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College of Engineering

Civil & Architectural Engineering Department

Surveying and Geomatics Engineering

Graduation Project

The use of mobile phone camera in close range photogrammetry

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الإهداء

إلى شهداء الوطن الحبيب اللذين امتزجت دمائهم بثرى الوطن الحبيب ليرسمو الطريق الحرية

إلى القابعين خلف قضبان الحديد ينتظرون يوم الحرية

إلى من أصبحت المستشفيات بيوتهم الثانية

إلى أمي الغالية رفيقة دربي في ليالي السهر الطوال إلى أبي رمز العطاء الدائم المغني عن السؤال

إلى كل من تحرك القلم في يده بخط كلمه خير تشرق بها شموس الفجر

إلى الدموع السائلة ترقب الفجر القريب

إليك يا وطن و إلى كل القلوب الصافية

إلى إخواني وأخواتي وزملائي و إلى كل من علم حرفاً

وإلى كل من ساهم في انجاح هذا المشروع

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Abstract

The use of mobile phone camera in close range photogrammetry

Abstract

The project aims to use the simple technology owned by anyone for close range photogrammetric applications by using different mobile phone cameras in different levels of resolution. This is applied to make a 3D modeling of close objects by using different software. These cameras are nowadays available with high resolution in different levels. So we are going to study the use of these cheap tools in the fields of close range photogrammetry.

The project requires three stages. First we are going to test the use of the photos for 3D modeling of close range objects. Then, we are going to check the accuracy of the modeled objects. Finally we are going to summarize the proper use of these cameras for close range photogrammetry

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ملخص

استخدام كاميرات الهواتف المحمولة في التصوير الارضي

الملخص:

يهدف المشروع إلى استخدام التكنولوجيا البسيطة المتاحة بين يدي أي شخص في تطبيقات التصوير عن قرب عن طريق استخدام كاميرات لأنواع مختلفة من الهواتف بمستويات مختلفة من الدقة. هذا يطبق لعمل مجسم ثلاثي الأبعاد لأجسام مختلفة باستخدام برامج حاسوب مختلفة . لذا نحن سندرس استخدام هذه الأدوات الرخيصة في مجال التصوير عن قرب.

يمر المشروع بثلاث مراحل : أولا سنختبر استخدام الصور لجسم عن قرب في عمل مجسم ثلاثي الأبعاد، ثانيا سنختبر دقة المجسم الثلاثي الأبعاد، وأخيرا سنلخص خصائص الكاميرات المستخدمة في عمل مجسم ثلاثي في التصوير عن قرب.

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Table Of Abbreviations

Abbreviation	
UAS	Unmanned Aerial System
US	United State
DTM	Digital Terrain Models
CRP	Close Range Photogrammetry
GPS	Global Position System
TB	Tubercle Bacillus
GNSS	Global Navigation Satellite System
IMU	Inertial Measurement Unit
CCD	Charge Coupled Device
CMOS	Complementary Metal Oxide Silicon
VIM	International Vocabulary of basic and general terms in Metrology
CFL	Calibrated Focal Length
IO	Interior Orientation
INS	Internal System
AP	Additional Parameters
Z-D	Zoom Dependent
LED	Light Emitting Diode
HRD	High Dynamic Range
HD	High Definition
TV	Television
MP	Mega Byte
DMM	Dimensional Measuring and Modeling
AR	Accident Reconstruction
OHV	Off Highway Vehicles
DSM	Dense Surface Modeling
LCD	liquid Crystal Display
HDR	High Dynamic Range
GB	Giga Byte

CHAPTER ONE
INTRODUCTION

1.1 Background

1.2 Objective

1.3 Time Schedule

1.4 Methodology

1.5 Project Scope

1.1 Background

Terrestrial photogrammetry is an important branch of the photogrammetric science. It deals with photographs taken with cameras located on or near the surface of the earth. The term close range photogrammetry is generally used for terrestrial photographs having object distances up to about 300 m. Terrestrial photography can applied in two ways:

- Static: photos stationary objects. Stereo pairs can be obtained by using a single camera and making exposures at both ends of a baseline or two different cameras.
- Dynamic: photos of moving objects. Two cameras located at the ends of a baseline must make simultaneous exposures.

1.2 Objective

The project aims to use the simple technology owned by anyone for close range photogrammetric applications by using different mobile phone cameras in different levels of resolution. This is applied to make a 3D modeling of close objects by using different software. These cameras are nowadays available with high resolution in different levels. So we are going to study the use of these cheap tools in the fields of close range photogrammetry.

The project requires three stages. First we are going to test the use of the photos for 3D modeling of close range objects. Then, we are going to check the accuracy of the modeled objects. Finally we are going to summarize the proper use of these cameras for close range photogrammetry.

1.3 Time Schedule:

The time schedule shows the stages for achieving our work and the process of project growth. The time schedule includes Project determination, literature review, collecting data, designing the entire system. Table (1-1) shows the project growth.

1.4 Methodology

Method of working on this project is to be achieved by taking several pictures using mobile phone cameras. Afterwards we are going to Install the taken pictures to create 3D models using photo modeler Scanner software that are available in the university (PPU) or online for free. Finally the mobile camera will be calibrated to make a model more precise.

1.5 Project Scope

Table (1 .1) Time Schedule of project growth

week **Tasks**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Project idea	🟩	🟩	🟩	🟩												
Collecting information				🟩	🟩	🟩										
Reading					🟩	🟩	🟩									
Training on using 3D software							🟩	🟩	🟩							
Selection of model									🟩	🟩						
Design											🟩	🟩	🟩	🟩		
Documentation					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Presentation																★
Week Tasks	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	**32**
Observation of points	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩							
Scaling Models										🟩	🟩	🟩	🟩			
Data Analysis													🟩	🟩	🟩	🟩
Presentation																★

This project consists of five chapters as follows:

- Chapter One: An introduction of the project and its description.
- Chapter Two: Introduction to photogrammetry that introduces the history of the photogrammetry.

- Chapter Three: Mobile Camera and camera calibration.

- Chapter four: Discusses some applications of close range photogrammetry and display the program that we used to make a three dimensional model and Displays three-dimensional stereo model was photographed by a camera phone.

- Chapter five: Displays the results and accuracy that we obtained from camera phones in the work of three-dimensional model.

- Chapter six: Display the conclusion of the hole project and the recommendations .

CHAPTER TWO

INTRODUCTION TO PHOTOGRAMMETRY

2.1 Definition of Photogrammetry
2.2 History of Photographs
2.3 Aerial Photography
2.4 Close Range
2.5 Close Range Cameras
2.6 Horizontal and Oblique Terrestrial Photos
  2.6.1 Depression angle
  2.6.2 Horizontal and Vertical Angles
  2.6.3 Location points by intersection from two photos

2.1 Definition of Photogrammetry

Photogrammetry: is the science behind the creation of almost every topographic map made since the 1930s.

The human ability to perceive depth is the basis for the science (and technology) of photogrammetry. This ability to see in three dimensions is due to the offset in perspective centers between the left and the right eyes. Photographs taken to mimic this perspective shift are referred to as stereoscopic or stereo (meaning two). A stereo pair (or series) of images is taken from consecutive positions and overlap each other by at least 60%. Through the use of photogrammetry, highly detailed three-dimensional data can be derived from the two-dimensional photographs of a stereo pair.[2]

The formal definition of 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 energy and other phenomena. In many instances, the use of photogrammetry can be more efficient, less labor-intensive, and more cost-effective than other types of field 3D data collection, resulting in products that have a level of detail, accuracy, range, and price that is difficult to match with other technologies . As described previously, the main component necessary for a photogrammetric project is a series of overlapping stereoscopic images. The stereo images may be captured by a large variety of cameras at almost any height or platform (from tripod to earth-orbiting satellite).[2]

Photogrammetry is informally divided into two basic categories according to the height of the platform:

1. traditional (or aerial) and
2. nontraditional (or close-range).[2]

Advances in commercially available and cost-effective photogrammetric software, high-resolution digital cameras, high-performance laptop computers, and unmanned aerial systems (UAS) have caused those categories to overlap in recent years. This document refers to the traditional process of acquiring and using large-format (e.g., 9 × 9 inch), vertical (film or digital) aerial images as aerial photogrammetry. Close range is used to refer to photographs with an object-to-camera distance of less than 300 m.[2]

2.2 History Of Photogrammetry

In the early 18th century Dr. Brook Taylor published his treatise on linear perspective, and soon afterward, J. H. Lambert suggested that the principles of perspective could be used in preparing maps.[2]

The actual practice of photogrammetry could not occur, of course, until a practical photographic process was developed. This occurred in 1839, when Louis Daguerre of Paris announced his direct photographic process. In his process the exposure was made on metal plates that had been light-sensitized with a coating of silver iodide. This is essentially the photographic process in use today.[2]

The first actual experiments in using photogrammetry for topographic mapping occurred in 1849 under the direction of Colonel Aime Laussedat of the French Army Corps of Engineers. In Colonel Laussedat's experiments kites and balloons were used for taking aerial photographs. Due to difficulties encountered in obtaining aerial photographs, he curtailed this area of research and concentrated his efforts on mapping with terrestrial photographs. In 1859 Colonel Laussedat presented an accounting of his successes in mapping using photographs. His pioneering work and dedication to this subject earned him the title "father of photogrammetry." [2]

Topographic mapping using photogrammetry was introduced to North America in 1886 by Captain Eduard Deville, the Surveyor General of Canada. He found Laussedat's principles extremely convenient for mapping the rugged mountains of western Canada. The U.S. Coast and Geodetic Survey, now the National Geodetic Survey, adopted photogrammetry in 1894 for mapping along the border between Canada and the Alaska Territory.[2]

2.3 AERIAL PHOTOGRAMMETRY

Aerial photogrammetry utilizes large-format imagery and ground coordinate information to effectively recreate the geometry of a portion of the earth in a virtual environment. In this virtual environment, reliable horizontal and vertical measurements can be made and recorded (or compiled) directly into a geospatial data file. Accurate measurements can be recorded from aerial photographic images, by using traditional methods, only when the following conditions are met[2]:

1. stereoscopic image pairs (two or more overlapping photographs) cover the object to be analyzed;
2. accurate x, y, and z coordinates are known for at least three defined object points in the overlapping photographs; and
3. a calibrated mapping or metric camera is used to take the photographs.

The compilation of planimetric features (such as roads and streams) and topographic information (such as digital terrain models [DTM] and topographic contours) from the photographic sources is accomplished through the use of digital stereoscopic instruments. Digital, or softcopy, photogrammetric workstations require specialized software and hardware for viewing a pair of stereo images. In this virtual environment, an experienced operator can link the images with the ground control to collect precise horizontal and vertical coordinates for a point, line, polygon, or surface. The photogrammetric workstation recreates the geometry of the field subject through a series of mathematical operations. These procedures require a high level of expertise and repetition to maintain the operator’s skill. The softcopy instrument has analytical capabilities to a submillimeter level. Thus, high-accuracy ground control coordinate positions are needed to fully exploit the analytical capabilities of these instruments [2].

2.4 Close Range

The same basic principles of traditional aerial photogrammetry can be applied to stereoscopic pictures taken from lower altitudes or from the ground. Terrestrial, ground-based, and close-range are all descriptive terms that refer to photos taken with an object-to-camera distance of less than 300 m (1,000 feet). This distance equates to the minimum safe flying height above populated areas[3].

A variety of cameras and platforms may be used to obtain the photographic images to be used in CRP processing, including cameras :

1- housed in unoccupied airborne vehicles figures(2.1)and (2.2),
2- suspended below helium-filled blimps figure(2.3), and
3- mounted on tripods figure(2.4).

Through the use of these nontraditional methods, a resolution or ground sample distance of 0.25 mm and a spatial accuracy equivalent to 0.025 mm can be achieved. Theoretically, there is no limit to the resolution that can be achieved from CRP images[3].

Figure (2 . 1) Camera housed in unoccupied airborne vehicles[23]

Figure (2 . 2) Camera housed in unoccupied airborne vehicles[23]

Figure (2 . 3) Camera suspended below helium-filled blimps[24]

Figure (2 . 4) Camera mounted on tripods[25]

2.5 **Close Range Cameras**

A great variety of cameras are used for taking terrestrial photographs, and these may include:
1. Hobby cameras, which are handheld.

