6,1983):

a) Outer Horizontal surface,
b) Inner Horizontal Surface,
c) Conical surface,
d) Approach surface,
e) Transitional surfaces,
f) Inner Approach Surface,
g) Inner Transitional Surface, and
h) Balked landing surface.

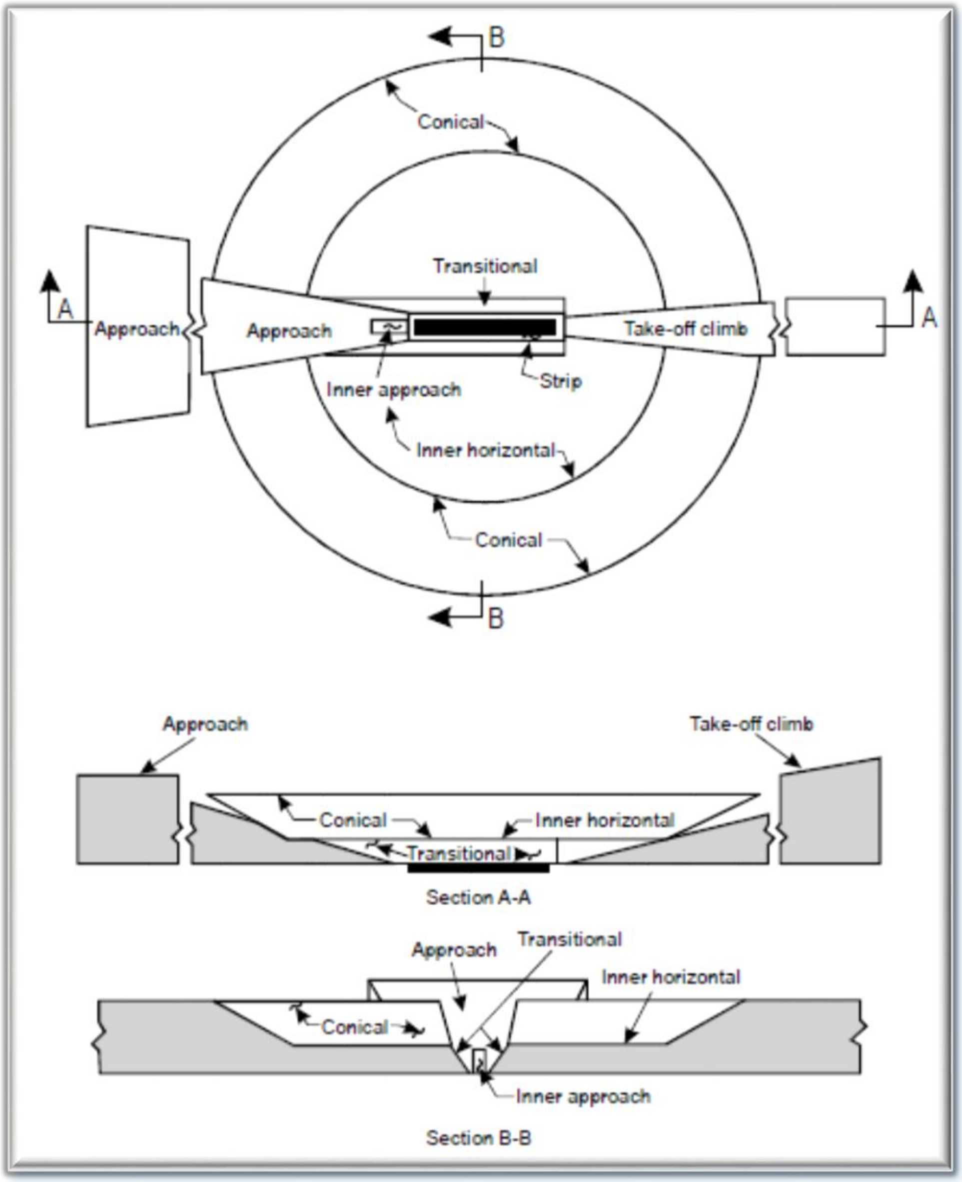


Figure (4.1): Obstacle limitaion surface (Annex 14).

4.2.1 Outer Horizontal Surfaces

Significant operational problems can arise from the erection of tall structures in the vicinity of airports beyond the areas currently recognized in Annex 14 (This Annex contains Standards and Recommended Practices (specifications) that prescribe the

physical characteristics and obstacle limitation surfaces to be provided for at aerodromes) as areas in which restriction of new construction may be necessary. The operational implications fall broadly under the headings of safely and efficiency.
As a broad specification for the outer horizontal surface, tall structures can be considered to be of possible significance if they are both higher than 30 m above local ground level, and higher than 150 m above aerodrome elevation within a radius of 15 000 m of the centre of the airport.

4.2.2 Inner Horizontal Surface and Conical Surface

The purpose of the inner horizontal surface is to protect airspace for visual circling prior to landing, possibly after a descent through cloud aligned with a runway other than that in use for landing.
Description of Conical surface is a surface sloping upwards and outwards from the periphery of the inner horizontal surface.

Note: The shape of the inner horizontal surface and conical surface need not necessarily be circular

4.2.3 Approach and Transitional Surfaces

Approach and Transitional Surfaces define the volume of airspace that should be kept free from obstacles to protect an aeroplane in the final phase of the approach-to-land manoeuvre.

4.2.4 Inner Approach, Inner Transitional and Balked Landing Surfaces

Together, these surfaces define a volume of airspace in the immediate vicinity of a precision approach runway which is known as the Obstacle-Free Zone (OFZ). This zone shall be kept free from fixed objects, other than lightweight frangible aids to air navigation which must be near the runway to perform their function, and from transient objects such as aircraft and vehicles when the runway is being used for category I1 or III Instrument Landing System (ILS) approaches.

For a non-instrument runway, and a non-precision instrument runway, the following OLS are to be applied:

(a) conical surface;

(b) inner horizontal surface;

(c) approach surface;

(d) transitional surface; and
(e) take-off climb surface.

4.3 Aerodrome Operator's Responsibilities for the OLS

The aerodrome operator is to monitor the OLS and report to Civil Aviation Safety Authority (CASA) any infringement or potential infringement of the OLS. When a new obstacle (which will infringe the OLS) is going to appear, the aerodrome operator is to ensure that appropriate notification to pilots is made in accordance with the procedures set out in the aerodrome manual.The information on the obstacle to be reported is to include at least the following: (Rules and Practices for Aerodromes,Aug 1999)

(a) The nature of the obstacle, e.g. structure or machinery;

(b) Distance and bearing of the obstacle from the end of the runway;

(c) Height of the obstacle in relation to the aerodrome elevation; and

(d) Times applicable, if temporary.

The aerodrome operator should prepare an OLS plan to facilitate the checking potential infringement of the OLS. Where prepared, a copy of the OLS plan is to be provided to CASA for aerodrome audit purposes.

4.4 Aerodrome Obstacle Charts

There are three main types of obstacle charts applicable to aerodrome operators:

i. Obstacle chart ICAO Type A (operating limitation).
ii. Obstacle chart ICAO Type B (non-mandotory chart).
iii. Obstacle chart ICAO Type C (conditionaly chart).

4.4.1 Obstacle chart ICAO Type A (Operating Limitation)

Providing obstacle data in the take-off climb area,in case of an engine failure during take-off and landing.

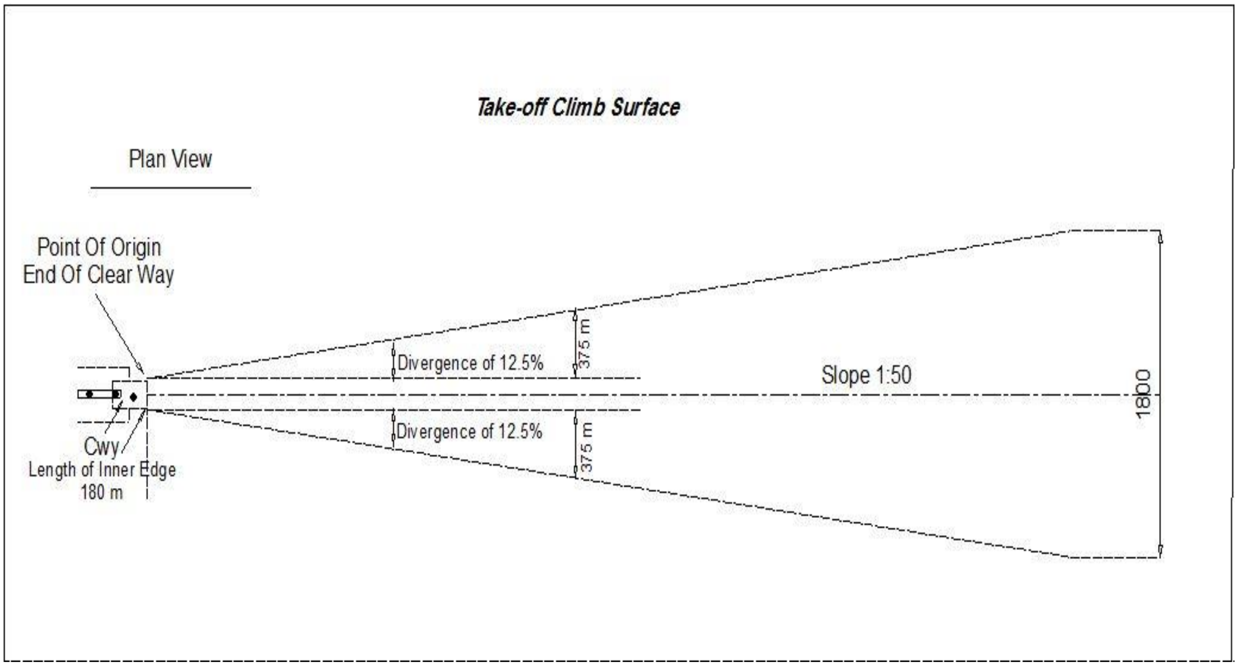


Figure (4.2): Obstacle chart type A in the take-off flight path area (Aerodrome Engineering Consultancy Co.Ltd)..

The obstacle data to be collected for the Type A chart, and the manner of presentation of the Type A chart, are to be in accordance with the standards and procedures set out in International Civil Aviation Orgnization (ICAO) Annex4 that is The basic slope shown on the chart is 1.2 percent which is below the slope of the protected take-off climb surface established for a runway.

4.4.2 Obstacle chart ICAO Type B (Non-Mandotory Chart)

The purpose of this chart is to prevent installations to penetrate Obstacle Limitation Surface. Where required, the obstacle data to be collected, and the manner of presentation of the Type B chart, are to be in accordance with the standards and procedures set out in ICAO Annex 4.

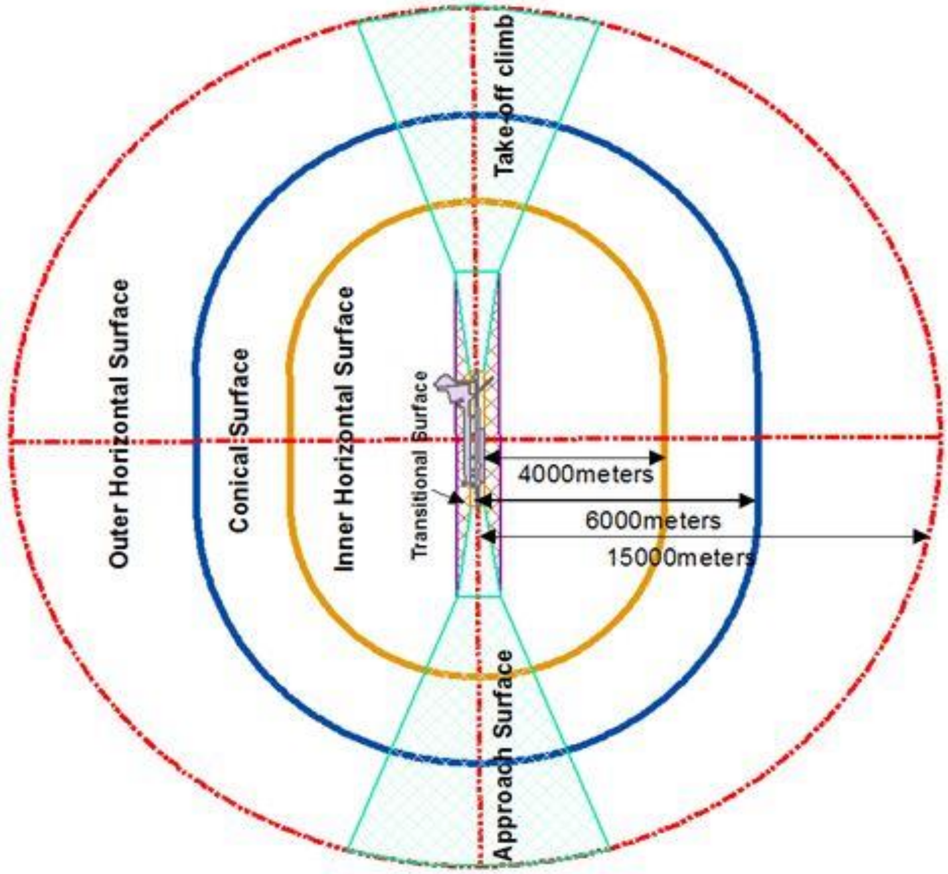


Figure (4.3): Obstacle chart type B in obstacle limitaion surface.

