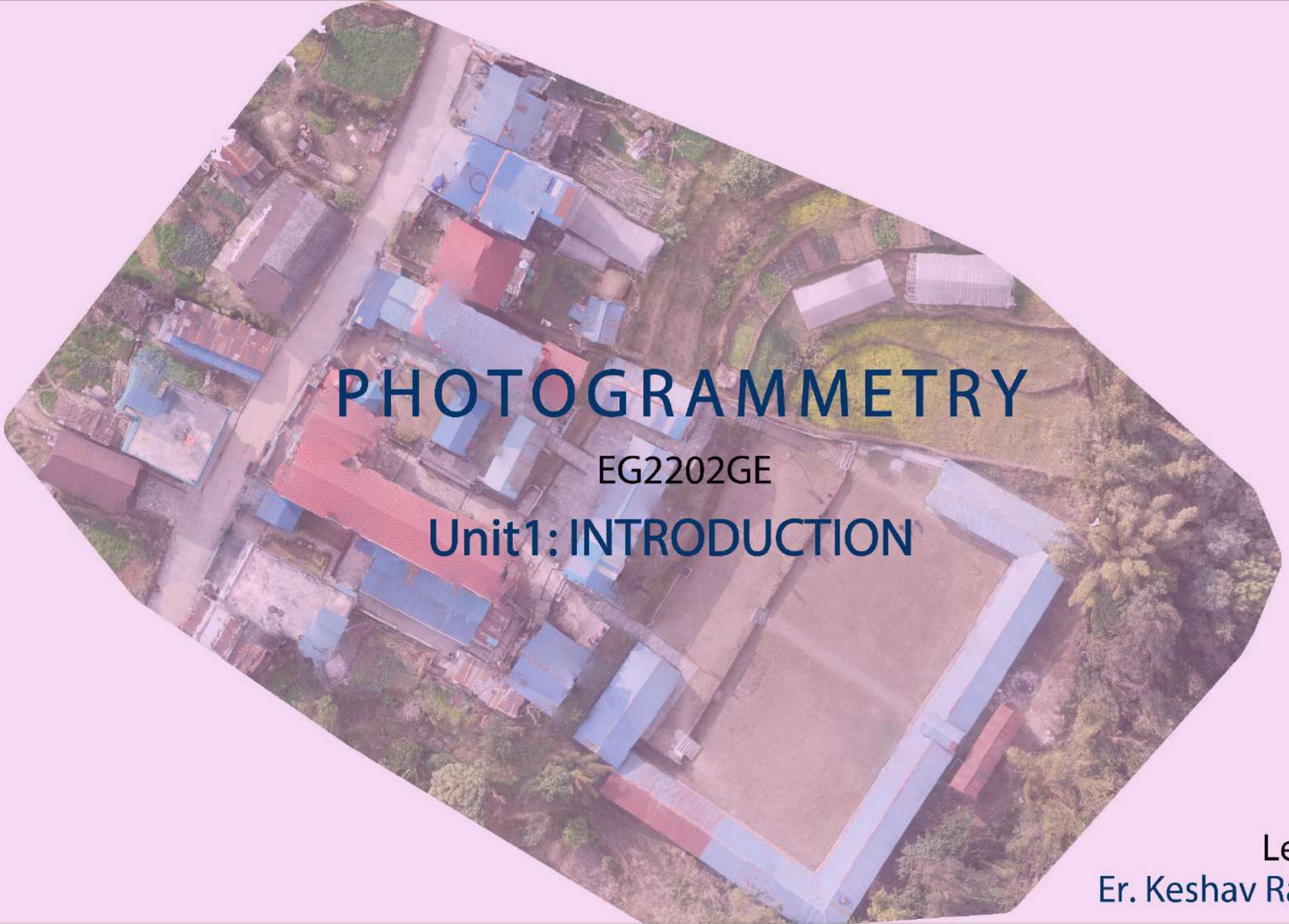

PHOTOGRAMMETRY

EG2202GE

Unit1: INTRODUCTION

Lecture by
Er. Keshav Raj Bhusal

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Definition of Photogrammetry

What is Photogrammetry?