2. Phototheodolite: is a combination camera and theodolite mounted on a tripod used for taking terrestrial photographs. The theodolite, a surveying instrument which is used to measure angles, facilitates aligning the camera in a desired or known azimuth and measuring its position and elevation. Figure (2.5) shows a terrestrial photograph taken with a camera of the type phototheodolite shown in Figure (2.6). [3]

Figure (2 . 5) terrestrial photograph[20]

3. ballistic camera : These large cameras were mounted at selected ground stations and used to obtain photographs of orbiting artificial satellites against a star background. The photographs were analyzed to calculate satellite trajectories; the size, shape, and gravity of the earth; and the precise positions of the camera stations. This procedure utilized precisely known camera constants, together with the known positions of the background stars at the instants of exposure. Ballistic cameras played an essential role in establishing a worldwide network of control points and in accurately determining the relative positions of the continents, remote ocean islands, etc. Use of ballistic cameras for this purpose has been made obsolete by the Global Positioning System (GPS), a network of transmitting satellites and ground based receivers which enables extremely accurate positions to be determined anywhere on or near the earth as shown in figure (2.7).[3]

Figure (2. 6) phototheodolite[21]

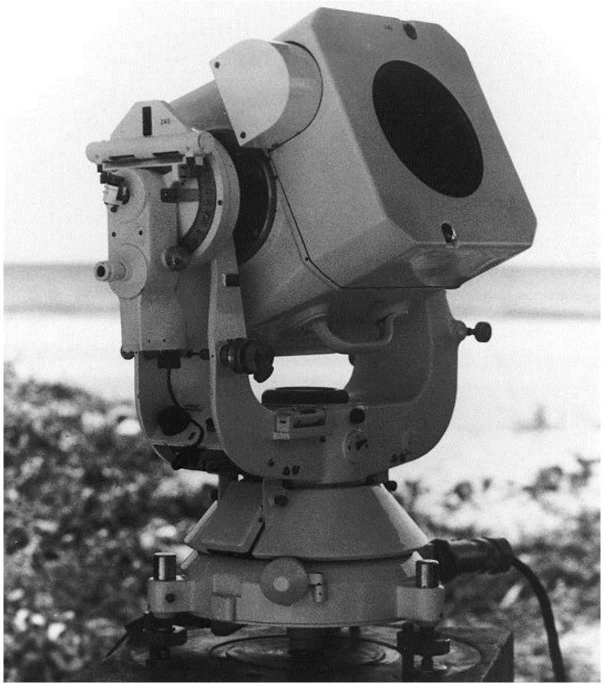


Figure (2. 7) Ballistic camera[22]

2.6 Horizontal and Oblique Terrestrial Photos

Classification of terrestrial photos depending on the orientation of the camera :

1. Horizontal: if the camera axis is horizontal when the exposure is made. , the plane of the photo is vertical. So if metric camera is used the x-axis is horizontal and the the y-axis is vertical. figure(2.8).[4]

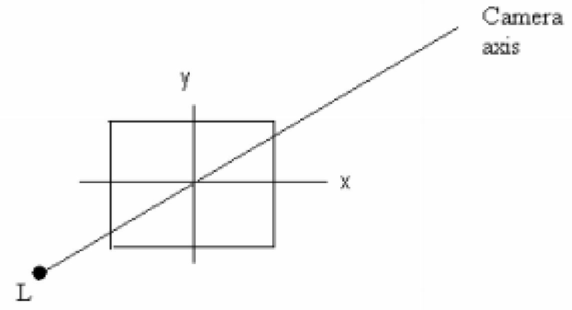


Figure (2 . 8) Horizontal Terrestrial Photo[4]

2. Oblique: the camera axis is inclined either up or down in an angle θ from horizontal. If θ is upward is called elevation angle. If its downward it called depressing angle. [4] Figure (2 . 9)

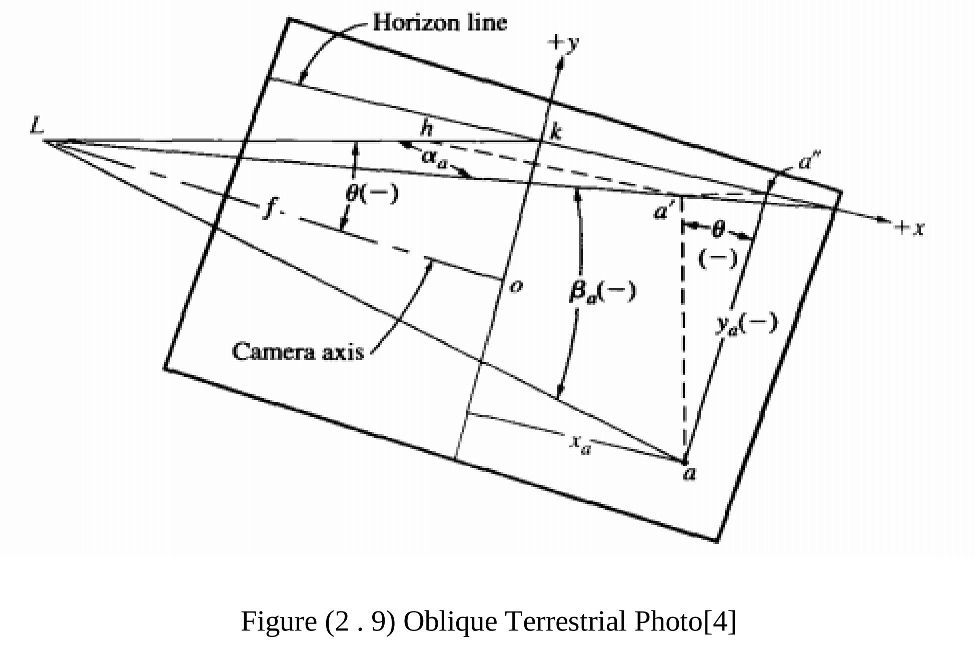


Figure (2 . 9) Oblique Terrestrial Photo[4]

2.6.1 Depression angle:

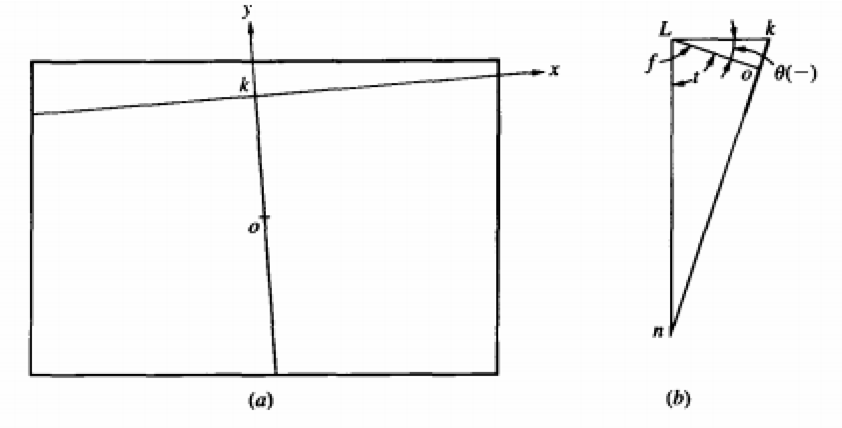


Figure (2 . 10) Depression angle[4]

Two ways to determine the depression [4] angle:

- **First:**

$\boldsymbol{\theta} = \mathbf{tan}^{-1}(\frac{y_o}{f})$ (6.1).

$y_o = ko$ (6.2).

θ is depression angle if $y_o = ko$ depression angle if is negative(as in the figure above), else it is an elevation angle.

- **Second:**

For the depression angle:

$\mathbf{t} = \mathbf{tan}^{-1}(\frac{on}{f})$ (6.3).

Where, n is the nadir point.

$\boldsymbol{\theta} = \mathbf{t} - \mathbf{90}^{\circ}$ (6.4).

If the angle is elevation angle:

$\boldsymbol{\theta} = \mathbf{90}^{\circ} - \mathbf{tan}^{-1}(\frac{oz}{f})$ (6.5).

2.6.2 Horizontal and Vertical Angles

Horizontal angle α between the vertical planes, **(La'a)**, containing image point **α** and the vertical plane, **Lko**, containing the camera axis is[4]:

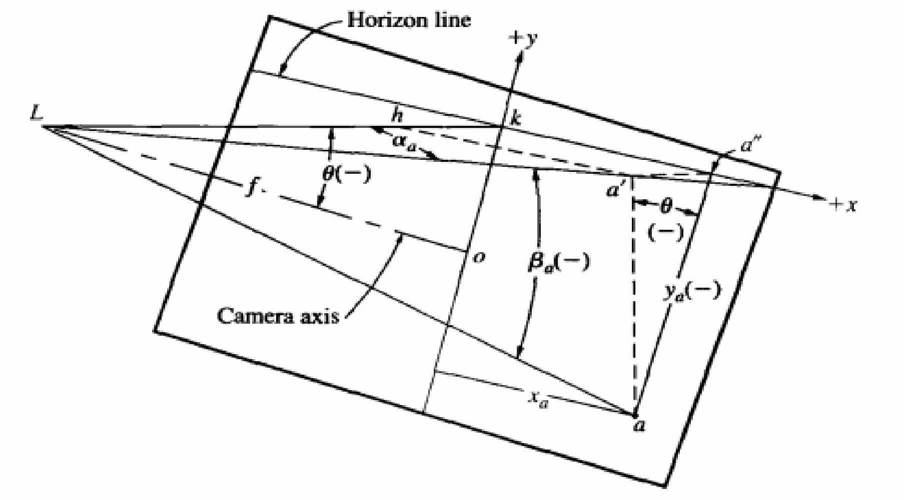


Figure (2 . 11) Horizontal angle[4]

$$\boldsymbol{\alpha_a = \tan^{-1}(\frac{ha\prime}{Lk-hk}) = \tan^{-1}(\frac{x_a}{f\sec\theta - y_a\sin\theta})} \qquad (6.6).$$

α is positive if it is clockwise, and negative if it is counter clockwise[4].

Vertical angle β_a to image point **α** can be calculated from the following equation:

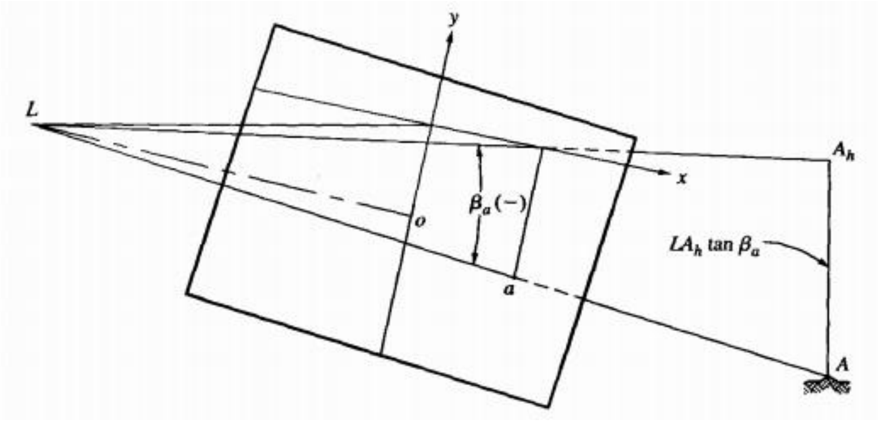


Figure (2. 12) Vertical angle[4]

$$\boldsymbol{\beta_a = \tan^{-1}\left(\frac{aa'}{La\prime}\right) = \tan^{-1}\left(\frac{aa\prime}{(Lk-hk)\sec\alpha_a}\right) = \tan^{-1}\left(\frac{y_a\cos\theta}{(f\sec\theta - y_a\sin\theta)\sec\alpha_a}\right)} \qquad (6.7).$$

2.6.3 Location points by intersection from two photos:

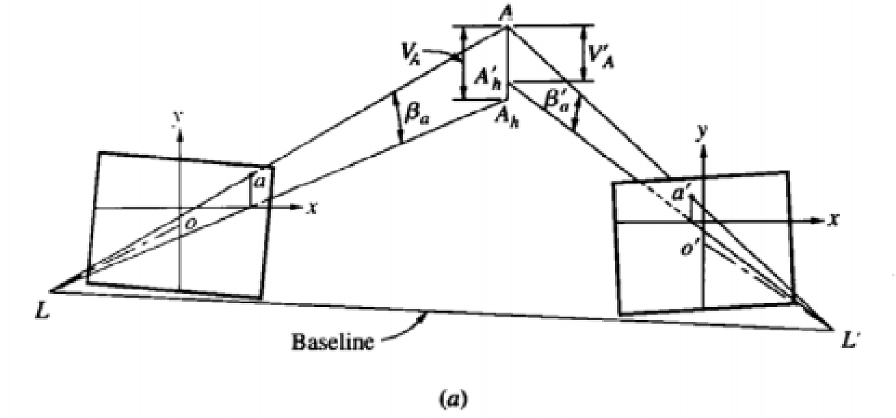


Figure (2. 13) Location points by intersection from two photos[4]

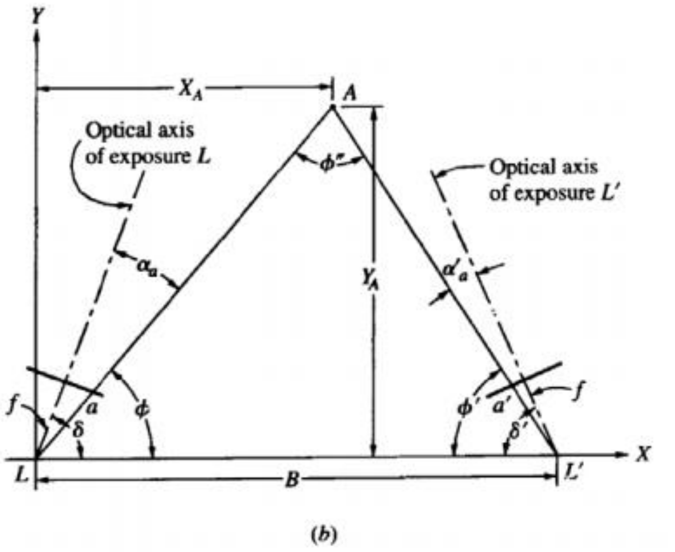


Figure (2. 14) position of a point A[4]

δ and **δ ′** can be determined by three points resection.