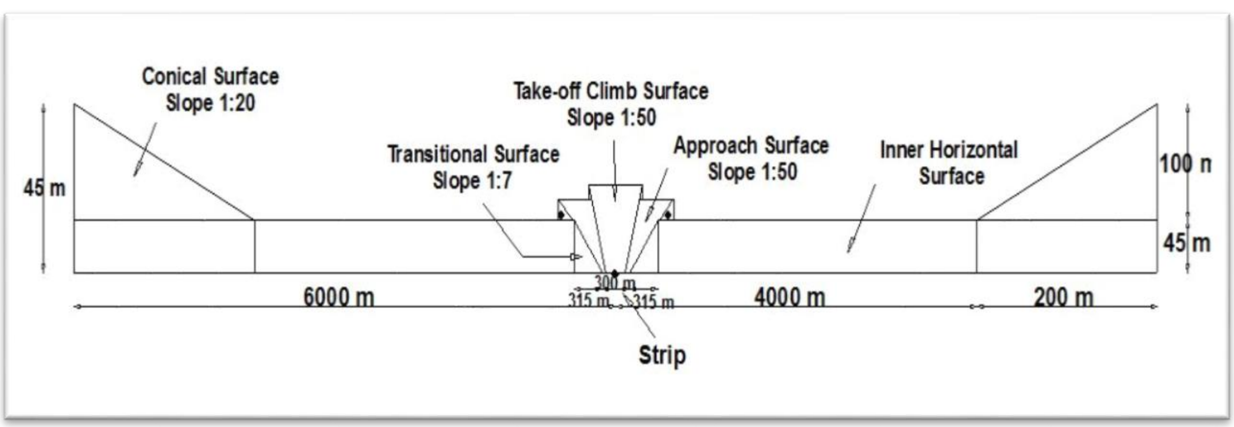


Figure (4.4): Profile view of obstacle chart type B (Aerodrome Engineering Consultancy Co.Ltd)..

4.4.3 Obstacle Chart ICAO Type C (Conditionaly Chart)

This chart illustrates natural conditions that related with location of airport e.g. some of airports are lying in mountainous area,or in ilands.

4.5 Control of Obstacles

Control can be achieved in a number of ways, by:(ICAO Document 9137 - Airport Service Manual Part 6,1983)

(a) Enactment of height zoning protection by the local government authority;

(b) Establishing an effective obstacle removal programme; or

(c) Purchasing of easement or property rights, or all of these.

4.5.1 Height Zoning

The objective of height zoning is to protect the aerodrome obstacle limitation surfaces from intrusion by manmade objects and natural growth such as trees. This is done by the enactment of ordinances identifying height limits underneath the aerodrome obstacle limitation surfaces. The responsibility for the enactment of such an ordinance is a matter between the aerodrome operator and the local government authority.

4.5.2 Obstacle Removal

When obstacles have been identified, the aerodrome operator should make every effort to have them removed, or reduced in height so that they are no longer an obstacle. If the obstacle is single object it may be possible to reach agreement with the owner of the property to reduce the height to acceptable limits without adverse effect. Examples of such objects are a tree, a television aerial or a cell phone tower.

Some aids to navigation both electronic, such as ILS components, and visual, such as approach and runway lights, constitute obstacles which cannot be removed. Such objects should be frangibly designed and constructed, and mounted on frangible couplings so that they will fail on impact without significant damage to an aircraft.

4.5.3 Easements or Property Rights

In those areas where zoning is inadequate the aerodrome operator may take steps to protect the obstacle limitation surfaces by other means. Examples of zoning inadequacies might be locations close to runway ends or where obstacles exist. Examples of other means might be such as gaining easements or property rights. They should include removal or reduction in height of existing obstacles and measures to ensure that no new obstacles are allowed to be erected in the future.

Where agreement can be reached for the reduction in height of an obstacle, the agreement should include a written aviation easement limiting heights over the property to specific levels unless effective height zoning has been established.

4.5.4 Marking and Lighting of Obstacles

Where it is impractical to eliminate an obstacle it should be appropriately marked or lighted, or both, to be clearly visible to pilots in all weather and visibility conditions.
Obstacles shall be marked and, if the aerodrome is used at night, lighted, except that:
(a) Lighting and marking may be omitted when the obstacle is shielded by another obstacle; and

(b) The marking may be omitted when the obstacle is lighted by high intensity obstacle lights by day.

Vehicles and other mobile objects, excluding aircraft, on movement areas of aerodromes should be marked and lighted, unless they are used on apron areas only.

The aerodrome operator should make a daily visual inspection of all obstacle lights on and around the aerodrome, and take steps to have inoperative lights repaired.

4.5.5 Obstacle Shielding

The principle of obstacle shielding is employed to permit a more logical approach to restricting new construction and to the requirements for marking and lighting of obstacles. Shielding principles are employed when some object, an existing building or natural terrain, already penetrates above one of the aerodrome design obstacle surfaces. If the obstacle is permanent, then additional objects within a specified area around it can penetrate the surface without being obstacles. The original obstacle dominates or shields the surrounding area.

CHAPTER FIVE

METHODS AND DATA

5.1 Introduction

Methdology used in this research can be devided into six steps:

- Data collection,
- Creating block file,
- Project setup,
- Import images and Frame editor,
- Interior and Exterior orientation and
- DEM Extraction

The procedures adopted in this study are applied using aerial photographs in two different regions (Inner Horizontal Surface and Outer Horizontal Surface). This procedures are summerized in the following flow chart as shown in figure (5.1).

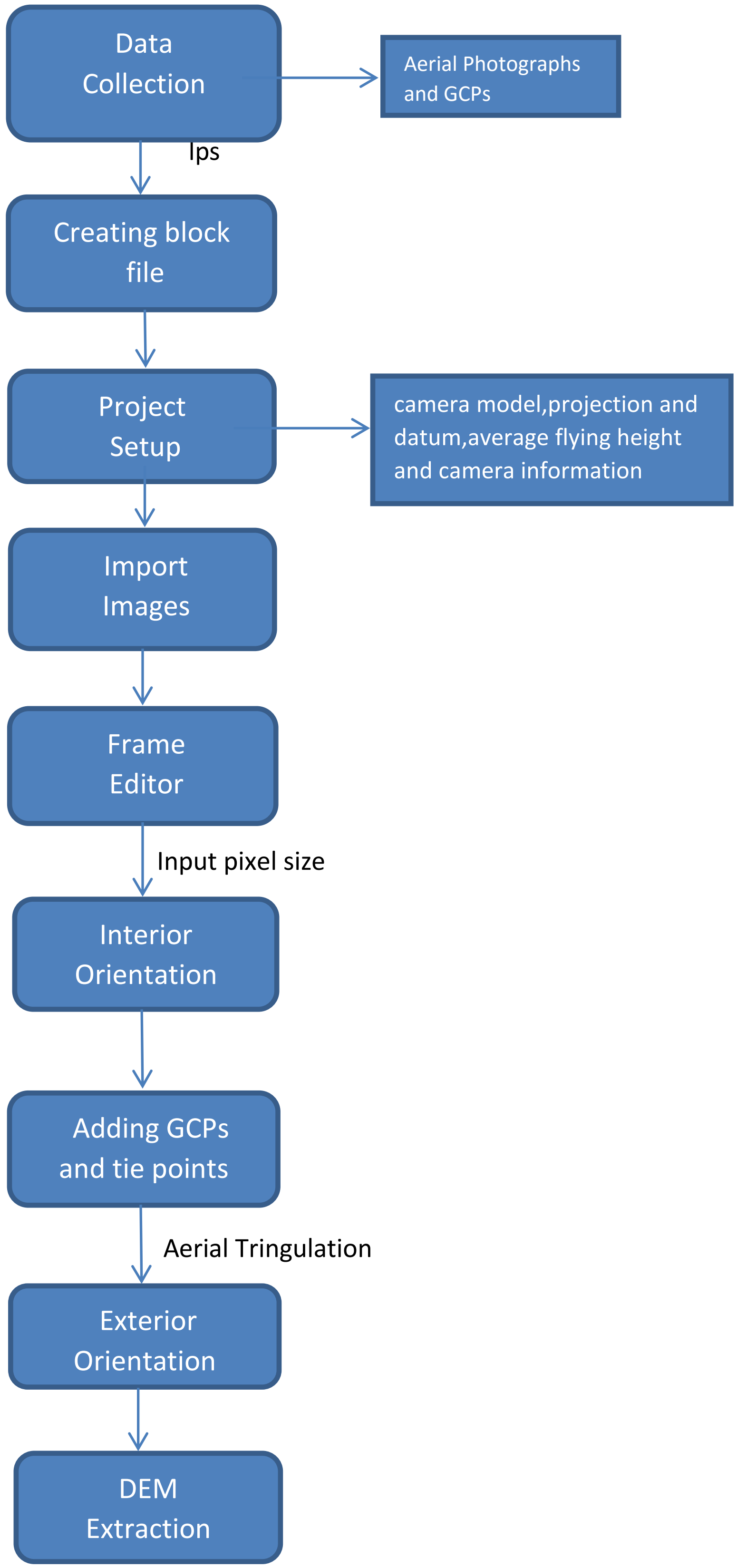


Figure (5.1): Flow chart of methdology.

5.2 Data Acquisition

In order to extract DEM of the study area the following data has been collected:

- Aerial photographs and Ground Control Points in Inner Horizental Surface were obtained from Sudan University of Science & Technology-School of Surveying Engineering. Aerial photographs were taken by Khartoum State Ministry of Planning and Urban Development-General Directorate of Surveying in 2008 with spatial resolution of 10 cm, 60% overlap and 30% sidelap.
- Obstacle Charts and Aerodrome Reference Point from Aerodrome Engineering Consultancy Co.Ltd..

- Heights of Obstacles from Sudanese Survey Authority.

- Aerial photographs and GCPs in Outer Horizontal Surface were obtained from Sudanese Survey Authority.

5.3 Aerial Photographs in Inner Horizontal Surface

The study area is located in Inner Horizontal Surface (west Khartoum Airport Area-Khartoum state), bounded by latitudes (15°36'20.29''N- 15°35'9.55''N) and Longitudes (32°31'0.59''E-32°32'36.64''E) displayed in figure (5.2).

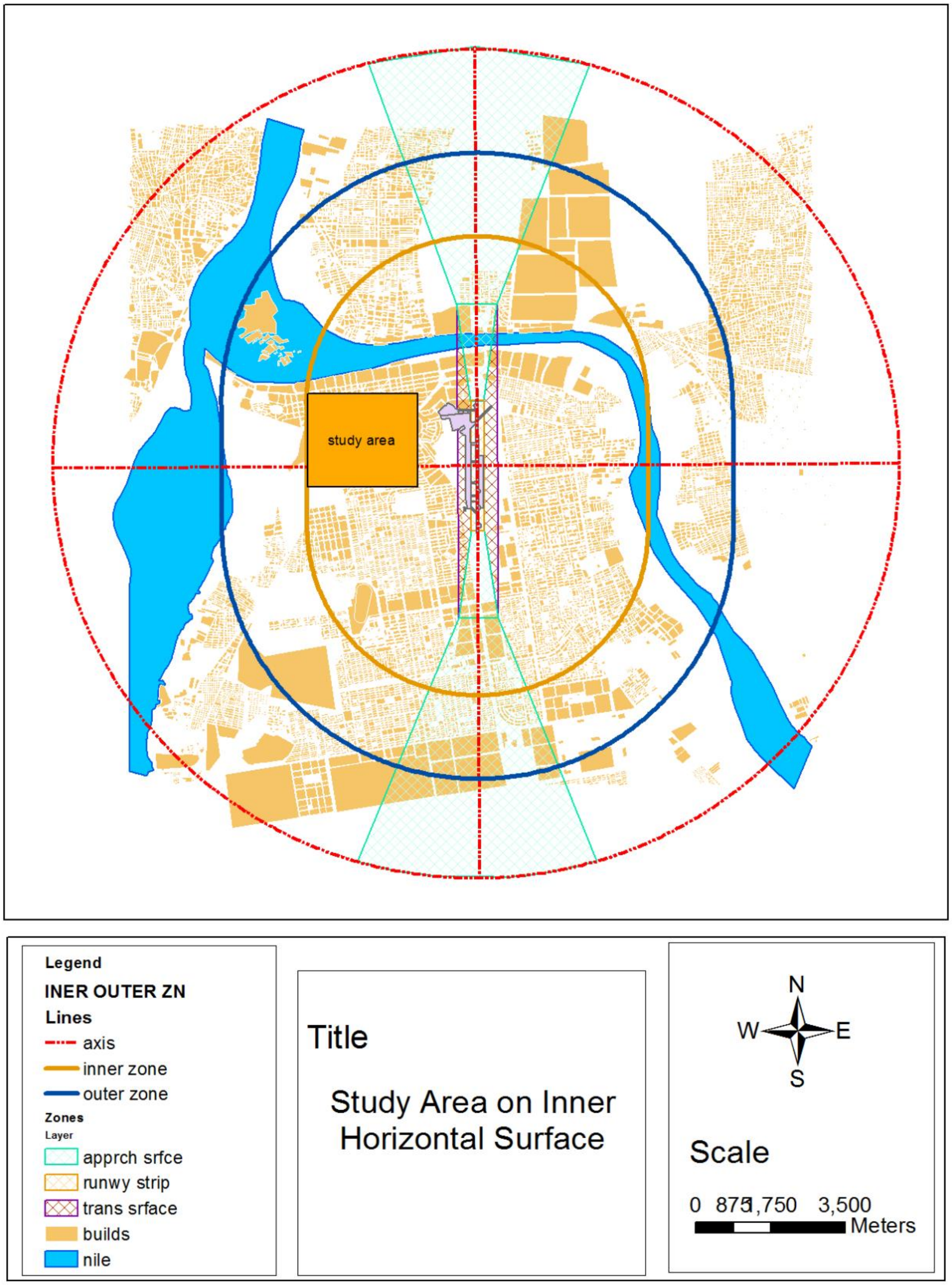


Figure (5.2): Study area in inner horizontal surface.