- Photogrammetry: photo(picture) + grammetry(measurement). It is simply the science of measurement from photographs.
- ASPR definition: “Art, science and technology of obtaining reliable information about the physical objects and environment through the process of recording , measuring; and interpreting photographic images and patterns of recorded radiant electromagnetic energy”.
- The most important feature of photogrammetry is the fact the objects are measured/interpreted without actually being touched.
- Photogrammetry is a technique that allows for the reconstruction of 3D models by analyzing photographs taken from different angles.

Classification

Types of Photogrammetry

❖ In General (according to ASPR)

1. Metric Photogrammetry (Semantic)

- It deals with obtaining measurements from photographs from which ground positions, elevations, distances, area and volumes can be computed.
- The most common applications of metric photogrammetry are the preparation of planimetric and topographic maps from photographs.

2. Non-metric Photogrammetry (Interpretative)

- It deals with evaluation of existing features in a qualitative manner such as vegetation cover, water pollution, soil erosion, geological formation, crop identification, military intelligence, etc.
- Information is usually obtained by interpreting the recorded data.
- Key semantic elements include size, shape, tone, texture, pattern, site/location, shadows, stereoscopic appearance, association, etc.

Classification

Types of Photogrammetry

❖ Based on platform

1. Aerial Photogrammetry (Semantic)

- Platform is in air.
- Series of photographs of terrain at an angle are captured in sequence using camera.
- Examples of such photogrammetric platforms are: Airplane, Unmanned platform

like kite, birds, ballon, UAV etc.

- The advantage of aerial photogrammetry is data collection of inaccessible/difficult environments and fast data collection speed.
- It’s application includes topographic mapping, urban planning, heritage documentation, forestry, agriculture etc.

Classification

Types of Photogrammetry

❖ Based on platform

2. Terrestrial Photogrammetry

- Platform is usually earth based and is mounted on a tripod.
- Examples of such photogrammetric platforms are: Handheld camera, camera mounted on tripods etc.
- Terrestrial photogrammetry dealing with object distance less than 300 m is also termed close-range photogrammetry.
- It's application include accident investigation, archaeology for documentation of ancient buildings, medical science for measuring sizes and shapes of body parts, recording tumor growth etc.

History and Development of Photogrammmetry

1. Invention of photography by Niepce and Daguerre in 1839.

First photograph taken

Source: http://www.close-range.com/docs/History_of_Photogrammetry--Dermanis.pdf

2. In 1849, French military topographer Aime Laussedat('Father of Photogrammetry') used terrestrial photographs for topographic map compilation for the first time.

3. In 1855, Nadar (Gaspard Felix Tournachon) used a balloon at 80- meters to obtain the first aerial photograph. Later he also took photographs from balloons for military interpretation purposes in the battle of Solferino in 1859.

Nadar capturing photographs from ballon

Source: http://www.close-range.com/docs/History_of_Photogrammetry--Dermanis.pdf

4. In 1858, the German architect A. Meydenbauer introduced measurements on photos for the documentation of public buildings.

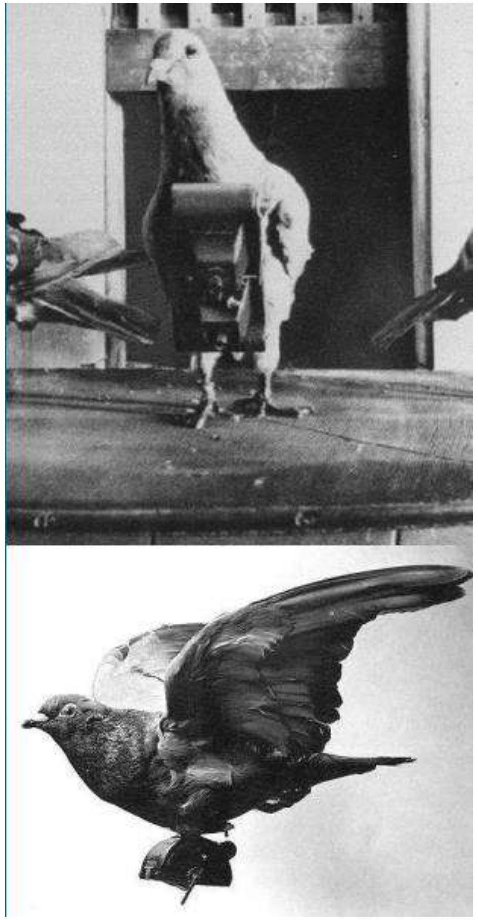
History and Development of Photogrammmetry

5. The English meteorologist E. D. Archibald was among the first to take successful photographs from kites in 1882. In France M. Arthur Batut took an aerial photographs using a kite, over Labruguiere, France, in May 1888.