α ,α′ , β ,and **β a ′** can be calculated as explained before[4].

Then the position of a point A is calculated as follows:

$$\emptyset = \boldsymbol{\delta} - \boldsymbol{\alpha_a} \qquad (6.8).$$

$$\emptyset' = \boldsymbol{\delta}' + \boldsymbol{\alpha_a}' \qquad (6.9).$$

$$\emptyset'' = \mathbf{180^{\circ}} - \emptyset - \emptyset' \qquad (6.10).$$

$$\boldsymbol{LA} = \frac{\boldsymbol{B}\sin\emptyset'}{\sin\emptyset''} \qquad (6.11).$$

$$\boldsymbol{LA} = \frac{\boldsymbol{B}\sin\emptyset'}{\sin\emptyset''} \qquad (6.12).$$

$$\boldsymbol{X_A} = \boldsymbol{LA}\cos\emptyset \qquad (6.13).$$

$$\boldsymbol{Y_A} = \boldsymbol{LA}\sin\emptyset \qquad (6.14).$$

For check $\boldsymbol{X_A}$ and $\boldsymbol{Y_A}$ use the following two equations :

$$\boldsymbol{X_A} = \boldsymbol{B} - \boldsymbol{L'A}\cos\emptyset' \qquad (6.15).$$

$$\boldsymbol{Y_A} = \boldsymbol{L'A}\sin\emptyset' \qquad (6.16).$$

$$\boldsymbol{Elev\ A} = \boldsymbol{elev\ L} + \boldsymbol{v_A} \qquad (6.17).$$

$$\boldsymbol{v_A} = \boldsymbol{LA_h}\tan\boldsymbol{\beta_{a'}} \qquad (6.18).$$

For check [4] to the $\boldsymbol{Elev\ A}$;

$$\boldsymbol{Elev\ A} = \boldsymbol{elev\ L'} + \boldsymbol{v'_A} \qquad (6.19).$$

$$\boldsymbol{v'_A} = \boldsymbol{L'A_h}'\tan\boldsymbol{\beta'_a} \qquad (6.20).$$

CHAPTER THREE

MOPILE CAMERAS

3.1 Introduction

13 years ago, phones with cameras inside seemed pointless, heavy bricks that gave you grainy approximations of images. Fast forward to today, and we now Mobile devices arebecoming more and more powerful ,they allow for “always on – anywhere, anytime”, creativity, and publicunderstanding of complex issues.

A prediction for the next five years expects 1 TB "Tubercle Bacillus" of storage capacity, fast x coreprocessors (x>4), communication speeds of up to 1Gbit/sec, and the integration with 41MP camera sensor, one with 10x optical zoom and phone that's adept at nabbing low light - besides compatibleGNSS receivers for GPS, Glonass, Baidou and Galileo – like Inertial Navigation (IMU), advanced pedometers, air temperature, air pressure a phone with

3.2 Camera Resolution

the resolution in the world of mobile phone displays is the number of columns and rows of pixels. A display with 240 pixel columns and 320 pixel rows would generally be said to have a resolution of 240x320. Resolution can also be used to refer to the total number of pixels in a digital camera image.[13]

mobile camera are available with very affordable and good resolution CCD/CMOSCMOS "Complementary Metal Oxide Silicon" is a kind of sensor that is normally 10 times less sensitivity then CCD sensor with range of 6 to 15 lux As human eye can see object under 1 lux illumination.[14]

Lux is a unit of illumination equal to the direct illumination on a surface that is everywhere one meter from a uniform point source of one candle intensity or equal to one lumen per square meter.

CMOS sensor have 10 times more fix pattern noise then CCD sensor, are normally using on toy or very low end home security, are very fast it is 10 ~100 times faster then CCD sensor, so it is very good for special application such as can have all the logic and control circuit be build on the same silicon wafer dice so as to make the camera simple and easy to handle. Hence CMOS camera can be very small in size.[14]

CCD"Charge Couple Device" sensor normally will see better or as good as human eye in the range of 0.1 ~3 lux and are 3 to 10 times more sensitive then CMOS sensor All camera for serious application are using CCD sensor .All CCD camera making by other company are consuming 12V/150~300mA, hence is 2 to 4 times more then CMOS camera that is on 5~12v and 35~70 mAhighens DSC camera (Cannon D-30) or fast frame camera.[14]

3.3 Camera Calibration

Camera calibration has been applied in different photogrammetric application and methods for several decades. A general definition of calibration by the International Vocabulary of Basic and General Terms in Metrology (VIM) is “set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards."[10]

Another definition, for photogrammetric camera calibration, was given as calibration is "the act and process of determining certain specific measurements in a camera or other instrument or device by comparison with a standard, for use in correcting or compensating errors for purposes of record."[10]

After it's production and before it's use, aerial cameras must be carefully calibrated to determine precise and accurate values for a number of variables. These variables, generally referred to as the elements of interior orientation, are needed so that accurate spatial information can be determined precisely from photographs with correct geometry.

In general, camera calibration methods may be classified into one of three basic categories:

1. Laboratory methods
2. Field methods
3. Stellar methods

Of these, laboratory methods are most frequently utilized and are normally performed by either camera manufacturers or agencies of the federal government. In one particular method of laboratory calibration, which uses a multicollimator, as well as in the field and stellar procedures, the general approach consists of photographing an array of targets whose relative positions are accurately known. Elements of interior orientation are then determined by making precise measurements of the target images and comparing their actual image locations with the positions they should have occupied had the camera produced a perfect perspective view. In another laboratory method, which employs a goniometer, direct measurements are made of projections through the camera lens of precisely positioned grid points located in the camera focal plane. Comparisons are then made with what the true projections should have been.[10]

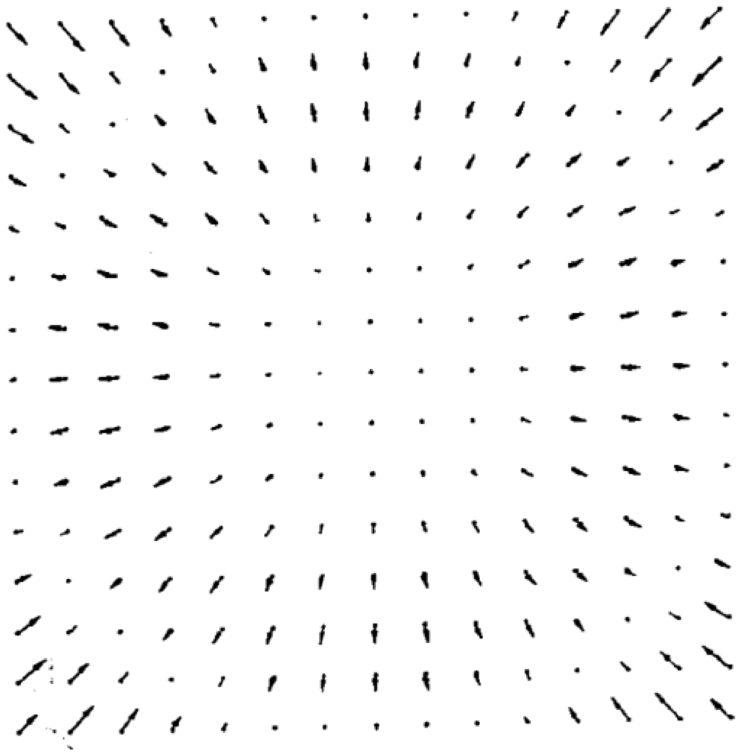
3.3.1 Elements Of Interior Orientation

The elements of interior orientation which can be determined through camera calibration are: calibrated focal length (CFL), Symmetric radial lens distortion, Decentering lens distortion, Principal point location and Fiducial mark coordinates.[1]

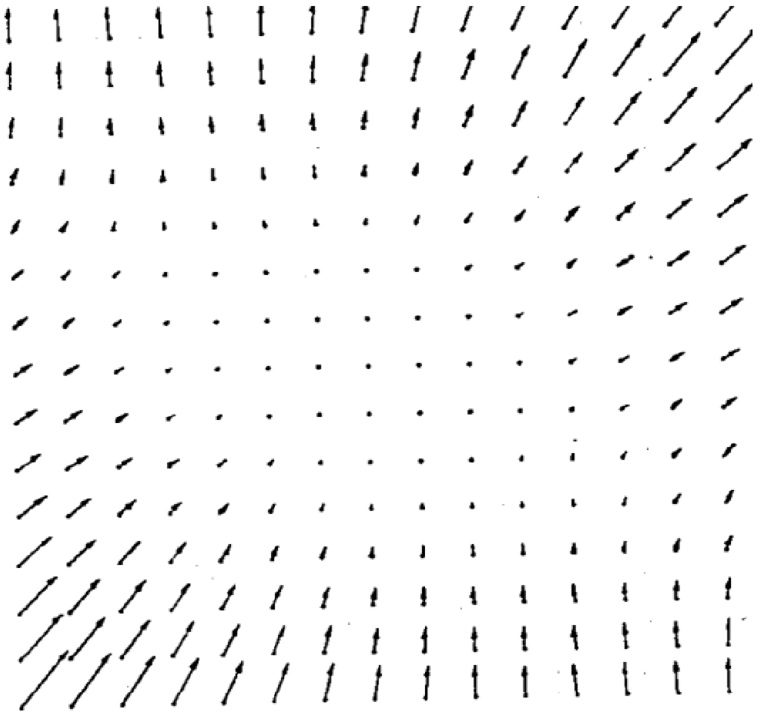
3.3.1.1Calibrated Focal Length (CFL): This is the focal length that produces an overall mean distribution of lens distortion. Actually this parameter would be better termed calibrated principal distance since it represents the distance from the rear nodal point of the lens to the principal point of the photograph. When aerial mapping cameras are manufactured, this distance is set to correspond to the optical focal length of the lens as nearly as possible, hence the more common, though somewhat misleading, term calibrated focal length.[1]

3.3.1.2Symmetric Radial Lens Distortion: This is the symmetric component of distortion that occurs along radial lines from the principal point. Although the amount may be negligible, this type of distortion is theoretically always present even If the lens system is perfectly manufactured to design specifications. Figure(3-1) shows a typical symmetric radial lens distortion pattern with magnitudes of distortion greatly exaggerated. Notice that distortion occurs in a direction inward toward, or outward from, the center of the image.[1]

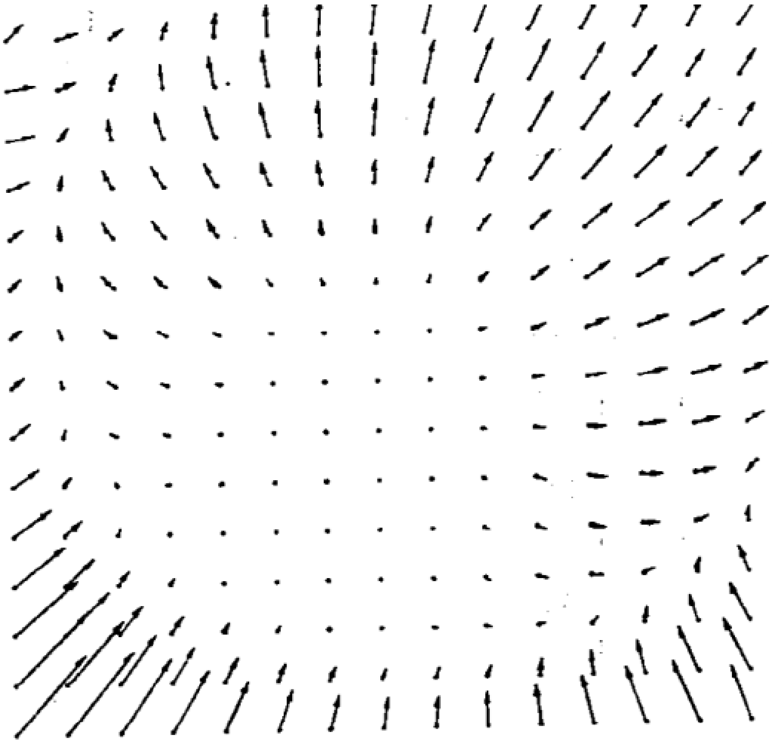
3.3.1.3Decentering Lens Distortion: This is the lens distortion that remains after compensation for symmetric radial lens distortion. Decentering distortion can be further broken down into asymmetric radial and tangential lens distortion components. These distortions are caused by imperfections in the manufacture and alignment of the lens system. Figure(3-2) shows a typical decenteringdistortion pattern, again with the magnitudes greatly exaggerated.[1]



Figure(3.1) a typical symmetric radial lens distortion pattern with magnitudes of distortion greatly exaggerated[1]



Figure(3.2) a typical decentering distortion pattern, again with the magnitudes greatly exaggerated.[1]



Figure(3.3) a typical pattern of combined symmetric radial and decentering distortion.[1]

3.3.1.4Principal Point Location: This is specified by coordinates of the principal point given with respect to the x and y coordinates of the fiducial marks. Although it is the intent in camera manufacture to place the fiducial marks so that lines between opposite pairs intersect at the principal point, there is always some small deviation from this ideal condition.[1]

3.3.1.5Fiducial Mark Coordinates: These are the x and y coordinates of the fiducial marks which provide the two-dimensional positional reference for the principal point as well as images on the photograph.[1]

3.3.2Laboratory Methods Of Camera Calibration

Laboratory calibration is generally used only for metric cameras. The IO parameters are determined by goniometers, multicollimator.