The aerial photographs of study area consists of three strips, every strip has 8 images as shown in figure (5.3)

Figure (5.3): Strips of aerial photographs in inner horizontal surface.

5.4 Aerial Photographs Processing in Inner Horizontal Surface

Lieca Photogrammetry Suit (LPS) version 14 software package was used to process aerial photographs. Steps of processing as shown in figure (5.1) are detailed as follow:

5.4.1 Creating Block File and Project Setup

The procees in DEM generation starts with creating block file. Camera informations were taken from camera calibration report. The calibration report is represented in figure (5.4).

VEXCEL

UltraCam D, Serial Number UCD-SU-1-0043

Calibration Report

Short Version

Camera:	UltraCam D, S/N UCD-SU-1-0043
Manufacturer:	Vexcel Imaging GmbH, A-8010 Graz, Austria
Date of Calibration:	July-03-2007
Date of Report:	Oct-19-2007
Camera Revision:	3.0
Revision of Report:	3.0

(1 of 13)

Vexcel Imaging GmbH, Münzgrabenstraße 11, A-8010 GRAZ, www.vexcel.co.at

VEXCEL

UltraCam D, Serial Number UCD-SU-1-0043

Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track cross track	67.5mm 103.5mm	7500 pixel 11500 pixel
Image Extent		(-33.75, -51.75)mm	(33.75, 51.75)mm
Pixel Size		9.000µm*9.000µm	
Focal Length	ck	105.200mm	± 0.002mm
Principal Point (Level 2)	X_ppa Y_ppa	0.000 mm 0.000 mm	± 0.002mm ± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Multispectral Camera

Medium Format Multispectral Output Image (Upscaled to panchromatic image format)

Image Format	long track cross track	67.5mm 103.5mm	2400 pixel 3680 pixel
Image Extent		(-33.75, -51.75)mm	(33.75, 51.75)mm
Pixel Size		28.125µm*28.125µm	
Focal Length	ck	105.200mm	
Principal Point (Level 2)	X_ppa Y_ppa	0.000 mm 0.000 mm	± 0.002mm ± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

(3 of 13)

Vexcel Imaging GmbH, Münzgrabenstraße 11, A-8010 GRAZ, www.vexcel.co.at

Figure (5.4) : Calibration report.

Table (5-1) Camera information of
aerial photographs in inner horizontal surface

Type of camera	Digital camera
Name	UltraCam
Focal length	105.2 mm
Pixel size	9*9

From Khartoum_DGPS_IMU as shown in figure (5.5), projection and datum has been chosen as (UTM WGS1984 zone 36) , exterior orientation parameters (x_0,y_0,z_0,ω,ϕ,k) were imported and average flying height has been computed.

'arameter setup:
POSPROC SBET file: C:\GPS_IMU\080514A\Proc\sbet_01.out
Camera mid-exposure event file: C:\GPS_IMU\080514A\Extract\event1_01.dat
Event time shift: 0.000000 sec
Photo ID file: C:\GPS_IMU\080514A\UCDINFO\photoID1_01_nzam.txt
Photo ID file format: 3 Fields (Time, Photo ID, Strip) Format
Offset between PHOTO ID and EVENT file times: 0.000000 sec
Mapping frame datum: WGS84 ; Mapping frame projection : TM;
central meridian = 33.000000 deg;
latitude of the grid origin = 0.000000 deg; grid scale factor = 0.999600;
false easting = 500000.000000 m; false northing = 0.000000 m;
Sequence of the rotation from mapping to image frame:
First rotation is about the 'x' axis by the 'omega' angle.
Second rotation is about the 'y' axis by the 'phi' angle.
Third rotation is about the 'z' axis by the 'kappa' angle.
Kappa cardinal rotation: 0.000 deg.
Boresight values: tx = 5.9700 arc min, ty = 10.2100 arc min, tz = 4.0100 arc min.
Lever arm values: lx = 0.0000 m, ly = 0.0000 m, lz = 0.0000 m.
Shift values: X = 0.000000 meter, Y = 0.000000 meter, Z = 0.000000 meter

POS/AV Computed Data at Camera Perspective Centre
Grid: Universal Transverse Mercator ;Zone: UTM North 36 (30E to 36E) ;Datum: WGS84 ;Local Transformation: NONE ;

D	Event	EASTING	NORTHING	ELLIPSOID HEIGHT	OMEGA	PHI	KAPPA
	080530A_40_05370	450472.663	1723303.126	1595.371	-0.16798	-0.10185	-89.62783
	080530A_40_05371	450472.333	1723574.764	1594.505	-0.16719	-0.10402	-89.45963
	080530A_40_05372	450470.684	1723846.815	1594.069	-0.17341	-0.09312	-89.17806
	080530A_40_05373	450467.735	1724119.637	1594.124	-0.18638	-0.08552	-89.12423
	080530A_40_05374	450463.884	1724391.272	1594.65	-0.18672	-0.09574	-88.72759
	080530A_40_05375	450459.669	1724662.77	1595.356	-0.17466	-0.09909	-88.73162
	080530A_40_05376	450455.371	1724935.167	1596.016	-0.16677	-0.09528	-88.69266
	080530A_40_05377	450451.185	1725207.356	1596.497	-0.15849	-0.0989	-88.81016
	080602A_38_08281	448790.811	1725270.859	1602.606	0.18067	0.11479	90.66229
0	080602A_38_08282	448792.748	1724999.366	1600.537	0.16774	0.13713	90.67694
1	080602A_38_08283	448794.556	1724727.808	1599.753	0.18455	0.11108	90.64428
2	080602A_38_08284	448795.752	1724456.97	1600.585	0.1552	0.13028	90.25298
3	080602A_38_08285	448795.611	1724184.605	1602.61	0.16647	0.10943	89.87967
4	080602A_38_08286	448794.587	1723912.834	1605.266	0.16496	0.13458	89.85954
5	080602A_38_08287	448793.099	1723639.417	1607.355	0.1686	0.11611	89.74474
6	080602A_38_08288	448791.264	1723367.457	1607.448	0.1597	0.11127	89.71868
7	080602A_39_08021	449634.219	1723326.613	1602.461	-0.17043	-0.07834	-90.59829
8	080602A_39_08022	449636.343	1723598.519	1602.638	-0.17534	-0.107	-90.14487
9	080602A_39_08023	449637.189	1723871.223	1604.625	-0.17953	-0.10763	-90.03777
0	080602A_39_08024	449637.618	1724143.356	1607.54	-0.17465	-0.09316	-89.93163

Figure (5.5) :Khartoum_DGPS_IMU.

Average Flying Heght = Average Aircraft Altitude - Average. Relative Terrain Elevation

From Khartoum_DGPS_IMU Avg. Aircraft Altitude has been calculated,and from control points Avg. Relative Terrain Elevation has been calculated as follows

Average Flying Height = 1600.954 – 383.729 = 1217.225 (meter).

Once exterior parameters were imported , initial exterior orientation has been supplied.

5.4.2 Adding GCPs and Tie Poins

Well distributed control points were observed over the block , 16 points were entered as control and 2 points as check. Table (5-1) represents GCPs used and figure (5.6) shows distribution of them.

Table (5-2) Observed GCPs of aerial photographs in inner horizontal surface in meter.

NO	Post processing Coordinates		
	Easting(m)	Northing(m)	Height(m)
1	449101.669	1725509.714	383.113
2	448340.140	1725365.933	383.415
3	448412.645	1724739.837	383.519
4	448367.877	1724260.062	381.851
5	448470.900	1723645.658	382.161
6	448400.810	1723172.145	383.810
7	449144.144	1724130.761	381.782
8	449152.327	1723066.223	384.543
9	450199.025	1725462.274	381.784
10	450159.446	1724744.166	383.997
11	450067.027	1724230.469	385.429
12	450198.86	1723497.647	385.493
13	450078.078	1722963.961	383.832
14	450921.739	1725231.631	386.380
15	450718.066	1724957.814	383.806
16	450877.109	1724054.616	383.764
17	450775.234	1723581.077	383.200
18	451003.688	1723088.568	385.259

Points number 10 and 12 were used as check points. From aerial tringulation check points RMSE was calculated as shown in figure (5.7).

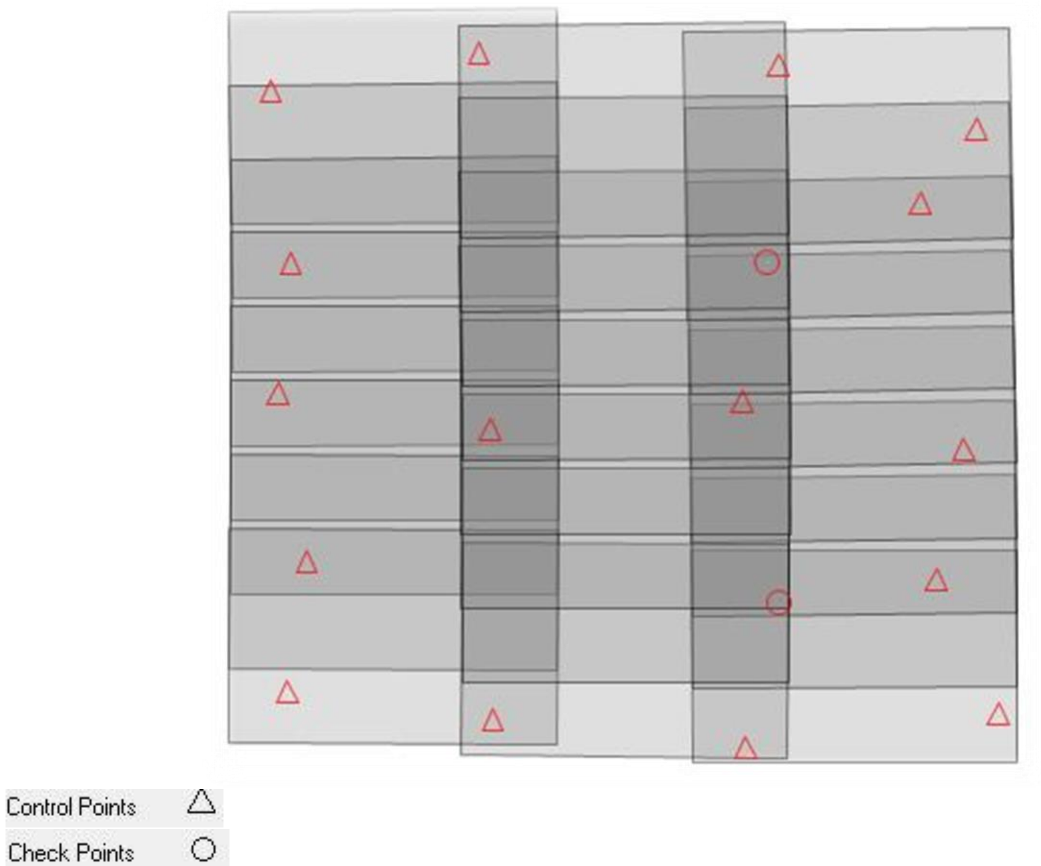


Figure (5.6): Distribution of control and check points.

Common tie points (46 points) on a block were measured manually, they were distributed according to the followings:

- They should be visually defiend in all images,
- They located in the fixed feature,
- They must be on the overlap area and
- They distributed well over the area of the block.