Source: http://www.close-range.com/docs/History_of_Photogrammetry--Dermanis.pdf

6. Stereo measurement principle developed around 1900.

7. In 1903, Julius Neubranner, photography enthusiast, designed and patented a breast-mounted aerial camera for carrier pigeons.

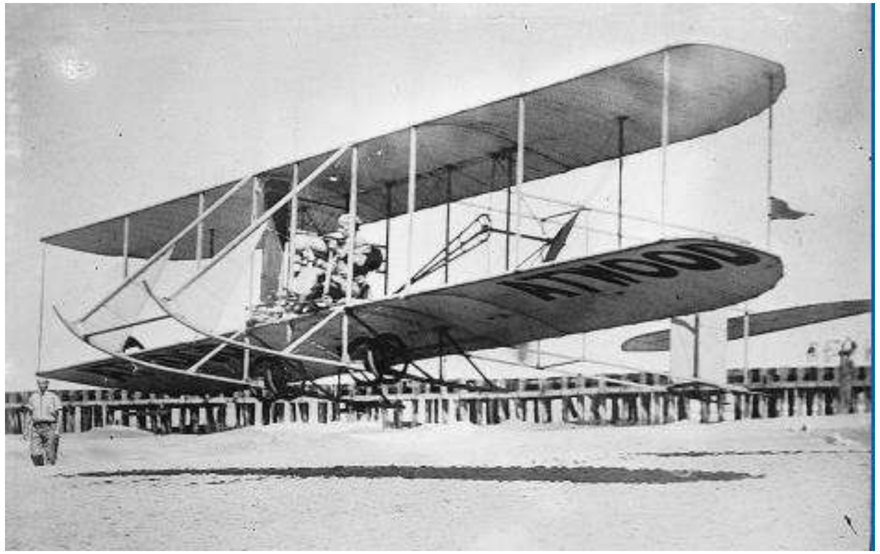


Source: http://www.close-range.com/docs/History_of_Photogrammetry--Dermanis.pdf

History and Development of Photogrammmetry

8. In 1903: Wright brothers invented Airplane; In 1909: the Wright brothers took the first photograph from a plane over Centocelli, Italy.

- More general use of photogrammetry was introduced after the availability of controllable aerial platforms and the motorized airplane of the Wright brothers (from 1903) soon became an accepted photogrammetric platform, which was used extensively for interpretive purposes during World War.



Source: http://www.close-range.com/docs/History_of_Photogrammetry--Dermanis.pdf

9. Oskar Messter in 1915 developed the aerial survey camera, which permitted a systematic survey of the terrain by near vertical aerial photographs.

History and Development of Photogrammmetry

10. After the end of World War I, the optical industry in Europe began to construct optical and mechanical devices for the stereo reconstruction of overlapping images.

11. In the period between World War I and World War II, aerial photogrammetry for topographic mapping progressed to the point of mass production of maps.

12. In the 1950s, computer systems became available for analytical solution that permitted a rigorous photogrammetric treatment, the first of which is point measurement in images or stereo model by a human operator.

- Not only automated many steps of the photogrammetric process but also made photogrammetry more accurate and more reliable by use of least square adjustment and statistical testing included in the computer solutions.

Development cycles(Phases of Photogrammetry)

Development cycles

1. Plane table photogrammetry (about 1850 to 1900)
2. Analog photogrammetry (about 1900 to 1960)
3. Analytical photogrammetry (1960 to present)
4. Digital photogrammetry (just beginning)

Development cycles(Phases of Photogrammetry)