The multicollimator method consists of photographing, onto a glass plate, images projected through a number of individual collimators mounted in a precisely measured angular array. A single collimator consists of a lens with a cross mounted in its plane of infinite focus. Therefore, light rays carrying the image of the cross are projected through the collimator lens and emerge parallel. When these light rays are directed toward the lens of an aerial camera, the cross will be perfectly imaged on the camera's focal plane because aerial cameras are focused for parallel light rays. One plane of collimators is illustrated in figure (3.4). The individual collimators are rigidly mounted so that the optical axes of adjacent collimators intersect at known measured angles.

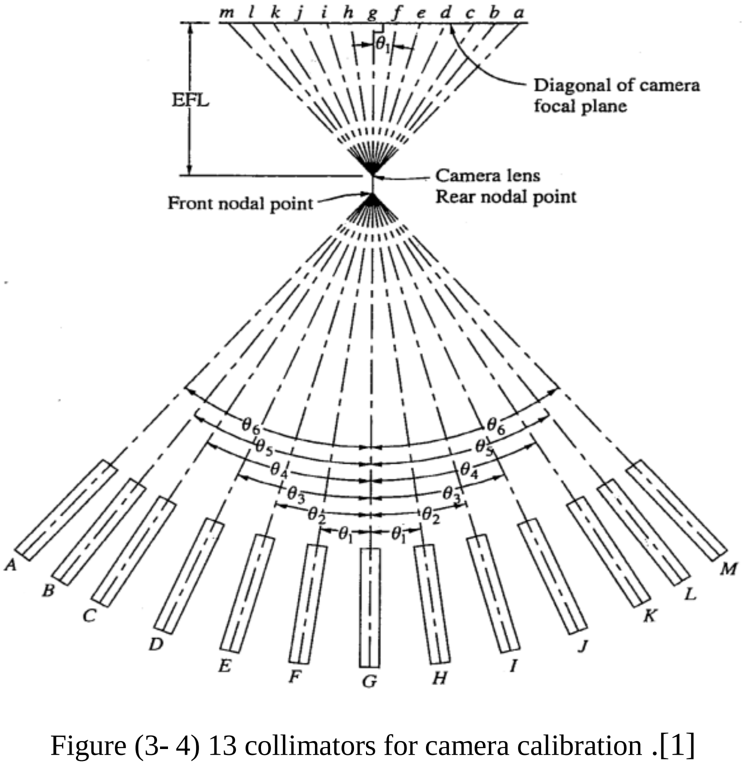


Figure (3- 4) 13 collimators for camera calibration .[1]

3.3.3Stellar Methods

In the stellar method, a target array consisting of identifiable stars is photographed, and the instant of exposure is recorded. Right ascensions and declinations of the stars can be obtained from an ephemeris for the precise instant of exposure so that the angles subtended by the stars at the camera station become known. Then these are compared to the angles obtained from precise measurements of the imaged stars. A drawback of this method is that since the rays of light from the stars pass through the atmosphere, compensation must be made for atmospheric refraction. On the other hand, there will be a large number of stars distributed throughout the camera format, enabling a more precise determination of lens distortion parameters.[1]

3.3.4Field Methods

Field procedures require that. an array of targets be established and that their positions with respect to the camera station be measured precisely and accurately in three dimensions. This can be achieved conveniently using GPS methods. The targets are placed far enough from the camera station so that there is no noticeable image degradation. Recall that an aerial camera is fixed for infinite focus. In this configuration, the camera must be placed in a special apparatus such as a fixed tower, so that camera station coordinates are correctly related to target coordinates. This enables the CFL (Calibrated Focal Length) and principal point location to be determined as well as lens distortion parameters, even if the target configuration is essentially a two-dimensional plane. If the targets are well distributed in depth as well as laterally, accurate location of the camera is less important.[1]

3.3.5Analytical Self Calibration

Analytical self-calibration is a computational process wherein camera calibration parameters are included in the photogrammetric solution, generally in a combined interior, relative and absolute orientation. The process uses collinearity equations that have been augmented with additional terms to account for adjustment of the calibrated focal length, principal point offsets, and symmetric radial and decentering lens distortion.[9]

In addition, the equations might include corrections for atmospheric refraction. The common form of the augmented collinearity equations is given as

$$x_a = x_\circ - x'_a(k_1 r_a^2 + k_2 r_a^4 + k_3 r_a^6) - (1 + p_3^2 r_a^2)[p_1(3x_a^2 + y_a^2) + 2p_2 x'_a y'_a] - f\frac{r}{q} \qquad (3.1)$$

$$y_a = y_\circ - y'_a(k_1 r_a^2 + k_2 r_a^4 + k_3 r_a^6) - (1 + p_3^2 r_a^2)[2p_1 x'_a y'_a + p_2(x_a^2 + 3y_a^2)] - f\frac{s}{q} \qquad (3.2)$$

Where $x_a, y_a = measured\ photo\ coordinates\ related\ to\ fiducials$

$x_\circ, y_\circ = coordinates\ of\ the\ principal\ point$

$k_1, k_2, k_3 = symmetric\ radial\ lens\ distortion\ coefficients$

$$p_1, p_2, p_3 = decentering\ distortion\ coefficients$$

$$f = calibrated\ focal\ length$$

$$r, s, q = collinearity\ eqation\ terms$$

$x'_a = x_a - x_\circ$ (3.3)

$y'_a = y_a - y_\circ$ (3.4)

$$r_a^2 = {x'_a}^2 - {y'_a}^2 \quad (3.5)$$

$$q = m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L) \qquad (3.6)$$

$$r = m_{11}(X_A - X_L) + m_{12}(Y_A - Y_L) + m_{13}(Z_A - Z_L) \qquad (3.7)$$

$$s = m_{21}(X_A - X_L) + m_{22}(Y_A - Y_L) + m_{23}(Z_A - Z_L) \quad (3.8)$$

$m_{11} = \cos\emptyset \cos k$ (3.9)

$m_{12} = \sin w \sin\emptyset \cos k + \cos w \sin k$ (3.10)

$m_{13} = -\cos w \sin\emptyset \cos k + \sin w \sin k$ (3.11)

$m_{21} = -\cos\emptyset \sin k$ (3.12)

$m_{22} = -\sin w\ \sin\emptyset\ \sin k + \cos w\ \cos k$ (3.13)

$m_{23} = \cos w\ \sin\emptyset\ \sin k + \sin w\ \cos k$ (3.14)

$m_{31} = \sin\emptyset$ (3.15)

$m_{32} = -\sin w \cos\emptyset$ (3.16)

$m_{33} = \cos w \cos\emptyset$ (3.17)

Where $w, \emptyset, k = rotational\ angles.$[9]

3.3.6Automatic Camera Calibration

The implementation of an automatic camera calibration system should consist of two stages:

1. Image processing: detecting targets, positioning target centers, and identify target number

2.Computation of self-calibration: initial value estimation and bundle adjustment

More than 50 artificial targets are generally needed for a camera calibration task. Due to their similarity, targets tend to be mismatched or misidentified among a set of images. For automatic target identification and for users being able to verify the results, coded targets are preferable to the implementation of automatic camera calibration. A coded target should meet the requirements below:

1.Independence of location, rotation and scale

2.Precise and accurate center point determination .

3 .Detection and localization in any patterned image without initial values.

4 .Short processing time.

5 .Compact target size.

6 .A low rate of manufacturing costs

Self-calibration is an extension of the bundle adjustment. It simultaneously solves the calibration parameters and points coordinates in object space with the measurements of a sufficient number of well-distributed points. Thus, the major problem of automatic self-calibration is how to estimate the initial value. Some research use additional equipmentssuch as the Inertial System (INS), to provide the position and the attitude of a camera. Some others use 3 object space control points and the closed-form space resection to estimate the initial values of orientation parameters. In this paper, the initial coordinates of targets are derived from the previous photogrammetric task, or simply measured by meters.[9]

3.3.7 Computation Of Self Calibration

Self-calibration technique does not require any object space control as a means of camera calibration. The observations of targets are used as the data required for both object points determination and for the determination of camera calibration parameters. The basic formulas of self-calibration are the collinearity equations with lens distortion and a series of additional parameters (APs), which can be written as:

$$x_{ij} - x_p + \frac{(x_{ij} - x_p)}{r}\delta_r + \Delta x = f_i^x \frac{(x_j - \overset{\circ}{x}_i)m_{11} + (y_j - \overset{\circ}{y}_i)m_{12} + (z_j - \overset{\circ}{z}_i)m_{13}}{(x_j - \overset{\circ}{x}_i)m_{31} + (y_j - \overset{\circ}{y}_i)m_{32} + (z_j - \overset{\circ}{z}_i)m_{33}} + dx_{AP} \quad (3.18)$$

$$y_{ij} - y_p + \frac{(y_{ij} - y_p)}{r}\delta_r + \Delta y = f_i^y \frac{(x_j - \overset{\circ}{x}_i)m_{11} + (y_j - \overset{\circ}{y}_i)m_{12} + (z_j - \overset{\circ}{z}_i)m_{13}}{(x_j - \overset{\circ}{x}_i)m_{31} + (y_j - \overset{\circ}{y}_i)m_{32} + (z_j - \overset{\circ}{z}_i)m_{33}} + dy_{AP} \quad (3.19)$$

Where $\circ$: $the\ perspective\ center$

i : $the\ ith\ photograph$

p : $the\ principale\ point$

j : $the\ jth\ point$

In equation (1), δ_r represents the radial distortion and Δx, Δy represent the decentering distortions. On the right side of the equation f_i^x, f_i^y are the principle distances form the image respect to x and y. These two factors are usually simplified as a common value f_i The terms $m_{11}, m_{12}, \ldots m_{31}$ are elements of the rotation matrix, which consists of three rotation angle: ω, φ, κ. The last terms dx_{AB} and dy_{AB} are additional parameters modeled with polynomials. The purpose of the camera calibration is to solve the interior orientation elements: xp, yp,f_i lens distortion parametersδ_r, Δx, Δy; and the additional parameters dx_{AP}, dy_{AP} In self-calibration, orientation parameters (m11, m12… m33) and observed points ground coordinates (X_j ,Y_j ,Z_j) are solved simultaneously. However, the collinearity equations are nonlinear, so that the Newton-Raphson approach of leastsquares adjustment is used to solve the unknowns, which is an iteration approach.[9]

3.3.8 Test Field

The test field applied for the experiments as shown in figure (3-5) is a three dimensional control field. There are 29 targets fixed on the aluminum rods hung on the ceiling or on the walls. The object coordinates of the targets were measured using Wild P32 metric camera. Six photographs were taken to form a solid intersection block. The distribution of exposure stations is shown in figure (3-6). Station 1 and 4 are on the same position but in different heights, so do the station pairs of (2, 5) and (3, 6). The image coordinates of the targets were measured using an analytical plotter.[12]

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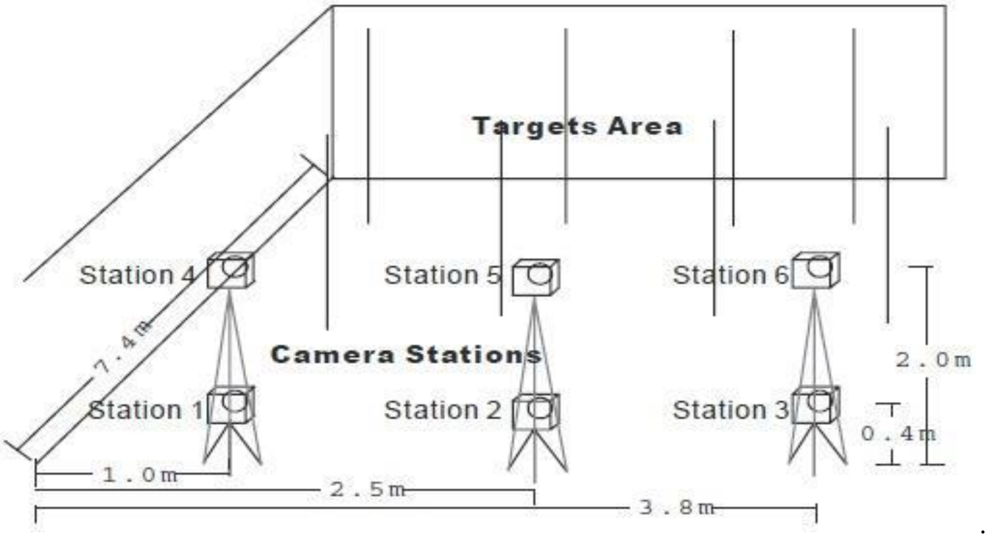
Figure (3 -5) The test field[12]



Figure(3 . 6). The distribution of exposure stations[12]