5.4.3 Aerial Tringulation

Then aerial tringulation has been applied to establish the mathmatical realationship between images, then calculate the exterior orientation. Tringulation summery is represented in figure (5.7).

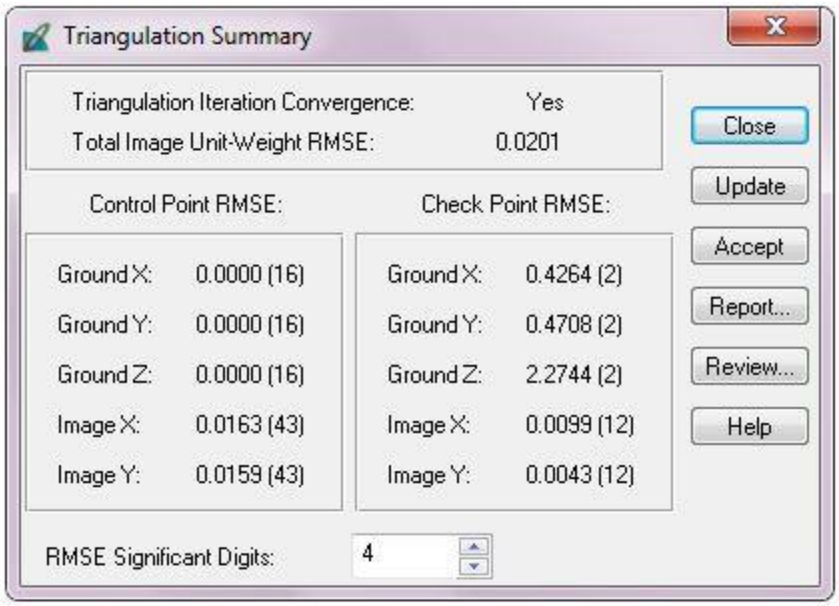


Figure (5.7) :Tringulation summary of aerial photographs in inner horizontal surfacce when using GCPs.

5.4.4 DEM Extraction

The first step in DEM is a chose Classic ATE from DTM Extraction as shown in figure (5.8).

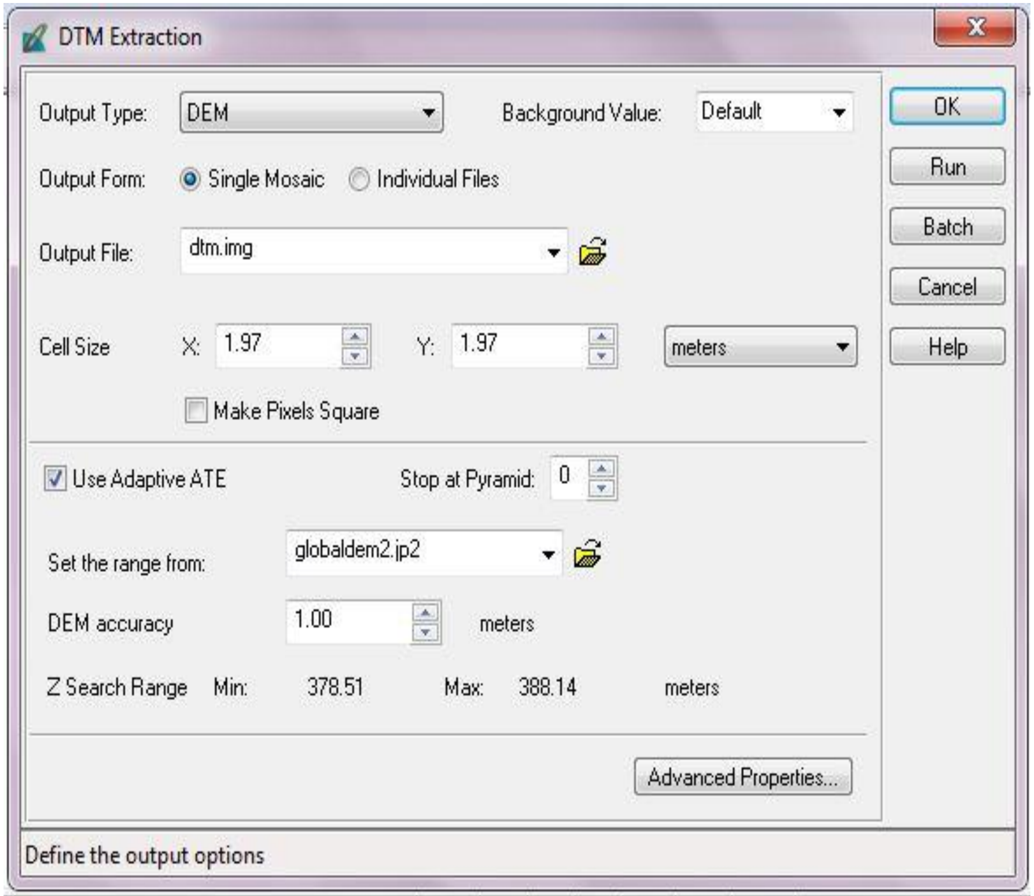


Figure (5.8): Options of DEM extreaction dialoge.

Output type has been chosen as DEM by the form single mosaic,cell size was automatically calculated 1*1 and the DEM accuracy changed to 1 meter. After running process the output of DEM has been given as shown in figure (5.9).

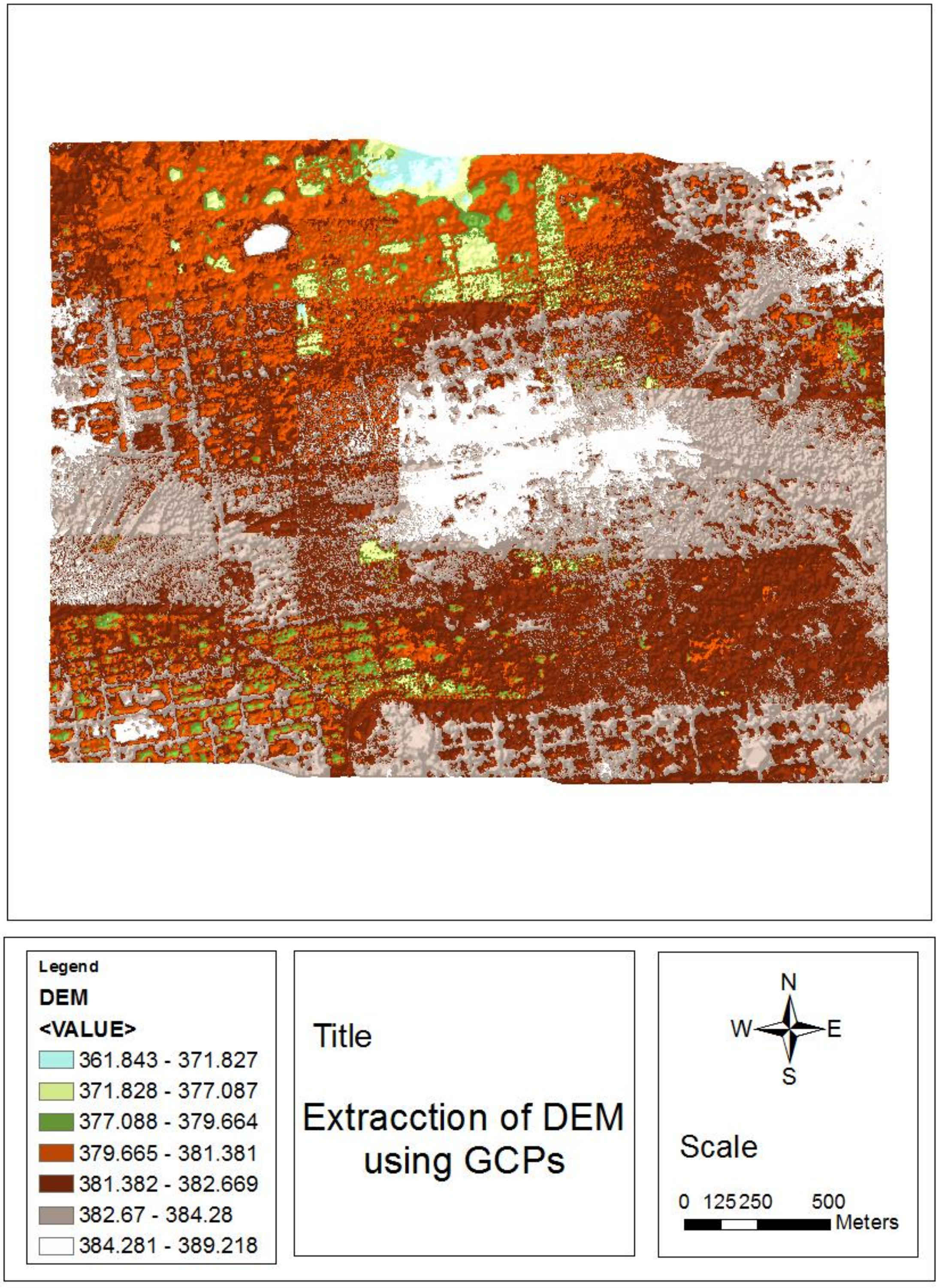


Figure (5.9): DEM of study area in inner horizontal surface using GCPs.

Digital Elevation Model was extracted from overlap area as in figure (5.10).

Figure (5.10): Extracted overlap area for DEM.

5.4.5 Generating DEM Without GCPs

Three images were tested without using GCPs, DEM was extracted according to exterior orientation parameters. After defining interior orientation and exterior orientation parameters measuering tie points could be processed dierctly as shown in figure (5.11).

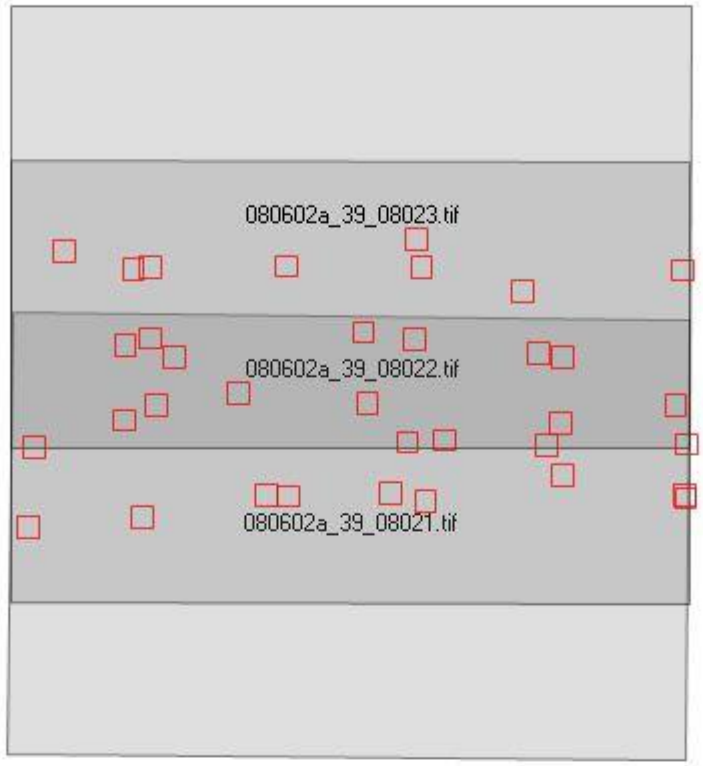


Figure (5.11): Distribution of tie points on overlap area.

Then Aerial Tringulation has been processed to check accuracy for images as in figure (5.12) .

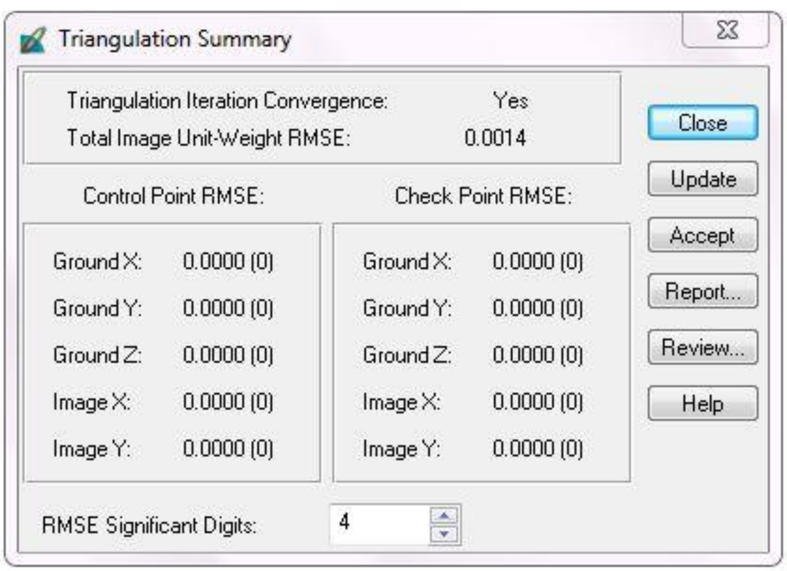


Figure (5.12): Tringulation summery of aerial photographs in inner horizontal surfacce without GCPs.