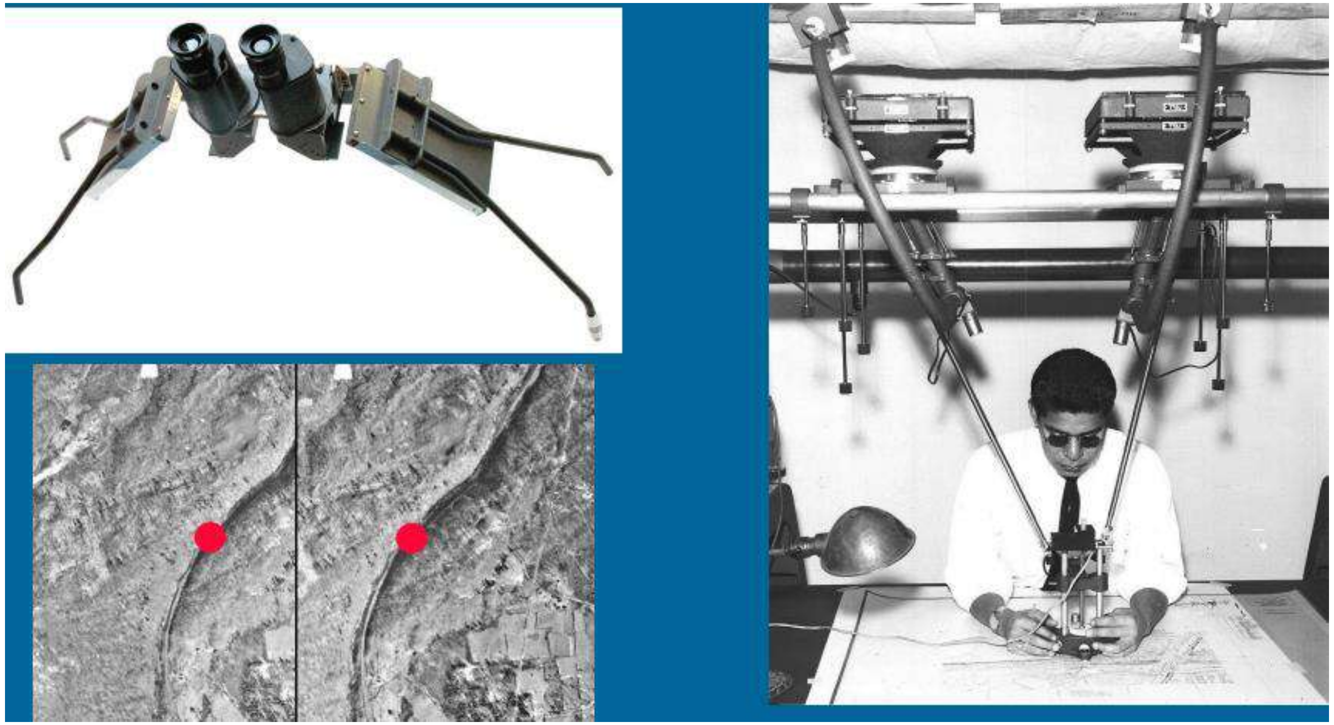
Plane table photogrammetry

- Plane table photogrammetry is an extension of the conventional plane table surveying.
- Measurement and drafting were done manually.
- Each exposure station was determined by resection and plotted on the plane table. The exposed photos were oriented on the plane table and the directions to the different objects were transferred onto the map sheets.

Development cycles(Phases of Photogrammetry)

Analog photogrammetry

- Instruments used are based on the concept of stereometric vision.
- Optical, mechanical and electronical components were used on harcopy images to reconstruct a 3D model for measurements in 3D space.
- The main product during this phase was topographic maps.



Source: http://www.close-range.com/docs/History_of_Photogrammetry--Dermanis.pdf

Development cycles(Phases of Photogrammetry)

Analytical photogrammetry

- In analytical photogrammetry, the computer replaced some expensive optical and mechanical components. The resulting devices were analog/digital hybrids.
- Analytical aerotriangulation, analytical plotters, and orthophoto projectors were the main developments during this phase.
- Outputs of analytical photogrammetry can be topographic maps but also can be digital products such as digital maps and DEMs.

Source: http://www.close-range.com/docs/History_of_Photogrammetry--Dermanis.pdf

Development cycles(Phases of Photogrammetry)

Digital photogrammetry

- It is a 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.
- Digital photogrammetry is sometimes called softcopy photogrammetry.
- Softwares are used for photogrammetric tasks and is highly automated e.g automatic DEM extraction, digital orthophoto generation etc.
- The output products are in digital form, such as digital maps, DEMs, and digital orthoimages saved on computer storage media.