3.3.9 Zoom Dependent Camera Calibration

A recently developed process, titled zoom-dependent (Z-D) calibration, removes the necessity for the zoom setting to be fixed during the image capture process. Implementation of Z-D calibration requires that the camera be pre-calibrated at four or more focal settings within the zoom range, nominally at shortest and longest focal lengths, and at two mid-zoom settings. This requirement, coupled with issues of data management in carrying different focal settings for potentially every image within a bundle adjustment, has largely accounted for the reason that Z-D calibration has not previously been implemented within COTS software for close-range photogrammetry

Cameras employed for photogrammetric measurement have traditionally utilized unifocal lenses where, for a give focus setting, a fixed camera model can be applied. The parameters of this model are well-known: the principal distance, principal point offsets and coefficients of radial and decent ring distortion. These parameters are physically interpretable and can fully describe the metric behavior of a camera/lens combination at a specified focal setting to an accuracy of 0.1 pixel and better. In close-range photogrammetry, the recovery of camera parameters is nowadays generally performed via the self calibrating bundle adjustment

3.3.10 Z-D Calibration Model

A practical, empirically derived adjustable camera model that characterizes the variation of calibration parameters with zoom settings is the following

$$x^{corr} = x - x_p^{(c_i)} + \left(x - x_p^{(c_i)}\right) k_1^{(c_i)} r^2 \qquad (3.20)$$

$$y^{corr} = y - y_p^{(c_i)} + \left(y - y_p^{(c_i)}\right) k_1^{(c_i)} r^2 \qquad (3.21)$$

Here, x and y are the measured image coordinates x^{corr}, and $y^{corr}$the corrected coordinates and r the radial distance. The Z-D calibration parameters for principal

distance ci are the principal point offsets $x_p^{(c_i)}$, and $y_p^{(c_i)}$, and $k_1^{(c_i)}$the coefficient for the cubic radial lens distortion functionThe individual Z-D calibration parameters are obtained as follows

Principal distance

$$c_i = a_\circ + a_1 f_i \qquad (3.22)$$

Principal point offsets

$$x_p^{(c_i)} = b_\circ + b_1 c_i \qquad (3.23)$$

Radial lens distortion

$$k_1^{(c_i)} = d_\circ + d_1 {c_i}^{d_2} \qquad (3.24)$$

3.4 Best Smartphone Cameras of 2014

3.4.1 Infinix

Infinix Hot 2 Smartphone was launched in August 2015. The phone comes with a 5.00-inch touch screen display with a resolution of 720 pixels by 1280 pixels

The Infinix Hot 2 is powered by 1.3GHz quad-core and it comes with 2GB of RAM. The phone packs 16GB of internal storage that can be expanded up to 32GB via a microSD card. As far as the cameras are concerned, the Infinix Hot 2 packs a 8-megapixel primary camera on the rear and a 2-megapixel front shooter for selfies.

The Infinix Hot 2 runs Android 5.1 and is powered by a 2200mAh non removable battery.

The Infinix Hot 2 is a dual SIM (GSM and GSM) Smartphone Connectivity options include Wi-Fi, GPS, Bluetooth, FM. Sensors on the phone include Proximity sensor, Ambient light sensor, Acceleromete. [29]

Figure (3-7) Infinix mobile[15]

Table (3 .1) Infinix mobile Properties

Phone Size	Dimensions	140x70x7.9mm
	Weight	156 gm
DISPLAY	Type	IPS capacitive touch screen with 16,000,000 colors
	Size	5.0 inches, 720 x 1280 pixels, 294 pixels per inch
CAMERA	Primary	13MP, up to 4128 x 3096-pixel pictures camera, HDR, Geo-tagging, auto focus camera with LED flash
	Video	1080p@30fps
	Features	Accelerometer
	Secondary	2MP, up to 1600 x 1200-pixel pictures
Software	OS	Android 4.4.2 KitKat
	RAM	1GB

3.4.2 Samsung Galaxy Grand

The Samsung Galaxy Grand Duos is powered by 1.2GHz dual-core and it comes with 1GB of RAM. The phone packs 8GB of internal storage that can be expanded up to 64GB via a microSD card. As far as the cameras are concerned, the Samsung Galaxy Grand Duos packs a 8-megapixel primary camera on the rear and a 2-megapixel front shooter for selfies.

The Samsung Galaxy Grand Duos runs Android 4.1 and is powered by a 2100mAh removable battery. It measures 143.50 x 76.80 x 9.60 (height x width x thickness) and weighs 161.00 grams.

The Samsung Galaxy Grand Duos is a dual SIM (GSM and GSM) Smartphone that accepts two Regular SIMs. Connectivity options include Wi-Fi, GPS, Bluetooth, FM, 3G. Sensors on the phone include Proximity sensor, Ambient light sensor, Accelerometer, and Gyroscope. [30]

Figure (3-8) Galaxy Grand mobile phone

Table (3 . 2) Samsung Galaxy Grand Properties

Phone Size	Dimensions	143.5 x 76.9 x 9.6 mm (5.65 x 3.03 x 0.38 in)
	Weight	162 g (5.71 oz)
DISPLAY	Type	TFT capacitive touch screen, 16M colors
	Size	5.0 inches (~64.5% screen-to-body ratio)
	Resolution	480 x 800 pixels (~187 ppi pixel density)
CAMERA	Primary	8 MP, autofocus, LED flash
	Video	1080p@30fps, stereo sound rec
	Features	Geo-tagging, touch focus, face/smile detection
	Secondary	2 MP
Software	OS	Android OS, v4.1.2 (Jelly Bean), upgradable to v4.2.2 (Jelly Bean
	RAM	8 GB, 1 GB RAM

3.4.3 Sony Xperia Z2

Coming only six months after the release of the Xperia Z1 it’s no great surprise to find that the Z2 uses the same 20.2MP Exmor RS sensor found inside its predecessor. At 1/2.3in it’s larger than the 1/3in sensors used in the iPhone 5S and HTC One M8, or indeed the 1/2.5in sensor of the Samsung Galaxy S5. One thing to note, however, is that the Z2 outputs images at a standard 8MP of resolution when used in any of the automatic modes (including Superior Auto). To shoot at full resolution you need to put the camera in ‘Manual’ modes and select the full 20.7MP.

In terms of features, the Z2 comes loaded with useful tools. There are plenty of pre-loaded digital effects filters to play around with and, in addition, the Z2 also sports automatic Panoramic and HDR modes. Built-in image stabilization comes as standard, as does the ability to shoot 4K and 1080p Full HD video. What really sets the Z2 apart from the competition though, is that it is sealed against water penetration, meaning it can safely be used underwater (fresh water, not salt water) at a maximum depth of 1.5m. If you’re looking for an all-weather camera phone the Z2 is by far your best bet see table(6.3).[17]

Figure (3- 9) .Sony Xperia Z2[18]

Table (3 . 3) Sony Xperia Z2 Properties

Phone Size	Dimensions	146.8x 73.3 x 8.2 mm (5.78 x 2.89 x 0.32 in)
	Weight	163 gram
DISPLAY	Type	IPS LCD capacitive touch screen, 16M colors
	Size	5.2inches (69.3% screen-to-body ratio)
	Resolution	1080x 1920 pixels (424 ppi pixel density)
CAMERA	Primary	20.7MP, 5248 x 3936 pixels, autofocus, LED flash
	Video	2160p@30fps, 1080p@60fps, 720p@120fps, HDR
	Features	1/2.3" sensor size, geo-tagging, touch focus, face detection, HDR, panorama
	Secondary	2.2MP,1080p@30fps
Software	OS	Android OS, v4.4.2 (KitKat), upgradable to v5.0.2(Lollipop)
	RAM	3GB RAM

3.4.4 Samsung Galaxy S3

Samsung Galaxy S3 Slim Smartphone was launched in March 2014. The phone comes with a 4.50-inch touch screen display with a resolution of 540 pixels by 960 pixels

The Samsung Galaxy S3 Slim is powered by 1.2GHz quad-core and it comes with 1GB of RAM. The phone packs 8GB of internal storage that can be expanded up to 32GB via a microSD card. As far as the cameras are concerned, the Samsung Galaxy S3 Slim packs a 5-megapixel primary camera on the rear and a 0.3-megapixel front shooter for selfies.

The Samsung Galaxy S3 Slim runs Android 4.2 and is powered by a 2100mAh removable battery. It measures 133.00 x 66.00 x 9.70 (height x width x thickness) and weighs 139.00 grams.

The Samsung Galaxy S3 Slim is a single SIM (GSM) Smartphone that accepts a Micro-SIM. Connectivity options include Wi-Fi, GPS, Bluetooth, FM. Sensors on the phone include Proximity sensor, Ambient light sensor, Accelerometer. [17]

Figure (3-10) Samsung Galaxy S3

Table (3 . 4) Samsung Galaxy S3 Properties

Phone Size	Dimensions	136.6 x 70.6 x 8.6 mm (5.38 x 2.78 x 0.34 in)
	Weight	133 g (4.69 oz)
DISPLAY	Type	Super AMOLED capacitive touch screen, 16M colors
	Size	4.8 inches (~65.9% screen-to-body ratio)
	Resolution	720 x 1280 pixels (~306 ppi pixel density)
CAMERA	Primary	8 MP, autofocus, LED flash
	Video	1080p@30fps
	Features	Geo-tagging, touch focus, face/smile detection
	Secondary	1.9 MP, 720p@30fps
Software	OS	Android OS, v4.0.4 (Ice Cream Sandwich), 4.3 (Jelly Bean
	RAM	16/32/64 GB, 1 GB RAM

3.4.5 Samsung Galaxy E7

Samsung Galaxy E7 Smartphone was launched in January 2015. The phone comes with a 5.50-inch touch screen display with a resolution of 720 pixels by 1280 pixels at a PPI of 267 pixels per inch.

The Samsung Galaxy E7 is powered by 1.2GHz quad-core and it comes with 2GB of RAM. The phone packs 16GB of internal storage that can be expanded up to 64GB via a microSD card. As far as the cameras are concerned, the Samsung Galaxy E7 packs a 13-megapixel primary camera on the rear and a 5-megapixel front shooter for selfies.

The Samsung Galaxy E7 runs Android 4.4 and is powered by a 2950mAh non removable battery. It measures 151.30 x 77.20 x 7.30 (height x width x thickness).

The Samsung Galaxy E7 is a dual SIM (GSM and GSM) Smartphone Connectivity options include Wi-Fi, GPS, Bluetooth, FM, 3G, 4G. Sensors on the phone include Proximity sensor, Accelerometer. [32]

Figure (3-11) Samsung Galaxy E7

Table (3 .5)Samsung Galaxy E7Properties

Phone Size	Dimensions	151.3 x 77.2 x 7.3 mm (5.96 x 3.04 x 0.29 in)
	Weight	141 g (4.97 oz)
DISPLAY	Type	Super AMOLED capacitive touch screen, 16M colors
	Size	5.5 inches (~71.4% screen-to-body ratio)
	Resolution	720 x 1280 pixels (~267 ppi pixel density)
CAMERA	Primary	13 MP, autofocus, LED flash
	Video	1080p@30fps
	Features	Geo-tagging, touch focus, face detection, panorama, HDR
	Secondary	5 MP, 1080p@30fps
Software	OS	Android OS, v4.4.4 (KitKat), upgradable to v5.1.1 (Lollipop)
	RAM	16 GB, 2 GB RAM

CHAPTER FOUR
APPLICATIONS OF CLOSE RANGE PHOTOGRAMMETRY

4.1 Introduction

4.2 Medical Rehabilitation

  4.2.1 The Face

  4.2.2 The Back

  4.2.3 Skin

  4.2.4 Teeth

  4.2.5 Measurements Within the Body

4.3 Rail Ways

4.4Accident reconstruction

4.5 Crime scene

4.6 Cyclic Documentation for Change Detection

4.7Documenting Cultural Resources.

4.8PhotoModeler Scanner

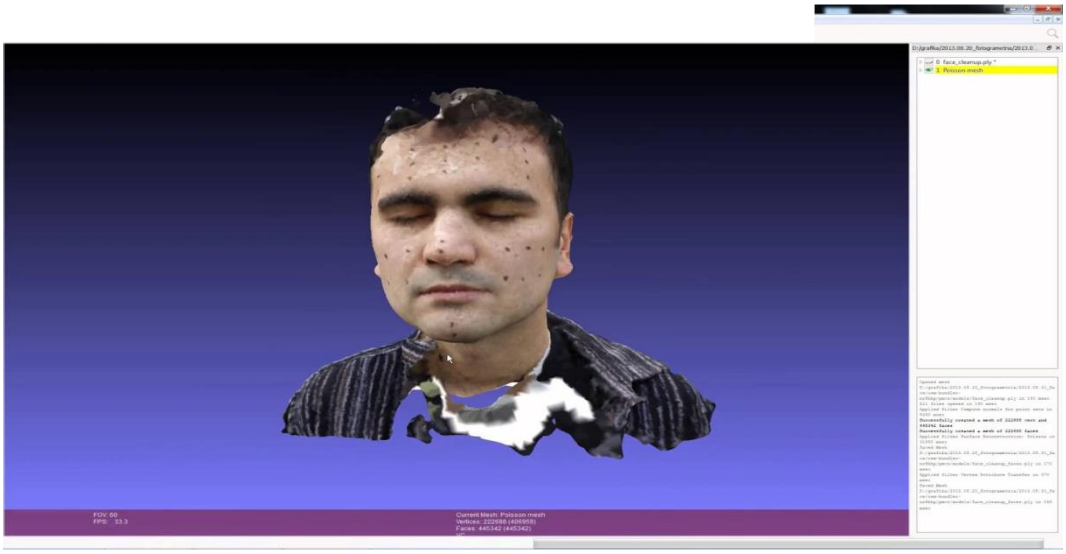
4.1 Introduction

Today Close range photogrammetry used in many fields by apply traditional techniques, workflow, close-range image capture, processing, three-dimensional measuring and modeling (3DMM) software. Here, we introduce some applications of close range photogrammetry such as medical rehabilitation, Rail ways, Accident reconstruction, crime scene, CyclicDocumentationfor Change Detection , Documenting Cultural Resources.