Digital Elevation Model has been extracted from overlap area of three images as shown in figure (5.13).

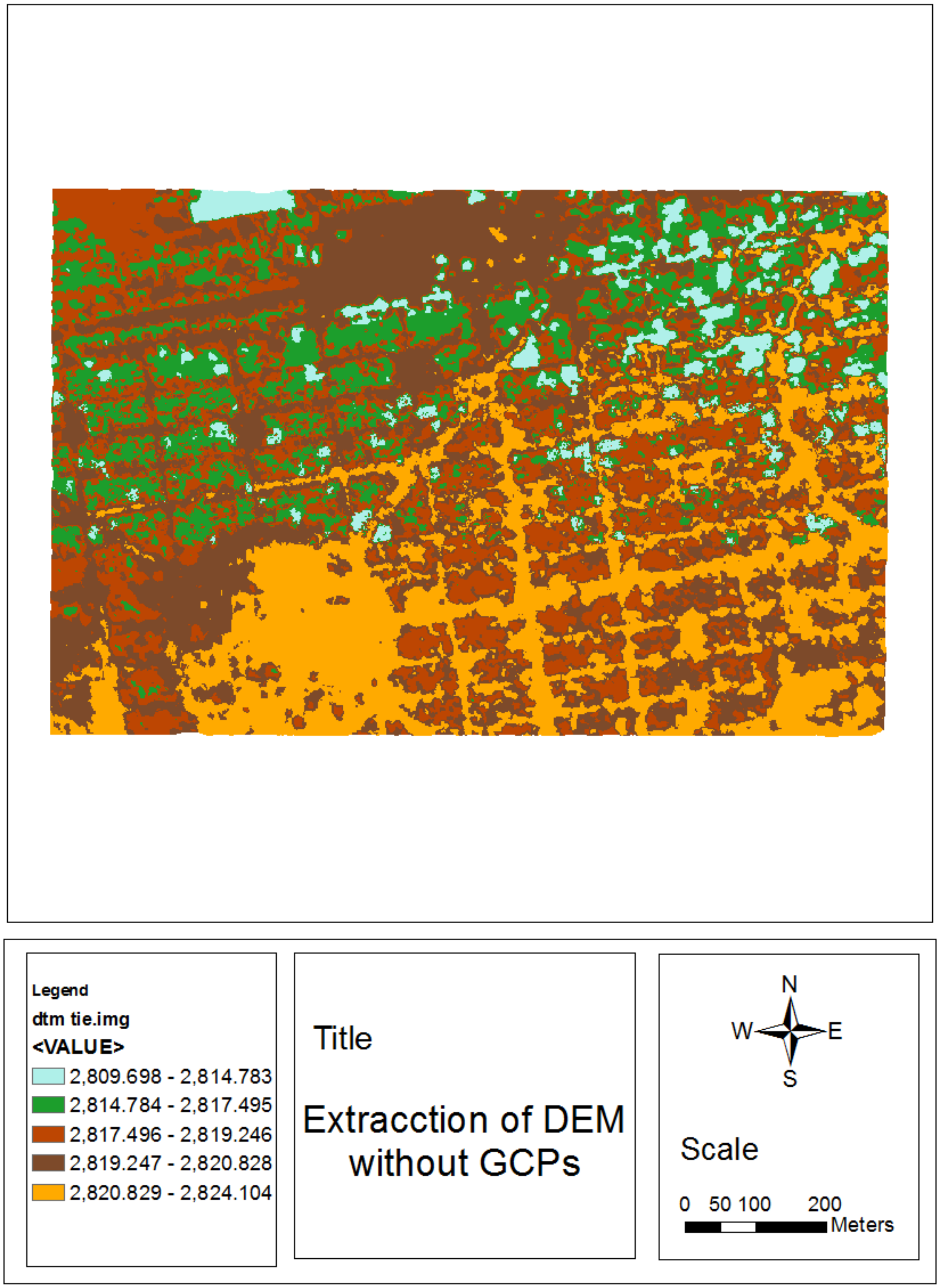


Figure (5.13): DEM of study area in inner horizontal surface without GCPs.

5.5 Aerial Photographs in Outer Horizontal Surface

Another data of aerial photographs and GCPs were used. Aerial photographs have been taken by Sudanese Survey Authority in the year 2011, with spatial resolution of 10 cm, 60% overlap, 30% sidelap and scale of images is 1:9957. The photographs consist of two strips, each one has three images.

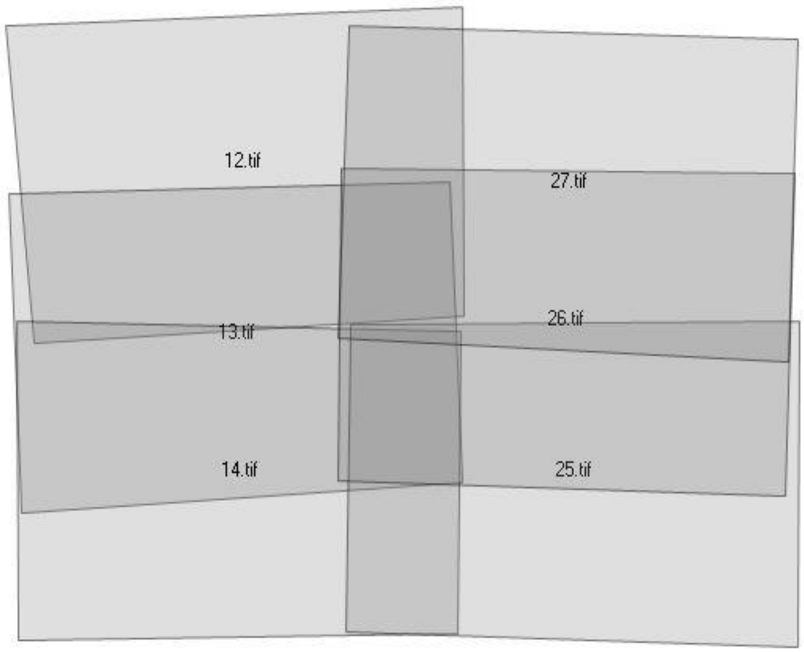


Figure (5.14): Two Strips of aerial photograph each one has three images.

Aerial photographs taken over Outer Horizontal Surface between latitudes (15°39'19.64"N- 15°38'31.14"N) and Longitudes (32°29'21.37"E- 32°28'20.7"E) as shown in figure (5.15) .

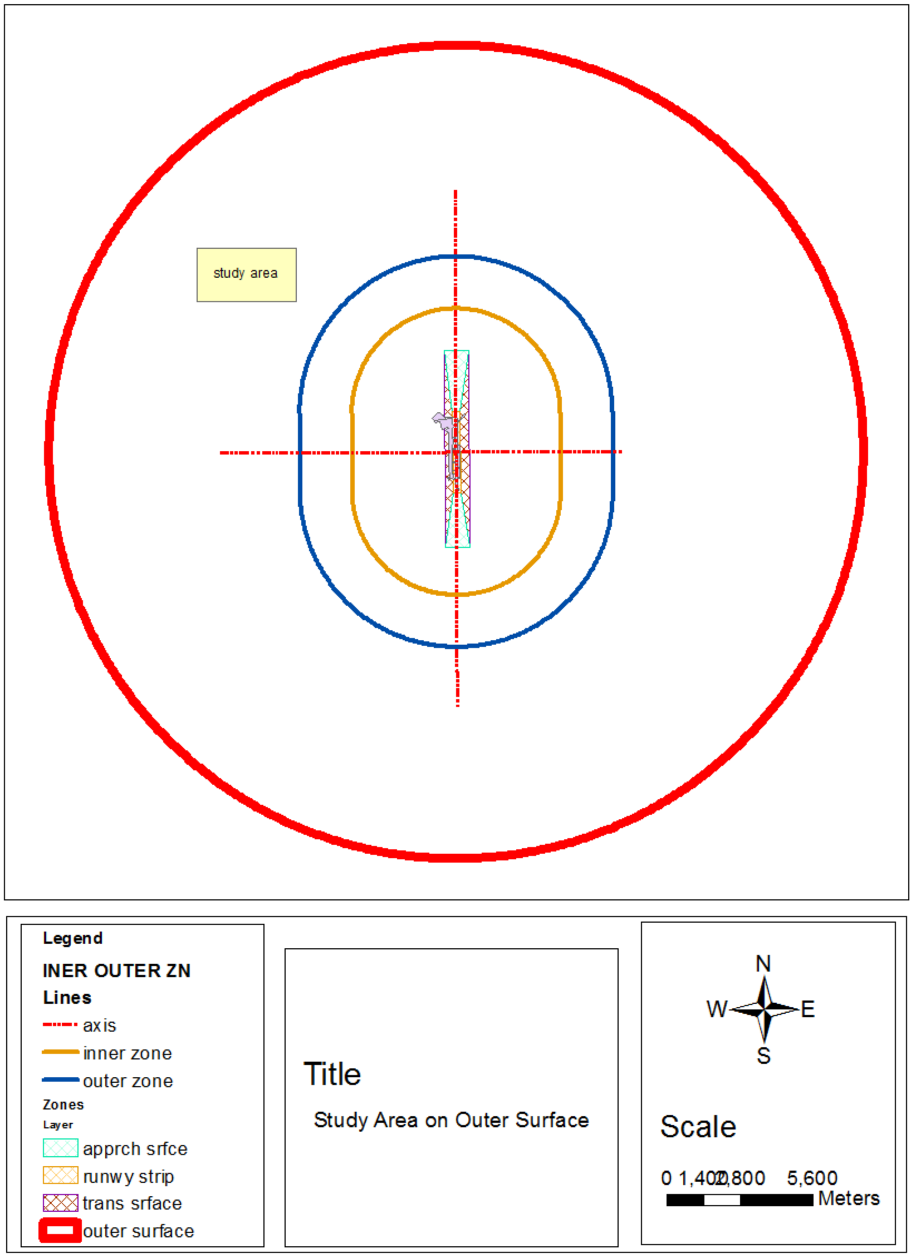


Figure (5.15): Location of study area in outer horizontal surface.

5.6 Aerial Photographs Processing in Outer Horizontal Surface

The same steps of data proccessing have been applied as follows:

5.6.1 Input Data:

-Camera information

Table (5-3) Camera information of
aerial photographs in outer horizontal surface

Type	Digital camera
Name	UltraCamxp
Focal length	70.2 mm
Pixel size(micron)	6*6

-Exterior orientation parameters

Table (5-4) Exterior orientation parameters

id	image name	Easting(m)	Northing(m)	Ellipsoidal height(m)	omega	phi	kappa
2	12	443988.294	1730329.635	1083.351	3.395	1.608	2.519
3	13	443990.41	1730022.205	1078.309	-0.285	2.541	2.48
4	14	443993.114	1729715.581	1079.648	0.467	2.369	-0.362
15	25	444676.18	1729724.981	1093.461	-0.578	-2.113	179.089
16	26	444678.51	1730028.385	1095.679	0.681	-1.041	178.619
17	27	444688.004	1730334.077	1095.392	-0.077	-0.994	177.682

-Average Flying Height

Average Flying Heght = Avg. Aircraft Altitude - Avg. Relative Terrain Elevation

Average Flying Heght = 1087.64 – 390.238 = 697.402 meter

5.6.2 Processing steps

-Interior Orientation

By defining the camera information (focal length, pixel size,..) interior orientaion was applied.

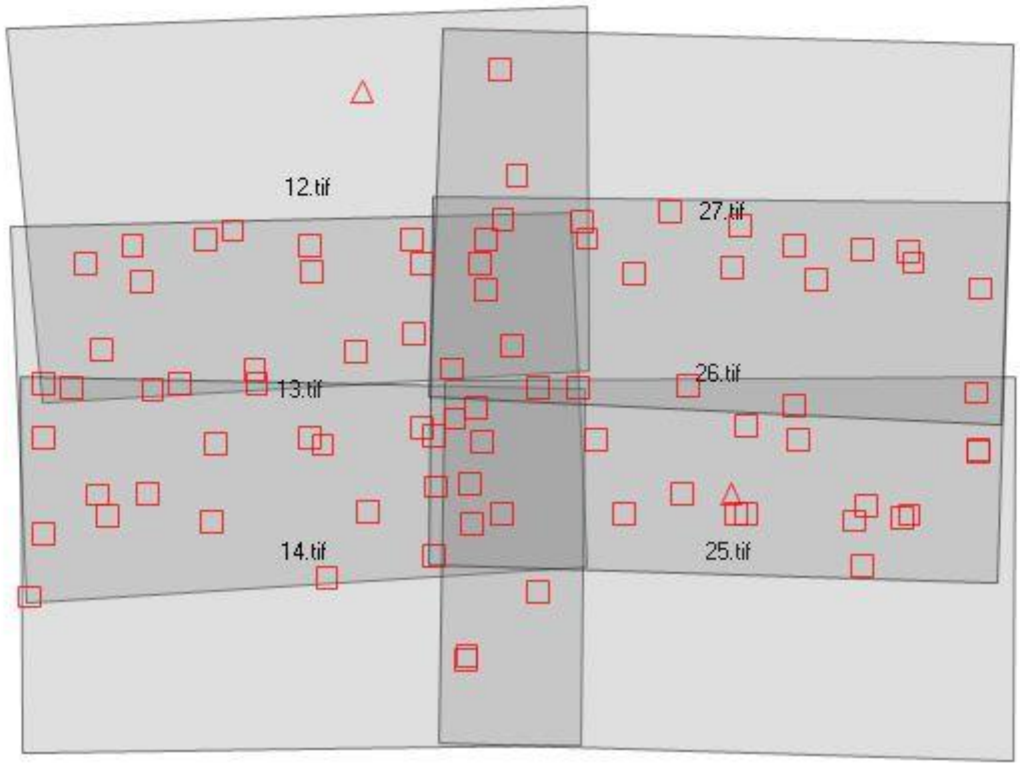
-Exterior Orientation

Two Ground Control Points (GCPs) that were observed in the year 2011 were listed. Table (5-4) represents two GCPs.