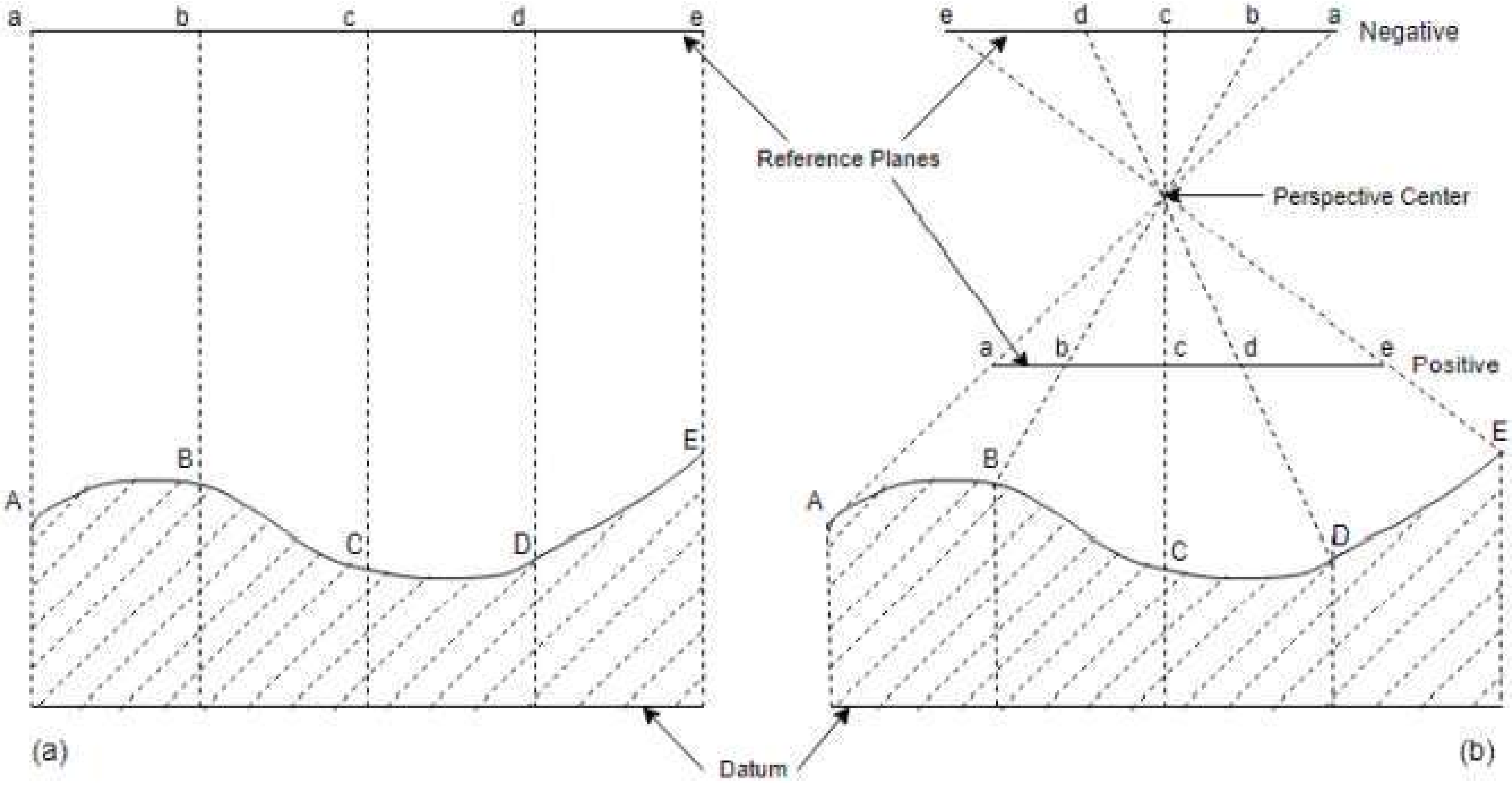
Projection and the properties of Orthogonal and Perspective Projections

Projection

- It is the transformation of higher dimensional space (usually 3d in object) into a lower dimensional space (2D in photographs).
- There are mainly two types of projection. They are:

1) Orthogonal Projection

2) Perspective Projection



Projection of Terrain Points in Orthographic vs Perspective Projection

Projection and the properties of Orthogonal and Perspective Projections

Orthogonal Projection

- Points are projected onto a plane in a certain uniform scale by rays perpendicular to that plane. The plane is usually parallel to a predetermined reference or datum plane.
- Points are projected in their planimetrically correct position.
- In this projection there is no displacement.
- Reference datum in orthographic projection are usually horizontal.