4.2 MEDICAL REHABILITATION

4. 2.1 The Face

Photogrammetric measurement has been used on the face more than on any other part of the body. Measurements have been made to monitor facial shape it changes over an extended period of time, through growth and during the treatment o fvarious conditions.



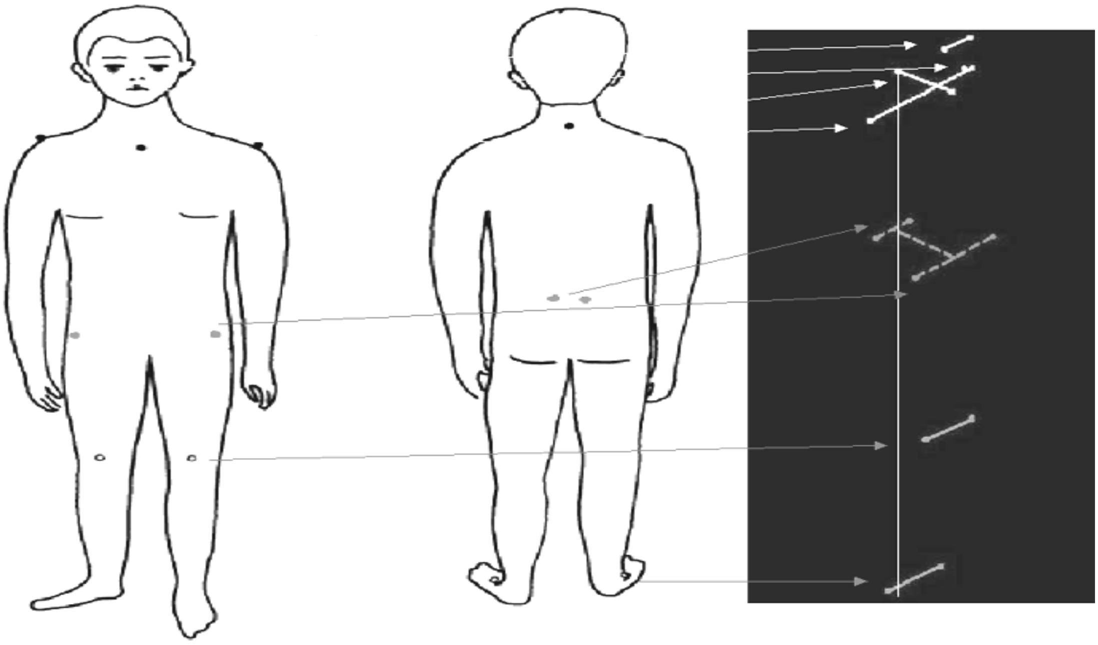
Figure(4.1) Three dimensional model for face measurement [27]

Photogrammetry has also been used to investigate changes over short periods of time, such as before and after surgery, as surgical intervention to improve cosmetics or dis-functional jaw structures is quite common ,the accurate and high-resolution spatial data which can depict the face with the very fine detail which is relevant to human recognition and cosmetics can be demanding, especially given its complex shape and the occlusions which can occur in stereo photographs. To be acceptable for use within medical organizations, measurement systems may need to supply facial features draped on a 3D model. Further, because facial measurement can be useful in surgical planning to provide both surgeons and patients with predictions of the outward changes expected from their operations, dynamic computer models may sometimes need to be an element of the measurement system. [6]

4. 2.2 The Back

The dominating need for back measurement is caused by the widespread occurrence of scoliosis, or curvature of the spine which often becomes apparent in teenage years, with both cosmetic and functional consequences. Measurements are needed to detect the condition and for monitoring the progress of treatment. Despite the apparent benefits offered by photogrammetry, the accuracy, and even the capability, of determining from the external shape measurement reliable values for spinal shape parameters for use in the disease's diagnosis and treatment is a matter of some argument.

Even so, external measurement is preferred by many orthopedic specialists because of the danger of excessive X-ray dosages with internal measurement systems, and photogrammetry can clearly compete with the cruder mechanical measurement tools that are used when radiography is to be avoided.[6]



Figure(4.2)Back measurement[6]

The moderate surface undulations of the back make it an ideal surface for photogrammetric recording, and even fully automated photogrammetry.

Accordingly, many medical photogrammetric developments have related to the back, most using cast texture to provide detail suited to point matching

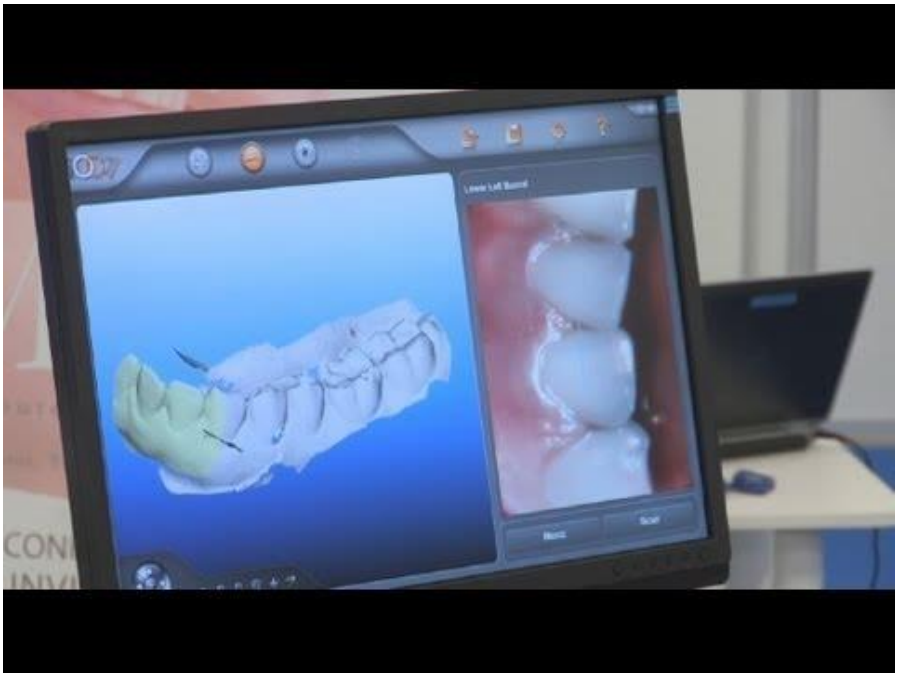
The benefit of measurement is indicated by the existence of a number of integrated measurement and analysis systems offered commercially. However, as for the face, photogrammetric systems are rare and they must compete with other optical systems .[6]

4. 2.3 Skin

Sores, ulcers, wounds, melanomas and other skin conditions have been studied by photogrammetry, typically to monitor change with time. For this reason, photogrammetry's main advantage lies in the provision of an accurate record, but a significant challenge lies in providing cheap and simple techniques for use in clinics outside hospitals. The only alternative seems to be simple observation, sometimes accompanied by photography, but despite a widespread interest in this work photogrammetric systems are not in common use.[6]

Teeth4. 2. 4

Measurements of teeth are utilised to detect the occurrence of wear, erosion and abrasion in both natural tooth surfaces and in tooth restoration materials, but the repetitive measurement has generally been carried out on teeth replicas derived from castings, rather than on teeth in situ., the photogrammetry has typically used microscope imagery and has been pursued because of the difficulty of finding alternatives that can be used with such small objects.[28]



Figure(4.3)Three-dimensional representation to solve a problem in the teeth[28]

The common difficulties faced by photogrammetric solutions here are the need to determine camera orientation parameters and a lack of texture on the objects photogrammetry faces competition from a variety of sophisticated optical and mechanical devices in such investigations.

4. 2.5 Measurements within the Body

The benefits offered by imaging give photogrammetry an application in recording surgical processes, sometimes for teaching purposes. Some fully digital photogrammetric methods) have been developed for surgical use within specific hospitals.[6]

4.3 RAILWAY

The objective of the system in this application is determining three-dimensional co-ordinates of points located in selected planes which are perpendicular in relation to the track axis.

Figure (4.4)Frame of control points[8]

In this application we should taking into account the precise synchronization of the pictures, immediate transfer of pictures to the computer memory, stability of relative orientation elements of both cameras ,stability of control point co-ordinates in the travelling platform arrangement, taking into account corrections relating to the track curvature and recording onto the pictures the outline of the range of that part of cross-section, transverse in relation to the track, inside which the points will be measured.

The first two of these conditions affect the choice of proper digital cameras: they cannot be popular photo cameras since, in this case, precise synchronizing of their shutters is not possible. The stability of calibration parameters imposes application of cameras with focal distance locks, and quick picture transfer to the computer may be achieved through the application of wire frame, with the reduction of the picture file size through the application of monochromatic cameras.[8]

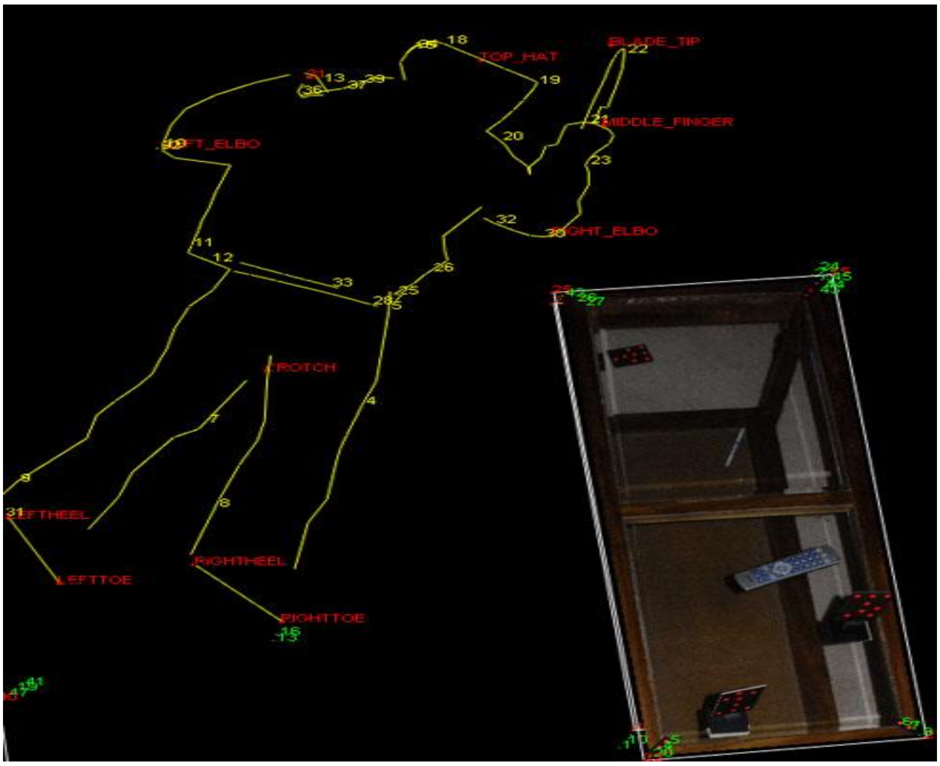
4. 4 Accident reconstruction

The aim of traffic accident reconstruction (AR) is, as the name implies, to reconstruct motor vehicle collision scenes. Whether the final requirements of the AR process are to assist in calculations (such as vehicle speed), to analyze the dynamics of the collision events. For most scenes, it’s a low-cost, fast and accurate method of permanently archiving & mapping critical scene evidence in 3D. Improves safety, less time on road, Easy to use (the photogrammetry software does all the ‘math’ automatically) .[7]

Figure(4-5)Analyze the dynamics of the collision event[7]