Table (5-5) Observed GCPs of aerial photographs in outer horizontal surface

ID	Easting (m)	Northing (m)	Ellipsoidal height (m)
GCP-4	444061.91	1730574.26	392.593
GCP-6	444727.58	1729848.9	392.396

Then automatic tie points generation has performed with succesful rate of 78%. Tie points were mesuered on the overlap area as shown in figure (5.16) .



Figurre (5.16): GCPs and tie points over the block.

Finally aerial tringulation was processed to check accurecy of image and perform exterior orientation.The Total Image Unit-Weight RMSE as shown in figure (5.17).

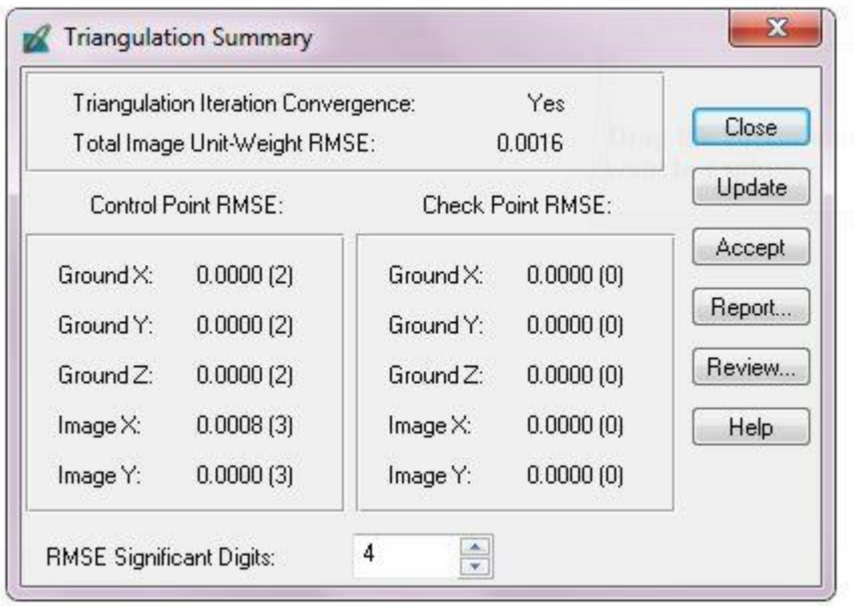


Figure (5.17): Tringulation summery of aerial photographs in outer horizontal surface using GCPs.

5.6.3 Output

DEM has been extracted from overlap area. Figure (5.18) represnts extracted DEM.

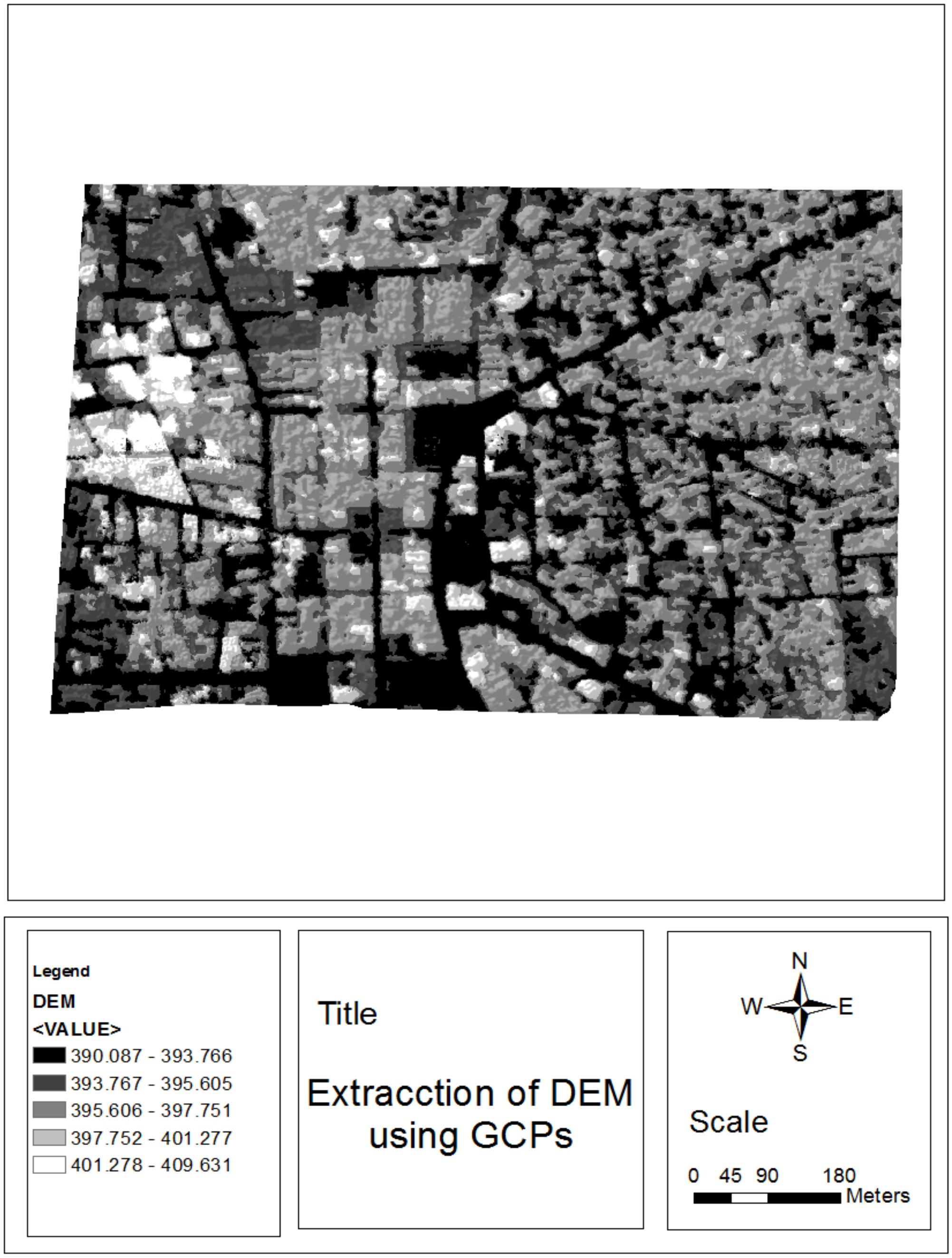


Figure (5.18): DEM of study area in outer horizontal surface using GCPs.

5.6.4 DEM Without Mesured GCPs

DEM was extracted without using GCPs, Total Image Unit-Weight RMSE was 0.0016 as in figure (5.19).

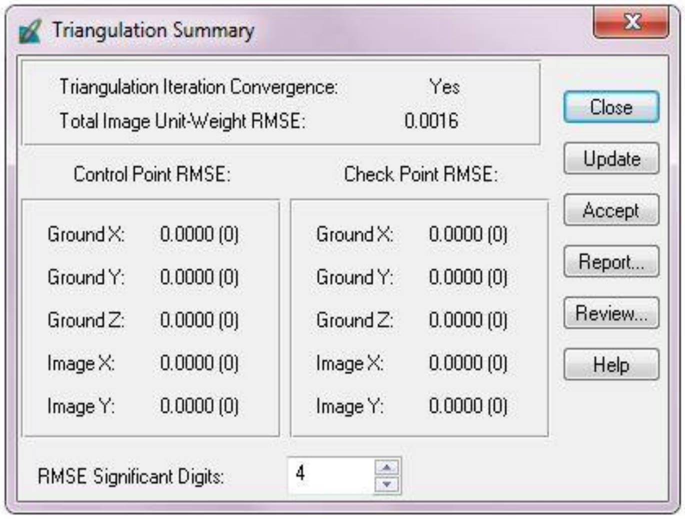


Figure (5.19): Tringulation summery of aerial photographs in outer horizontal surface without GCPs.

Then DEM has been extracted as shown in figure (5.20) .

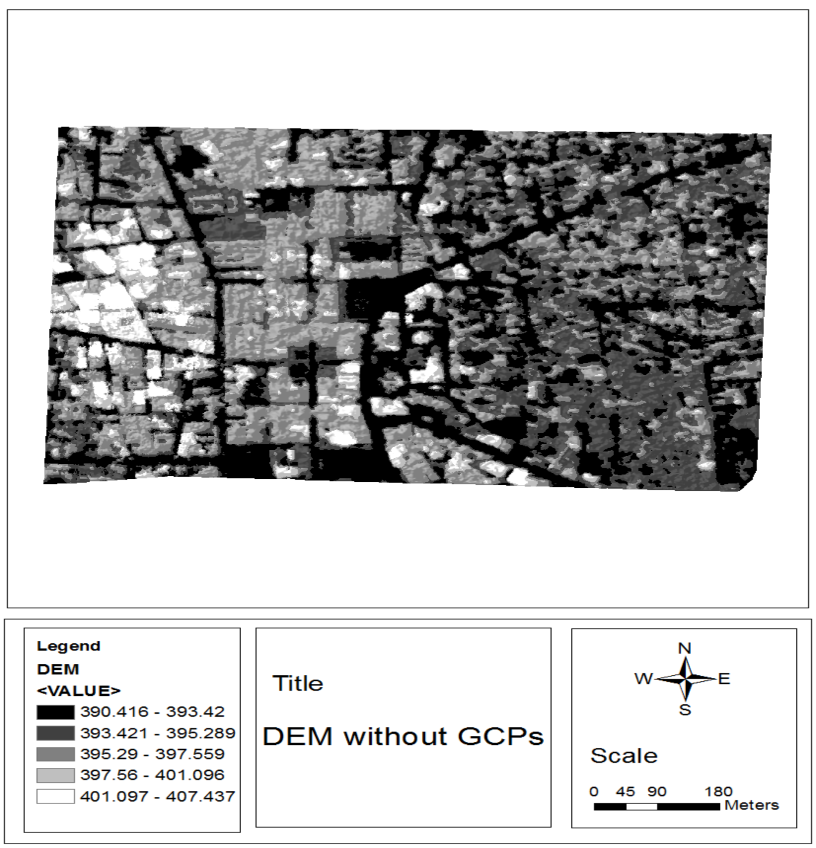


Figure (5.20): DEM of study area in outer horizontal surface without GCPs.

Figure (5.21): Overlap area of DEM extraction.

CHAPTER SIX

RESULTS AND DISCUSSIONS

6.1 Introduction

This study focused on extraction of DEM from aerial photographs around International Khartoum Airport, to detect any obstacles by determining heights of buildings from DEM.

6.2 Aerial Photographs in Inner Horizontal Surface

Aerial photographs were processed in two ways: using GCPs and without using GCPs depending on exterior parameters, the results are as follow:

6.2.1 DEM Using GCPs

DEM was extracted from overlap area as shown in figure (6.1), range of heights from 361.843 to 389.218 meters. Elepsoidal heights of ground from 382.670 to 384.28 meters and elepsoidal heights of building from 377.088 to 382.669 meters.