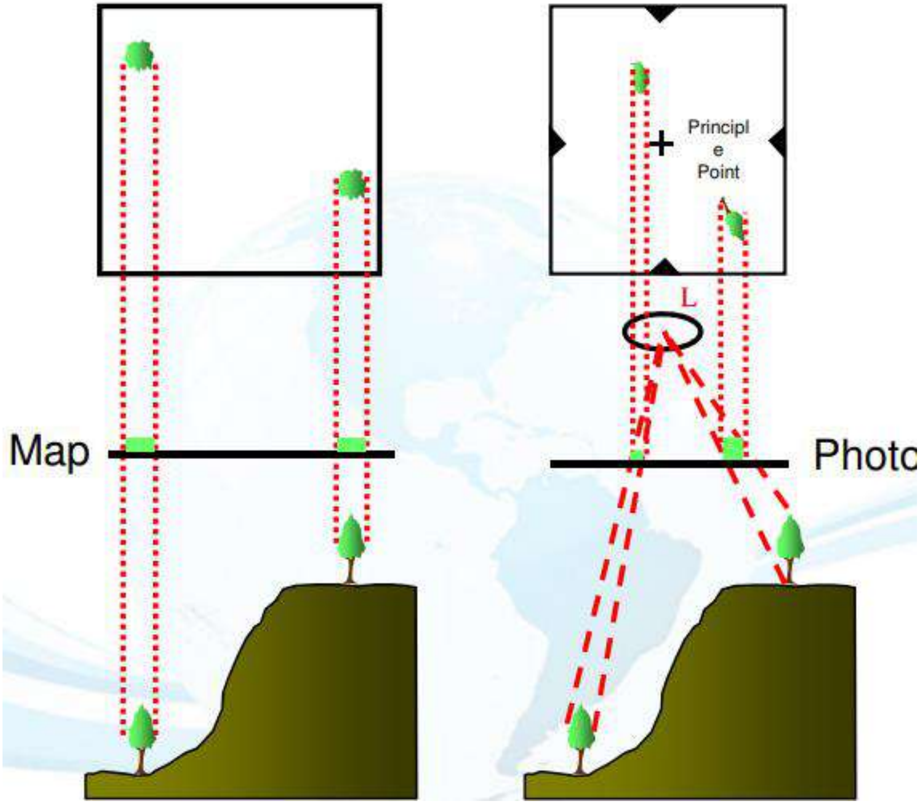
E.g Map

Projection and the properties of Orthogonal and Perspective Projections

Perspective Projection (Central Perspective Projection)

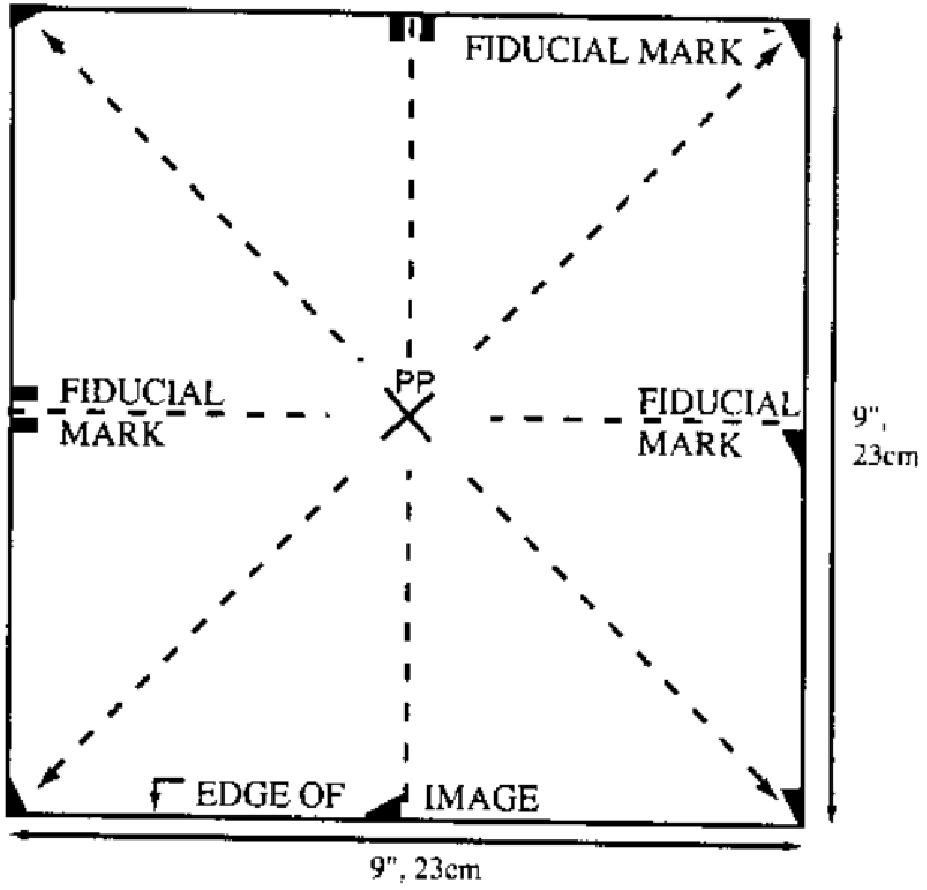
- It is also called central projection in which all rays pass through a common point called the projection center or perspective center.
- Image points displaced from their planimetrically correct positions either due to terrain relief (elevation) or due to tilt (object plane and image plane not in parallel).
- Varying scale.
- Reference datum may be horizontal, vertical or tilted.