Crime scene 4.5

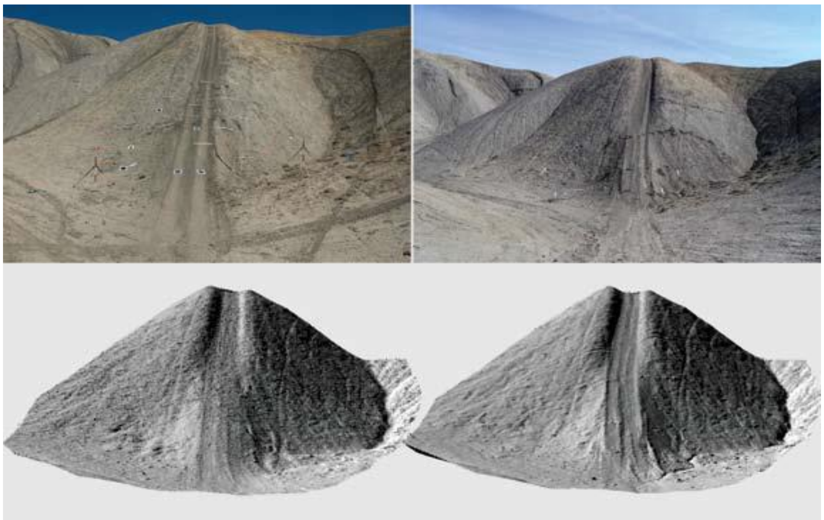
Crime scene investigators in law enforcement were always looking for new methods to make their job easier, more accurate and more efficient. To process a crime scene in an organized approach, one of the vital stages in processing is scene documentation. The scene documentation is an important stage because it is visualization record of evidences on the scene. Hence, this study focus on how to do the scene documentation by mapping those evidences using the iwitness and crime zone software. Close range photogrammetry method used in iwitness software to help crime scene investigators dealing with non-contact measurement data acquisition. Physical evidences on the crime scene were measured and verified with tape and laser scanner measurement. Then the output .dxf data from iwitness exported to crime zone in order to generate 3d visualization of the crime scenes whether it is homicide scenes, evidence and bullet trajectories. Combination of iwitness and crime zone software is a vital tool in forensic mapping applications for law enforcement and investigators. It provides the practical solution to mapping crime scene by using close-range photogrammetry methodology.[5]



Figure(4.6)Example of images of crime scene[5]

4.6 Cyclic Documentation for Change Detection

Cyclic Documentation for Change Detection The ability to detect small changes in soil movement can provide valuable insight for assessing the effects of surface disturbing activities across the landscape. Close-range photogrammetry is an excellent method for capturing detailed information about changes, such as erosion, on scales ranging from 1 square meter plots up to an entire hill slope. CRP is especially effective for monitoring erosion on areas that are devoid of vegetation, such as roads, OHV trails, and construction sites.[11]



Figure(4.7)Three dimensional model for detect small changes in soil movement[11]

Documenting Cultural Resources.4.7

Conservation of historical buildings and constructions, being important parts of cultural heritage, determining the historical buildings facades is one of the main operations. Historical buildings are usually characterized by irregular geometry, very complex surface. In this context, close range photogrammetry is inevitable and has been used successfully for documentation of cultural heritage for many years.

Digital close range photogrammetry is currently an effective system providing both vector and raster data type. This method is also allowing metric-morphological reconstruction of cultural heritage.[11]

(4.8)Documenting Cultural Resources in charge [11]

CHAPTER Five

Results and Accuracy

5.1 Introduction

In this chapter, the results introduced of the field work. Mobile phone cameras are used to apply 3D models for close range objects. Several experiments on a 3D model were applied using set of mobile phones cameras from fixed and variable distance with different resolution.

The work started from finding deferent objects to make the project on it , passing through making camera calibration for the camera that used, taking photos to the object, until building 3D model of the objects by several software and comparison between them.

In the next sections will be saw a results of building a 3D model in several software from Exterior shape to the accuracy of each on.

5.2 Used Software

Deferent software are used to make a 3D close range model, like Photo-Modeler, Agisoft photo scan professional , Memento Autodesk. These software are available online on internet.

5.2.1 PhotoModeler Scanner

PhotoModeler Scanner provides the tools for the user to create accurate, high quality 3d models and measurements from photographs. The process is called photo-based 3d scanning.

PhotoModeler Scanner is a 3d scanner that provides results similar to a 3d laser scanner. This 3d scanning process produces a dense point cloud (Dense Surface Modeling, DSM) from photographs of textured surfaces of virtually any size.

The PhotoModeler Scanner software has all the capabilities of the base PhotoModeler product plus the capability to do Dense Surface Modeling (DSM), 3D scanning and Smart Match.

PhotoModeler Scanner is a sophisticated tool to build accurate Dense Surface Models and get measurements from your photos. Use PhotoModeler Scanner to build:

- Dense Surface Models where a large number of 3D points are needed.
- Models that traditionally would require a 3d laser scanner
- Scale-independent object modeling - model small objects or big scenes

5.2.2 Agisoft photo scan professional

Agisoft PhotoScan is an advanced image-based 3D modeling solution aimed at creating professional quality 3D content from still images. Based on the latest multi-view 3D reconstruction technology, it operates with arbitrary images and is efficient in both controlled and uncontrolled conditions. Photos can be taken from any position, providing that the object to be reconstructed is visible on at least two photos. Both image alignment and 3D model reconstruction are fully automated.

5.2.3 Memento Autodesk

Autodesk Memento is an end-to-end solution for converting any captured reality input (photos or scans) into high definition 3D meshes that can be cleand up, fixed, and optimized for the Web, mobile or 3D printing/fabbing.

Scanners and cameras are becoming ubiquitous and they let us digitize the world around us. Creating useful and meaningful 3D models from reality however, is a quite challenging and tedious process that is slow, requires expertise and use of multiple and expensive solutions. Memento aims to simplify that process and thus make Reality Computing scalable and accessible to a variety of users.

5.2.4 MeshLab

MeshLab is an open source, portable, and extensible system for the processing and editing of unstructured 3D triangular meshes.

The system is aimed to help the processing of the typical not-so-small unstructured models arising in 3D scanning, providing a set of tools for editing, cleaning, healing, inspecting, rendering and converting this kind of meshes.

5.3 Work procedure

The set of steps followed to make 3D models :

- choose objects with specific characteristics
- made camera calibration for mobile camera that used to determine precise and accurate values for a number of variables.
- Take some photos for the object in a variable and fixed distance .
- Measuring the real distance of the object.
- Built 3D model using several software .
- Analyze the 3D model data and Reduce the errors.
- Measuring the program distance.
- Compare the program distance with real distance of object.

5.4 Results

Four different models were used for testing in this project, in order to make a comparison with different mobile phone with different cameras resolution, as described in chapter (3.4). The models and their results are described in the following sections.

5.4.1 Model #1

The first model is 3D house from Al Hila_Yatta see figure (5.1), formed from the floor and settlement, it's approximate area is 110 m^2, the first part photos was taken from a fixed distance and the next one taken from a deferent distances by using Samsung Galaxy E7 camera. It's done by Photomodeler software.

Figurer(5.1)photo for the house that would be built 3D model to it

The first part of first 3D model ,see figure (5.2), was done by fixed distance 10 m from the object by Photomodeler software and the result in the table(5.1)

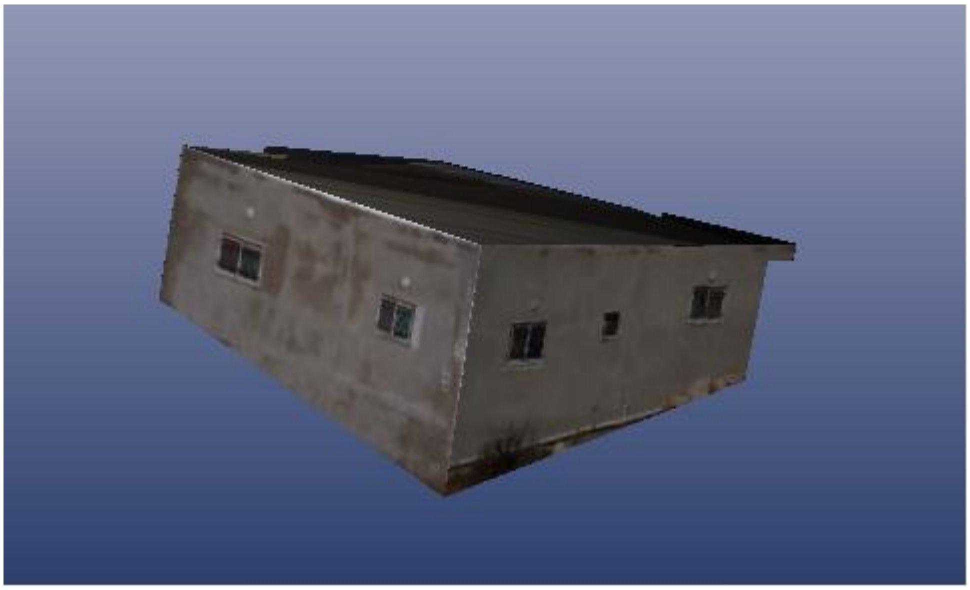
Figure(5.2) 3D model of the house by fixed distance 10 m from the house by Photomodeler software.

Table (5.1) Model #1 first part by Samsung Galaxy E7 results

Measured Distance (m)	Real Distance (m)	Differences (m)
5.940	5.940	0.000
1.580	1.580	0.000
3.330	3.300	0.030
3.630	3.600	0.030
1.260	1.260	0.000
0.720	0.720	0.000
1.250	1.250	0.000
1.000	1.000	0.000

Min= 0.000 m
Max= 0.030 m
Mean For Differences = 0.0075 m
Standard deviation Measured Distance= 0.0138 m
Standard deviation $=\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$= 0.0138 m

The second part of first 3D model, see figure (5.3), done by a variable distance from the object by Photomodeler software and the result in the table(5.2)



Figure(5.3) 3D model of the house by a variable distance from the house by Photomodeler software.

Table (5.2) Model #1 second part by Samsung Galaxy E7 results

Measured Distance (m)	Real Distance (m)	Differences (m)
5.940	5.940	0.000
1.580	1.580	0.000
3.320	3.300	0.020
3.640	3.600	0.040
1.260	1.260	0.000
0.710	0.720	-0.010
1.250	1.250	0.000
1.010	1.000	0.010

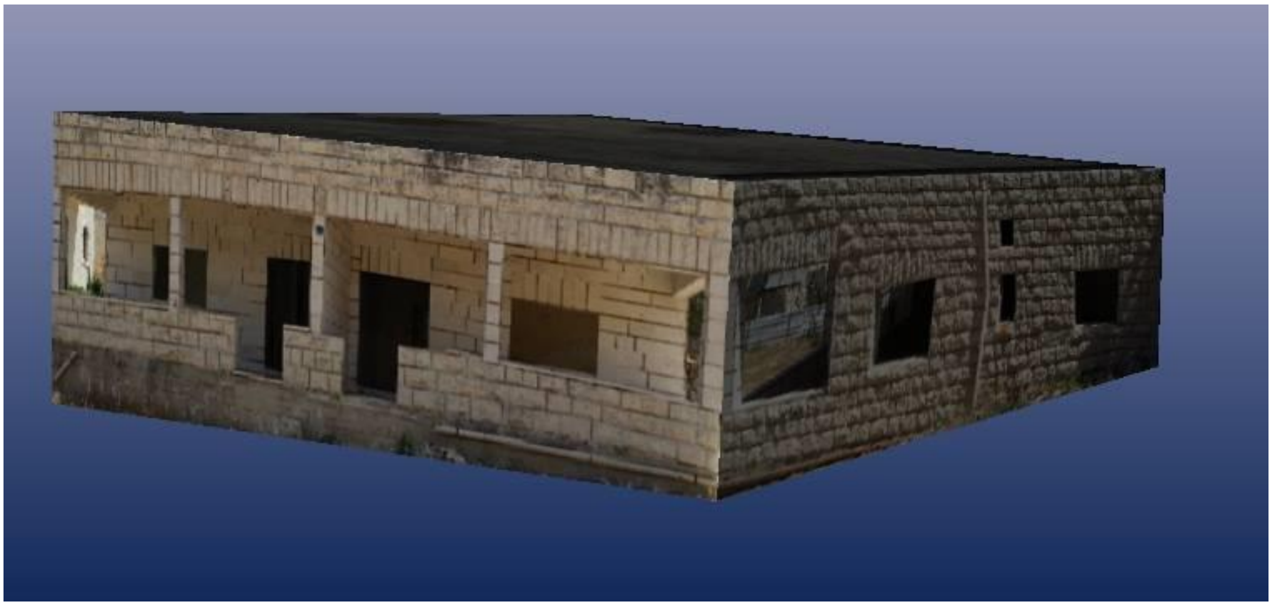
Min= 0.000 m
Max= 0.040 m
Mean For Differences = 0.0075 m
Standard deviation Measured Distance= 0.0158 m
Standard deviation $=\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$ = 0.0158 m

5.4.2 Model #2

This model is 3D house from al Salam Street-Hebron see figure (5.4) , formed from the floor and settlement, it's approximate area is 196 m^2, the photos taken from a variable distance by using Samsung Galaxy S3 camera. It's done by Photomodeler software.

Figure(5.4)photo for the house that would be built 3D model to it

The 3D model, see figure (5.5), done by a variable distance from the object by Photomodeler software and the result in the table(5.3):



Figure(5.5) 3D model of the house by a variable distance from the house by Photomodeler software.