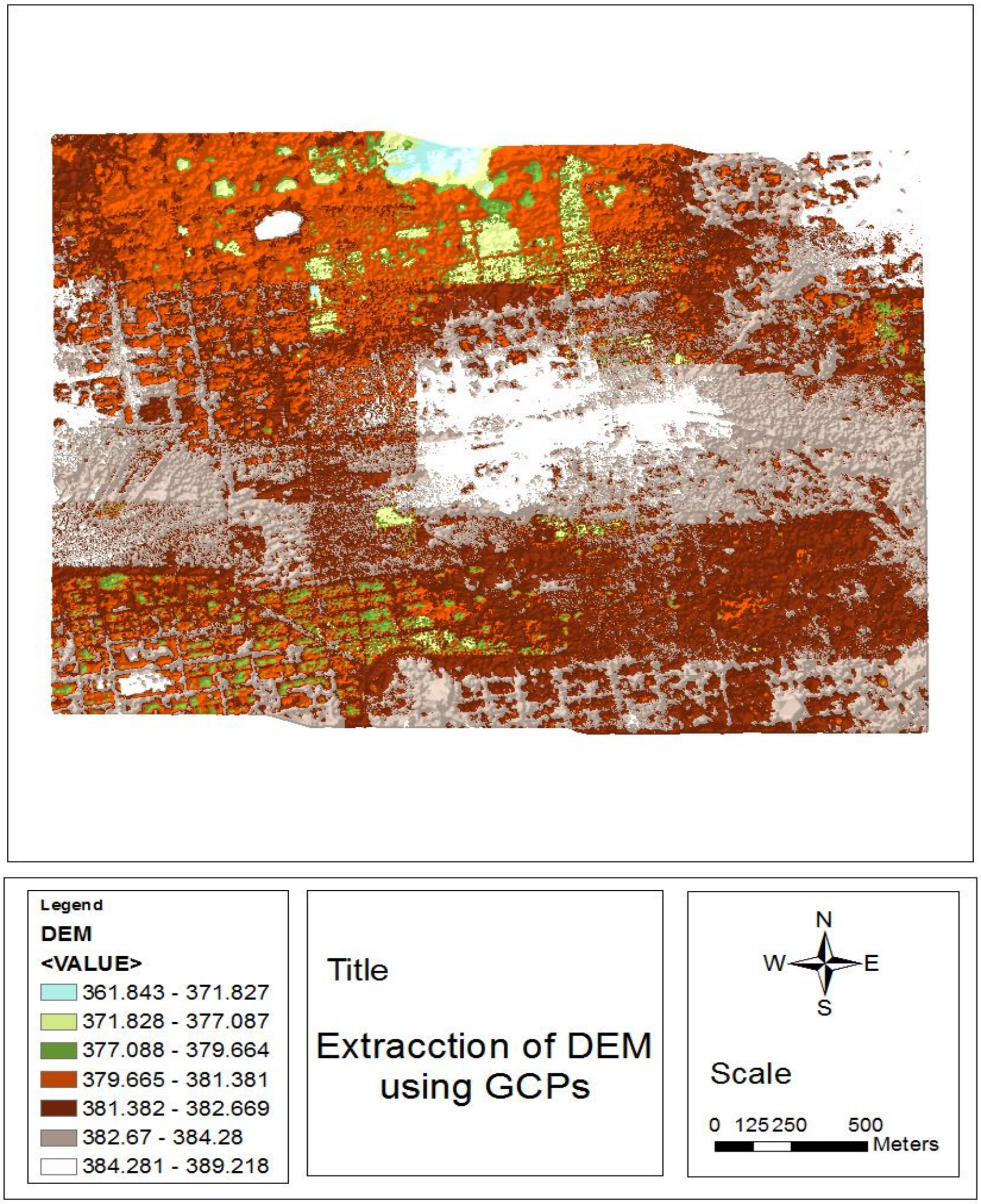


Figure (6.1): Results of extracted DEM using GCPs in inner horizontal surface.

6.2.2 DEM Without GCPs

Extracted DEM without using GCPs represented in figure (6.2), range of heights from 2809.698 to 2824.104 meters, elepsoidal heights of ground from 2820.827 to 2824.104 meters and elepsoidal heights of buildings from 2809.698 to 2819.287 meters.

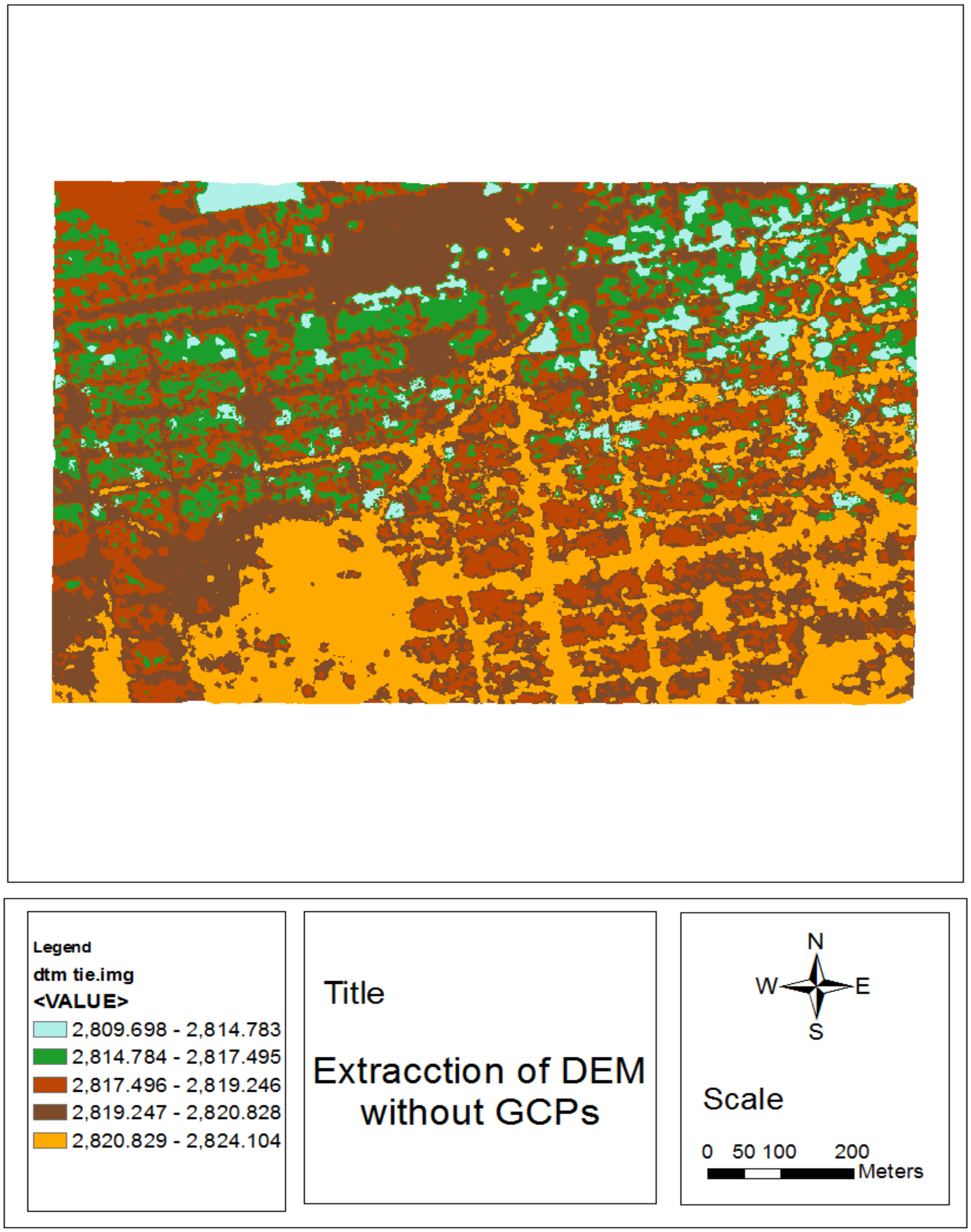


Figure (6.2): Results of extracted DEM without GCPs in inner horizontal surface.

6.3 Aerial Photographs in Outer Horizontal Surface

Aerial photographs were processed in two ways: using GCPs and without using GCPs, the results are as follow:

6.3.1 Extracted DEM Using GCPs

Digital Elevation Model range from 390.087 to 409.631 meters as shown in figure (6.3), heights from 390.087 to 393.766 meters represent the ground, and from 395.605 to 409.631 meters represent buildings and all other features such as trees.

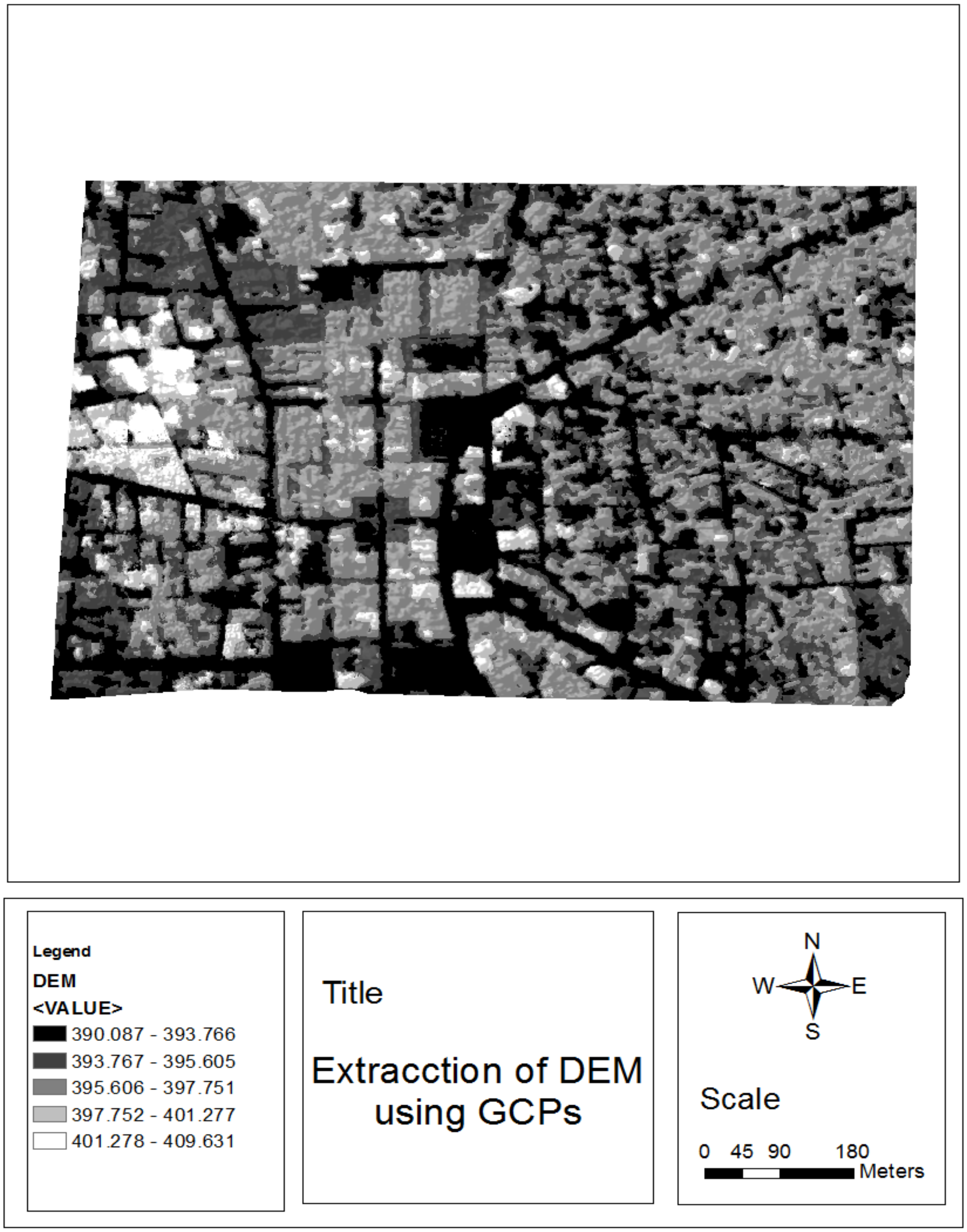


Figure (6.3): Results of extracted DEM using GCPs in outer horizontal surface.

6.3.2 Extracted DEM without GCPs

Elevation from 390.416 to 393.421 meters were ground and from 395.289 to 407.437 meters were natural features and man-made.