E.g Phtotgraph



1. Fiducial Marks

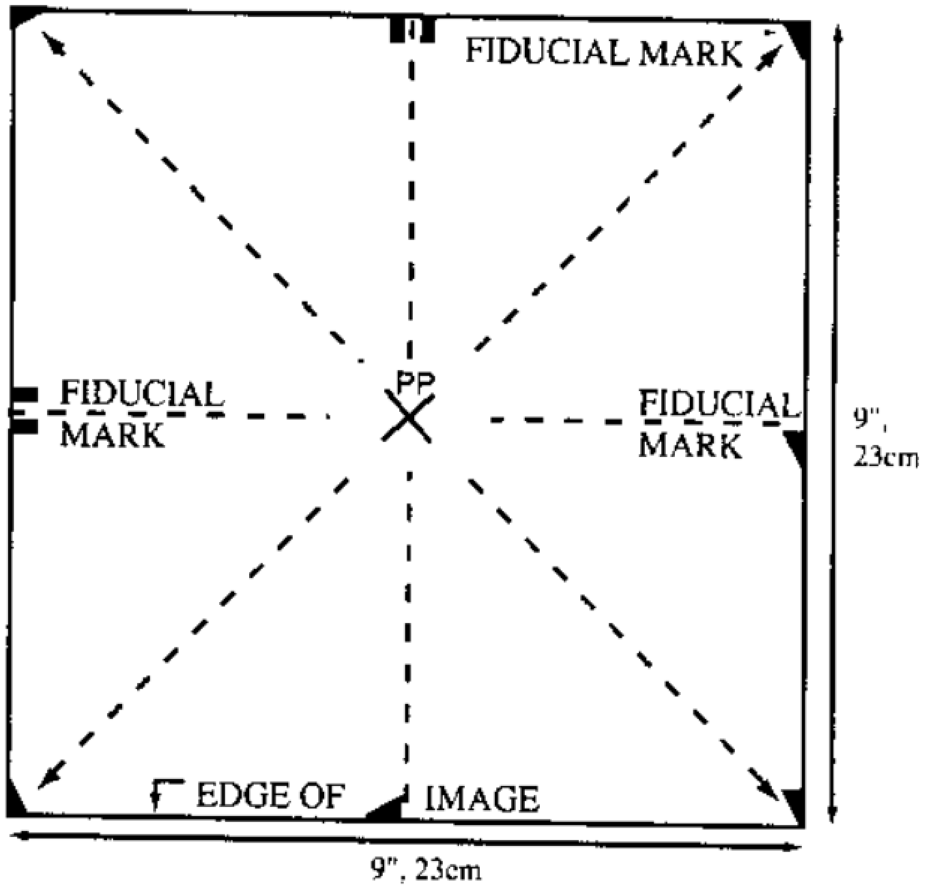
- Fiducial marks are small crosses or small V-shaped indents located precisely on each of the four corners or exactly midway along the four sides of a scanned-film photograph.