Table (5.3) Model #2 by Samsung Galaxy S3 results

Measured Distance (m)	Real Distance (m)	Differences (m)
14.900	14.900	0.000
14.040	14.080	-0.040
14.040	14.080	-0.040
14.930	14.900	0.030

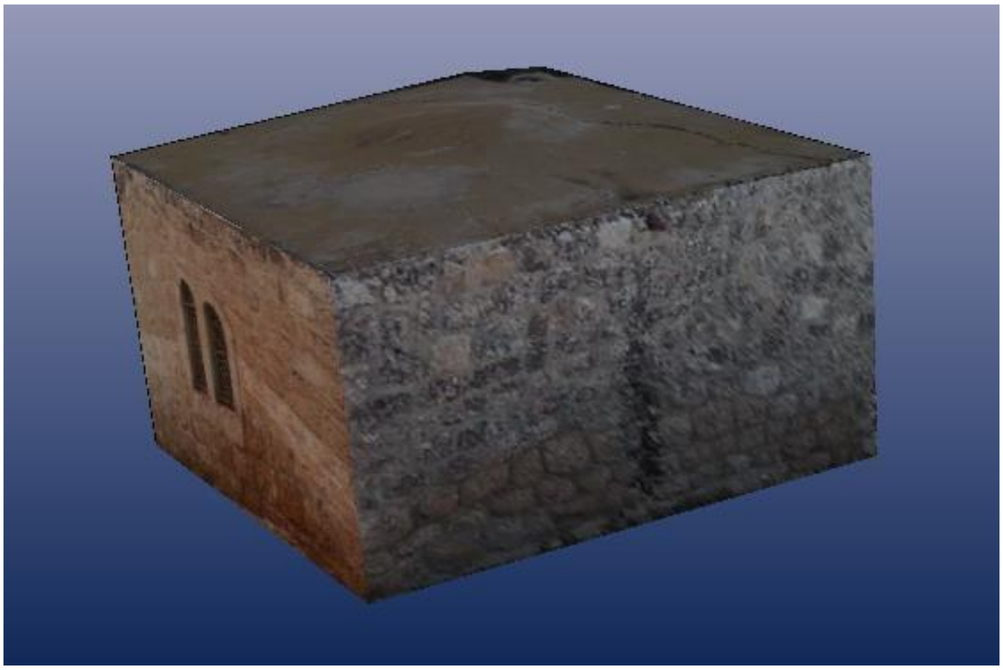
Min= 0.000 m
Max= 0.040 m
Mean For Differences = 0.0175m
Standard deviation Measured Distance= 0.0479m
Standard deviation $=\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$ =0.0479m

5.4.3 Model #3

This model is 3D house from Beat Awa-Dora see figure (5.6), formed from the floor, it's approximate area is 30 m^2, the photos taken from a variable distance by using Samsung Galaxy S3 camera. It's done by Photomodeler software.

Figure(5.6) photo for the house that would be built 3D model to it

The 3D model, see figure (5.7), done by a variable distance from the object by Photomodeler software and the result in the table(5.4):



Figure(5.7) 3D model of the house by a variable distance from the house by Photomodeler software.

Table (5.4) Model #3by Samsung Galaxy S3 results

Measured Distance (m)	Real Distance (m)	Differences (m)
5.340	5.340	0.000
5.720	5.720	0.000
5.300	5.340	0.040

Min= 0.000 m
Max= 0.040 m
Mean For Differences = 0.0133 m
Standard deviation Measured Distance= 0.0231m
Standard deviation =$\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$= 0.0231m

5.4.5 Model #4

This model is 3D house from Bet Awa-Dora see figure (5.8) , formed from the floor, it's approximate area is 57 m^2, the photos taken from a variable distance by using Samsung Galaxy S3 camera. It's done by Photomodeler software.

Figurer(5.8)photo for the old house that would be built 3D model to it

The 3D model, see figure (5.9), done by a variable distance from the object by Photomodeler software and the result in the table(5.5):

Figure(5.9) 3D model of the house by a variable distance from the house by Photomodeler software.

Table (5.5) Model #4 by Samsung Galaxy S3 results

Measured Distance (m)	Real Distance (m)	Differences (m)
8.220	8.220	0.000
7.400	7.450	-0.050
7.450	7.450	0.000
8.100	8.220	-0.120

Min= 0.000 m
Max= 0.120 m
Mean For Differences = 0.0425m
Standard deviation Measured Distance= 0.1134m
Standard deviation = $\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$ = 0.1134m

5.4.6 Model #5

This model is 3D house from Al Dahriah ,see figure (5.10), formed from the floor, it's approximate area is 55 m^2, the photos taken from a variable distance by using Samsung Galaxy Grand camera. It's done by Agisoft photo scan professional.

Figurer(5.10)photo for the old house that would be built 3D model to it

The 3D model, see figure (5.11), done by a variable distance from the object by Agisoft photo scan professional software and the result in the table(5.6)

Figure(5.11) 3D model of the house by a variable distance from the house
by Agisoft photo scan professional .

Table (5.6) Model #5 by Samsung Galaxy Grand results

Measured Distance (m)	Real Distance (m)	Differences (m)
5.900	5.900	0.000
11.800	11.800	0.000
3.300	3.310	0.010

Min= 0.000 m
Max= 0.010 m
Mean For Differences = 0.0033m
Standard deviation Measured Distance= 0.0057m
Standard deviation = $\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$= 0.0057m

5.4.6 Model #6

This model is 3D house from Dora see figure (5.12) , formed from the floor, it's approximate area is 196 m^2, the photos taken from a variable distance by using Sony XperiaZ2camera. It's done by Memento Autodesk.

Figurer(5.12)photo for the house that would be built 3D model to it

The 3D model, see figure (5.13), done by a variable distance from the object by Memento Autodesk software and the result in the table(5.7)

Figure(5.13) 3D model of the house by a variable distance from the house by Memento Autodesk software.

Table (5.7) Model #6 by Infinix results

Measured Distance (m)	Real Distance (m)	Differences (m)
9.330	9.330	0.000
4.060	4.060	0.000
4.550	4.550	0.000
9.330	9.330	0.000

Min= 0.000 m
Max= 0.000 m
Mean For Differences = 0.000 m
Standard deviation Measured Distance= 0.000 m
Standard deviation = $\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$= 0.000 m

5.4.7 Model #7

This model is 3D house from Dora see figure (5.14), formed from the floor, it's approximate area is 50 m^2, the photos taken from a variable distance by using Infinix camera. It's done by Memento Autodesk.

Figurer(5.14)photo for the house that would be built 3D model to it

The 3D model,see figure (5.15), done by a variable distance from the object by Memento Autodesk software and the result in the table(5.8):

Figure(5.15) 3D model of the house by a variable distance from the house by Memento Autodesk software.

Table (5.8) Model #7 by Infinix results

Measured Distance (m)	Real Distance (m)	Differences (m)
5.770	5.770	0.000
5.410	5.410	0.000
5.560	5.560	0.000
4.440	4.440	0.000

Min= 0.000 m
Max= 0.000 m
Mean For Differences = 0.000 m
Standard deviation Measured Distance= 0.000 m
Standard deviation = $\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$ = 0.000 m

5.4.9 Model #8

This model is 3D motor room from Palestine Polytechnic University – Hebron see figure (5.16) , formed from the floor, it's approximate area is 16 m^2, the photos taken from a variable distance by using Infinix camera. It's done by Memento Autodesk software.

Figurer(5.16)photo Motor room that would be built 3D model to it

The 3D model, see figure (5.17), done by a variable distance from the object by Memento Autodesk software and the result in the table(5.9):

Figure(5.17) 3D model of motor room by a variable distance from the object by Memento Autodesk software.

Table (5.9) Model #8 by Infinix results

Measured Distance (m)	Real Distance (m)	Differences (m)
8.000	8.000	0.000
8.000	8.000	0.000
8.000	8.000	0.000
8.000	8.000	0.000

Min= 0.000 m
Max= 0.000 m
Mean For Differences = 0.000 m
Standard deviation Measured Distance= 0.000 m
Standard deviation = $\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$= 0.000 m

5.4.9 Model #9

This is a 3D model for main front of a College of Engineering and Technology Building in Palestine Polytechnic University – Hebron see figure (5.18), the photos taken from a variable distance by using Infinix camera. It's done by Memento Autodesk software.

Figurer(5.18)photo for the front that would be built 3D model to it

The 3D model, see figure (5.19), done by a variable distance from the object by Memento Autodesk software and the result in the table(5.10):

Figure(5.19) 3D model of the front by a variable distance from the object by Memento Autodesk software.

Table (5.10) Model #9 by Infinix results

Measured Distance (m)	Real Distance (m)	Differences (m)
26.870	26.870	0.000

Min= 0.000 m
Max= 0.000 m
Mean For Differences = 0.000 m
Standard deviation Measured Distance= 0.000 m
Standard deviation = $\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$ = 0.000 m

5.4.11 Model #10

This model is 3D Peugeot car see figure (5.20), the photos taken from a variable distance by using Infinix camera. It's done by Memento Autodesk software.

(a) (b)

Figurer(5.20)photo for the Peugeot car that would be built 3D model to it

The 3D model, see figure (5.21), done by a variable distance from the object by object by Memento Autodesk and the result in the table(5.11):

(c) (d)

Figure(5.21) 3D model of the Peugeot car by a variable distance from the object by Memento Autodesk software.

Table (5.11) Model #10 by Infinix results

Measured Distance (m)	Real Distance (m)	Differences (m)
2.740	2.740	0.000

Min= 0.000 m
Max= 0.000 m
Mean For Differences = 0.000 m
Standard deviation Measured Distance= 0.000 m
Standard deviation = $\sqrt{\frac{\Sigma(x-mean)^2}{n-1}}$ = 0.000 m

5.4.12 Model #11

This model is 3D old house from Halhul see figure (5.22) , formed from the floor, it's approximate area is 32 m^2, the photos taken from a variable distance by using Infinix camera. It's done by Memento Autodesk software.

Figurer(5.22)photo for the old house that would be built 3D model to it

The 3D model, see figure (5.23), done by a variable distance from the object by Memento Autodesk and the result in the table(5.11):

Figure(5.23) 3D model of the old house by a variable distance from the object by Memento Autodesk software

Table (5.12) Model #11 by Infinix results

Measured Distance (m)	Real Distance (m)	Differences (m)
7.120	7.120	0.000
7.470	7.470	0.000
7.580	7.580	0.000

Min= 0.000 m
Max= 0.000 m
Mean For Differences = 0.000m
Standard deviation Measured Distance= 0.000m
Standard deviation = $\sqrt{\frac{\Sigma\,(\mathrm{x-mean})^2}{\mathrm{n-1}}}$ = 0.000m

CHAPTER SEX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

6.2 Recommendations

6.1 Conclusions

With the revolution of digital technology, digital cameras are nowadays being used as a new communication tool. The digital technology supplied us with the new digital camera, embedded in mobile phones. Four mobile phones digital cameras were used to find out if they could be used satisfactorily in close range photogrammetric measurements.

The results obtained from the cameras of the mobile phones were taken from vary distances measured using steel tape and then determined the standard deviation of each model to Identify the high accurate mobile phone .

The mobile phone camera has been used and the obtained accuracy is discussed and presented. Based on the experimental results, the following conclusions can be drawn:

- The mobile phone camera is efficient and has proved to be fast and useful;
- The accuracy of mobile phone camera in digital close range photogrammetry can be given good results in comparison with high resolution camera.
- The obtained accuracy improved rapidly with increasing the number of photos that be used to build 3D model and reduce the distortion in that model .
- Many of Programs used to build 3D model Where every program has special characteristics , the memento Autodesk program has high accuracy than the other ones where the error was zero, the highest error were be in PhotoModeler and it was be 11cm .
- Many of mobiles phone used to take photos in order to build 3D model Where every mobile phone has special characteristics , the Samsung Galaxy mobile phone and it's kinds has high accuracy than the other ones.

The following Obstruction have been faced :

- The existence of a group of buildings stuck together, which was a problem in taking photos of a fixed distance of some models.
- the IPhone mobile phone has been problem in PhotoModeler program where the residual error was very high.

6.2 Recommendations

After the completion of our project, the following points are recommended:

- Examination of more different mobile phones and professional/non-professional cameras.
- Examination of the effects and limitations of different object-camera distances.
- Examination different object sizes.
- Examination the use of close range photogrammetry by mobile phones and professional/non-professional cameras on the representation of topography.

Table (6.1) results comparison

The Model number	The Model	The program that used	The Standard deviation (m)
1 first part	3D house from Al Hila_Yatta	Photomodeler software	0.0138
1 second part	3D house from Al Hila_Yatta	Photomodeler software	0.0158
2	3D house from al Salam Street-Hebron	Photomodeler software	0.0479
3	3D house from Beat Awa-Dora	Photomodeler software	0.023
4	3D house from Bet Awa-Dora	Photomodeler software	0.1134
5	3D house from Al Dahriah	Agisoft photo scan professional	0.0057
6	3D house from Dora	Memento Autodesk	0.000
7	3D house from Dora	Memento Autodesk	0.000
8	3D motor room from Palestine Polytechnic University – Hebron	Memento Autodesk	0.000
9	3D model for main front of a College of Engineering and Technology Building in Palestine Polytechnic University – Hebron	Memento Autodesk	0.000
10	is 3D Peugeot car see	Memento Autodesk	0.000
11	3D old house from Halhul	Memento Autodesk	0.000

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