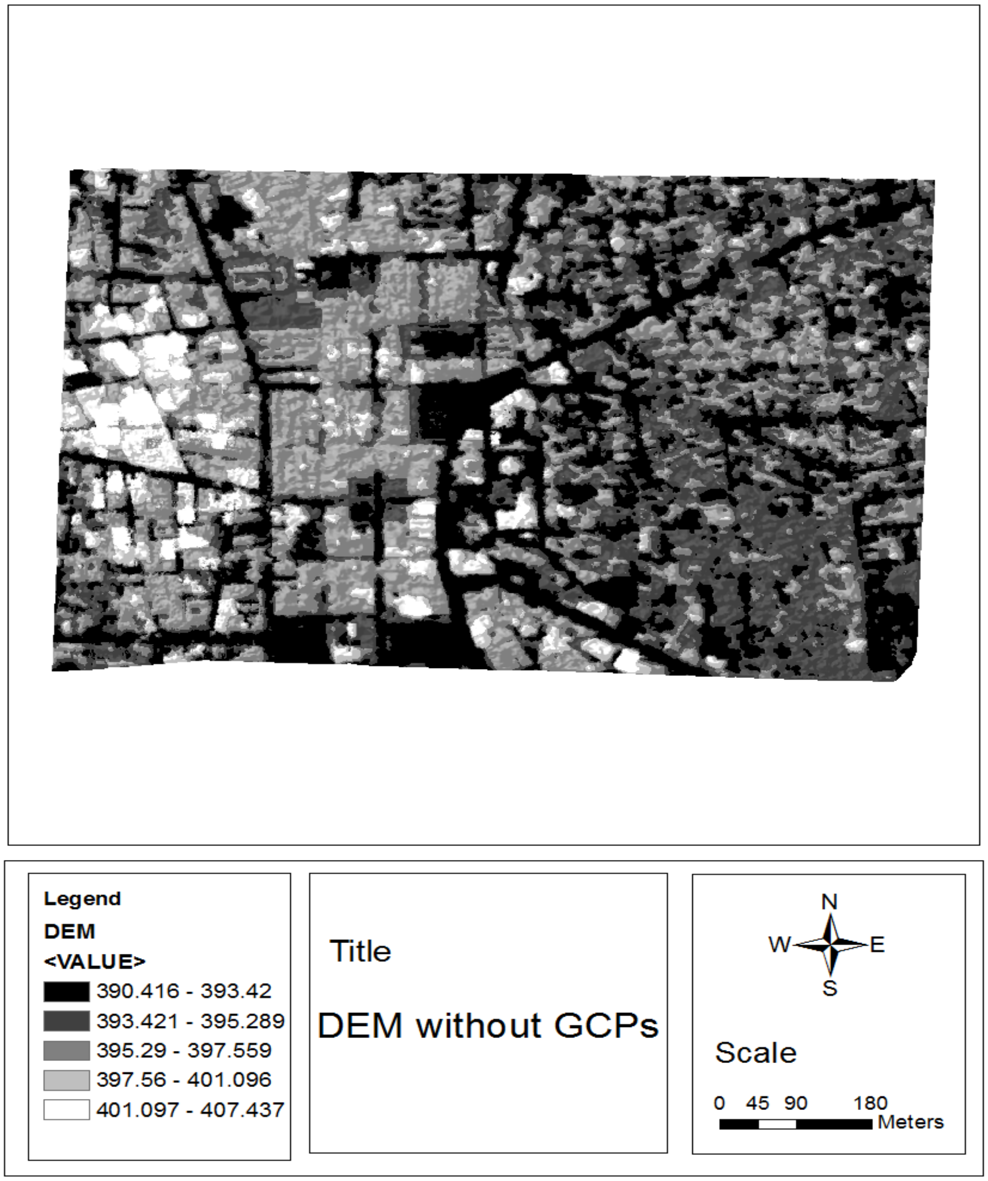


Figure (6.4): Results of extracted DEM without GCPs in outer horizontal surface.

6.4 Comparison of Results

6.4.1 Results of Aerial Photographs in Inner Horizontal Surface

Total Image Unit-Weight Root Mean Square Erorr (RMSE) and heights of buildings when using GCPs and without using GCPs are represented in Table (6-1).

Table (6-1) Compairing between extracted DEM using GCPs and without using GCPs in inner horizontal surface

Method	Total Image Unit-Weight RMSE	Heights of Buildings
Using GCPs	0.020 mm	377.088 - 382.669 meters
Without Using GCPs	0.001 mm	2809.698-2819.287 meters

6.4.2 Results of Aerial Photographs in Outer Horizontal Surface

Total Image Unit-Weight Root Mean Square Erorr (RMSE) and heights of buildings when using GCPs and without using GCPs are represented in Table (6-2).

Table (6-2) Compairing between extracted DEM using GCPs and without using GCPs in outer horizontal surface

Method	Total Image Unit-Weight RMSE	Heights of Buildings
Using GCPs	0.0016 mm	395.605 - 409.631 meters
Without Using GCPs	0.0016 mm	395.289 - 407.437 meters

6.5 Check of Extracted DEMs in Outer Horizontal Surface

GPS Navigator was used to check postition of GCP-6 in the field as represented in Table (6-3).

Table (6-3) Checked GCP-6

ID	Easting (m)	Northing (m)	Ellipsoidal height (m)
GCP-6	444727.58	1729848.9	392.396
Checked GCP-6	444730.000	1729858.000	393.000

Figure (6.5): Position of GCP-6.

Then buildings in images were compared in the field by using also navigator, two of them were used for checking heights in extracted DEM as follow:

Ellipsoidal height = Ground Elevation + Approximate height of the building from ground surface

Table (6-4) Ellipsoidal height of two buildings in the field

ID	Easting (m)	Northing (m)	Ground Elevation (m)	Approximate height from ground (m)	Ellipsoidal Height (m)
1	444730	1729858	393	7	400
2	444714	1729830	393	5.30	398.3

Table (6-5) Tow Buildings for checking extracted DEM with GCPs in outer horizontal surface

ID	Easting (m)	Northing (m)	Ellipsoidal height (m)
1	444708.972	1729870.474	397.298
2	444721.956	1729792.02	397.405

Table (6-6) Tow Buildings for checking extracted DEM without GCPs in outer horizontal surface

ID	Easting	Northing	Ellipsoidal height (m)
1	444710.254	1729865.569	397.069
2	444718.711	1729795.058	397.653

6.6 Discussion of Results

6.6.1 Extracted DEM in Inner Horizental Surface

From the equation (6,1)

S = f / Z (6,1)

Where

S : scale

f : focal length

Z : avg flying height

S = 105.2 / 1217 = 1:11590

It was found that scale used in photography (1:11590) is not suitable to extract accurate DEM from area that has more details such as buildings, in addition DEM was checked by one of the obstacles that was observed in 2008 ,it was found that observed height is 440.50 meter and the same building in DEM is 383.216 meter. According to this, an other area was selected with suitable scale (1:9957) as details in 6.6.2.

6.6.2 Extracted DEM in Outer Horizontal Surface

Differences between heights are acceptable, which means DEMs can be used to exrtact obstacles.

DEM is located in the Outer Horizental Surface, the maximum height permmitted in this surface from the ground surface is 150 meter.

So every feature's height that over 150 meters from ground is obstacle. This calculation done by determining height of feature in DEM and substract this height from Aerodrome Reference Point.

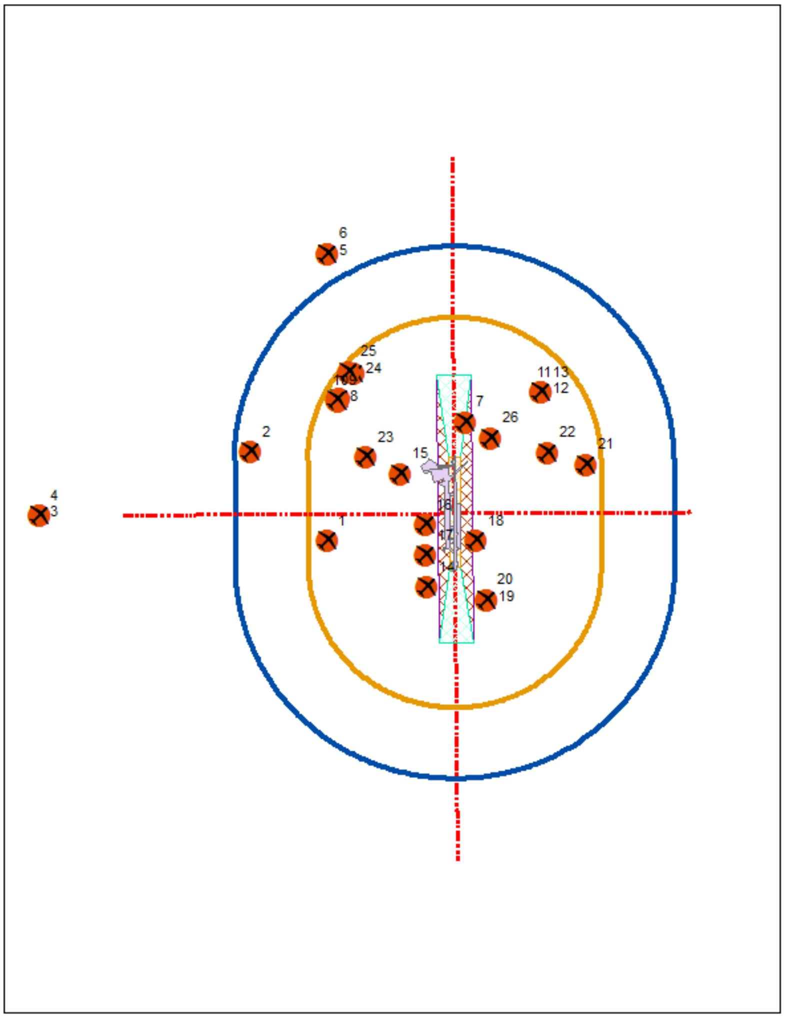
Aerodrome Reference Point plus 150 meter gives the maximum permitted ellipsoidal height:

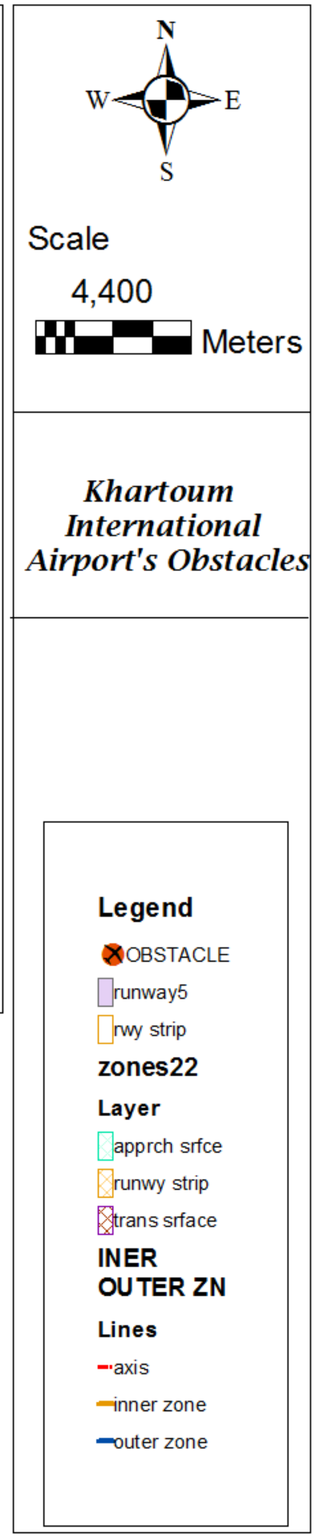
385.94 + 150 = 535.94 meter

It was found that there are not obstacles in this area, so the flight is safety on it.

6.6.3 Determine Flying Height From Observed Obstacles

To extract accurate DEM, observed obstacles by Sudanese Survey Authority in 2013 were used to determine flying height and scale in photography.





List of Obstacles

Id	Code	Latitude	Longtude	Elevation
1	Antenna	15.5823	32.520639	441.11
2	Petroleum tower	15.6049	32.501167	503.58
3	Antenna	15.5887	32.447334	542.95
4	Antenna	15.5887	32.447417	517.35
5	Antenna	15.6554	32.520806	421.25
6	Antenna	15.6554	32.520806	434.96
7	Antenna	15.6126	32.555767	418.08
8	Building	15.6185	32.52374	470.21
9	Building	15.618	32.523437	469.85
10	Building	15.6181	32.523278	429.71
11	electric tower	15.6201	32.57525	411.26
12	electric tower	15.6201	32.57525	452.04
13	electric tower	15.6201	32.57525	451.87
14	Antenna	15.5704	32.546167	442.42
15	Antenna	15.5994	32.539499	441.31
16	Antenna	15.5864	32.545645	418.13
17	Antenna	15.5786	32.545795	426.03
18	ACC Antenna	15.5823	32.558721	428.96
19	Building	15.5672	32.561254	416.14

Figure (6.6): Observed obstacles around khartoum airport.

From figure (6.6) the highest obstacle in Outer Horizental Surface is 542.95 meter, depending on this can be planned to fly e.g. average flying height must be as follow:

Average flying height = the highest obstacle + minimum clearence height

Average flying height = 542.96 + 30.48 = 573.44 meter.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

This research described a new method for extracting obstacles around International Khartoum Airport using DEM created from aerial photographs. The accurecy of this method is acceptable. Beside it minimises time and cost. The main findings of this study are as follow:

- DEM can be done without using GCPs.
- Aerial photographs of scale 1:9957 gave more accurate results than that obtained from aerial photographs of scale 1:11590.
- Heights in DEM when using GCPs and DEM without measured GCPs are approximal, so measuring GCPs is not neccery.

7.2 Recommendations

-Using aerial photographs to extract heights of obstacles instead of traditional surveying; to reduce time and cost.

-Using aerial photography on a regular basis to detect obstacles around airport.

-A broad area aound an airport is required to use workstation to process aerial photographs.

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