Fiducial marks and fiducial axis

2. Fiducial Axis

- The line joining opposite fiducial marks on a photograph.



Fiducial marks and fiducial axis

Definition of related Terminologies

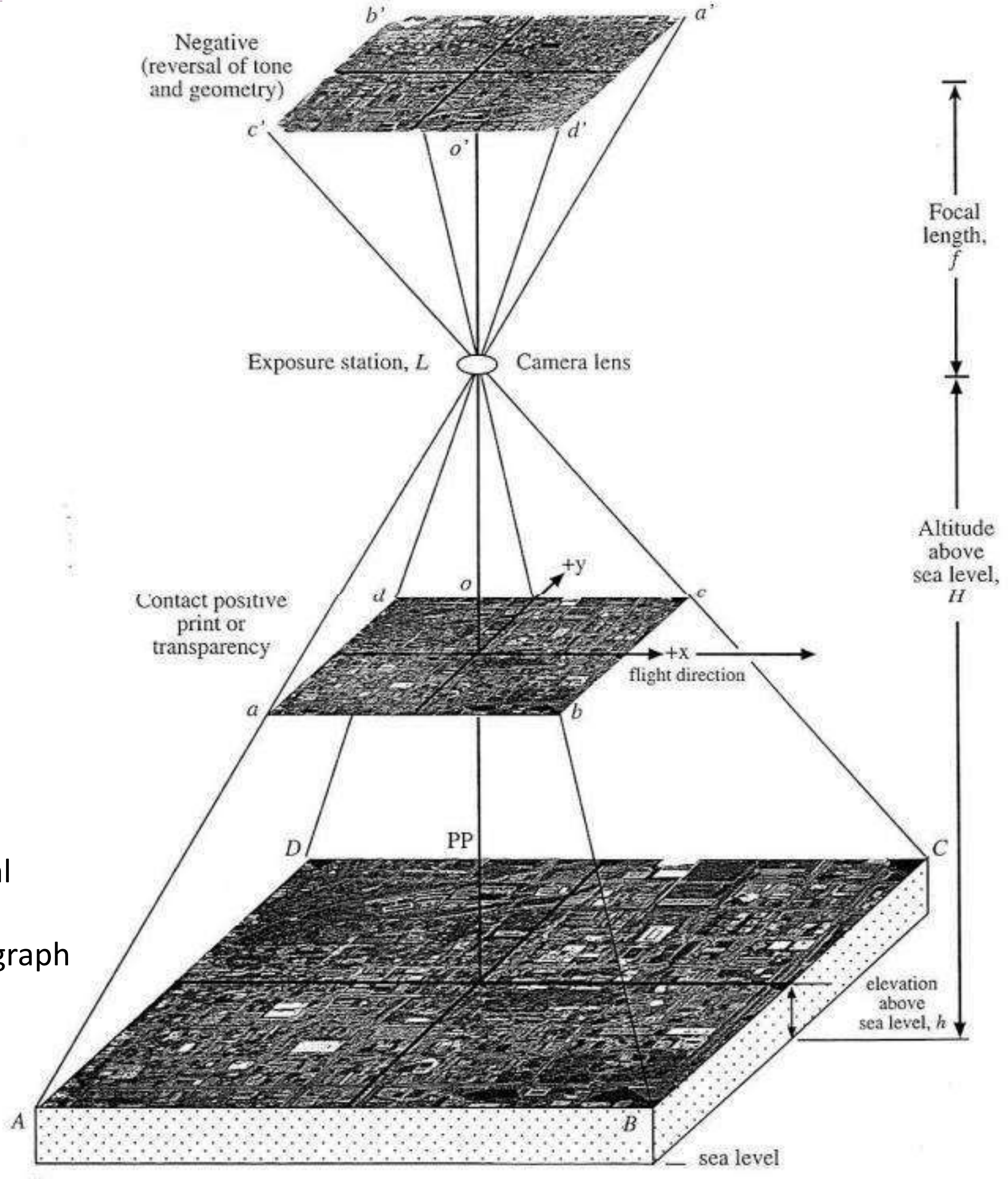


Figure 6-6 The geometry of a vertical aerial photograph obtained over flat terrain (Columbia, SC).

Fig2: Vertical aerial Photograph

Source: https://gisresources.com/important-terminologies-of-photogrammetry/

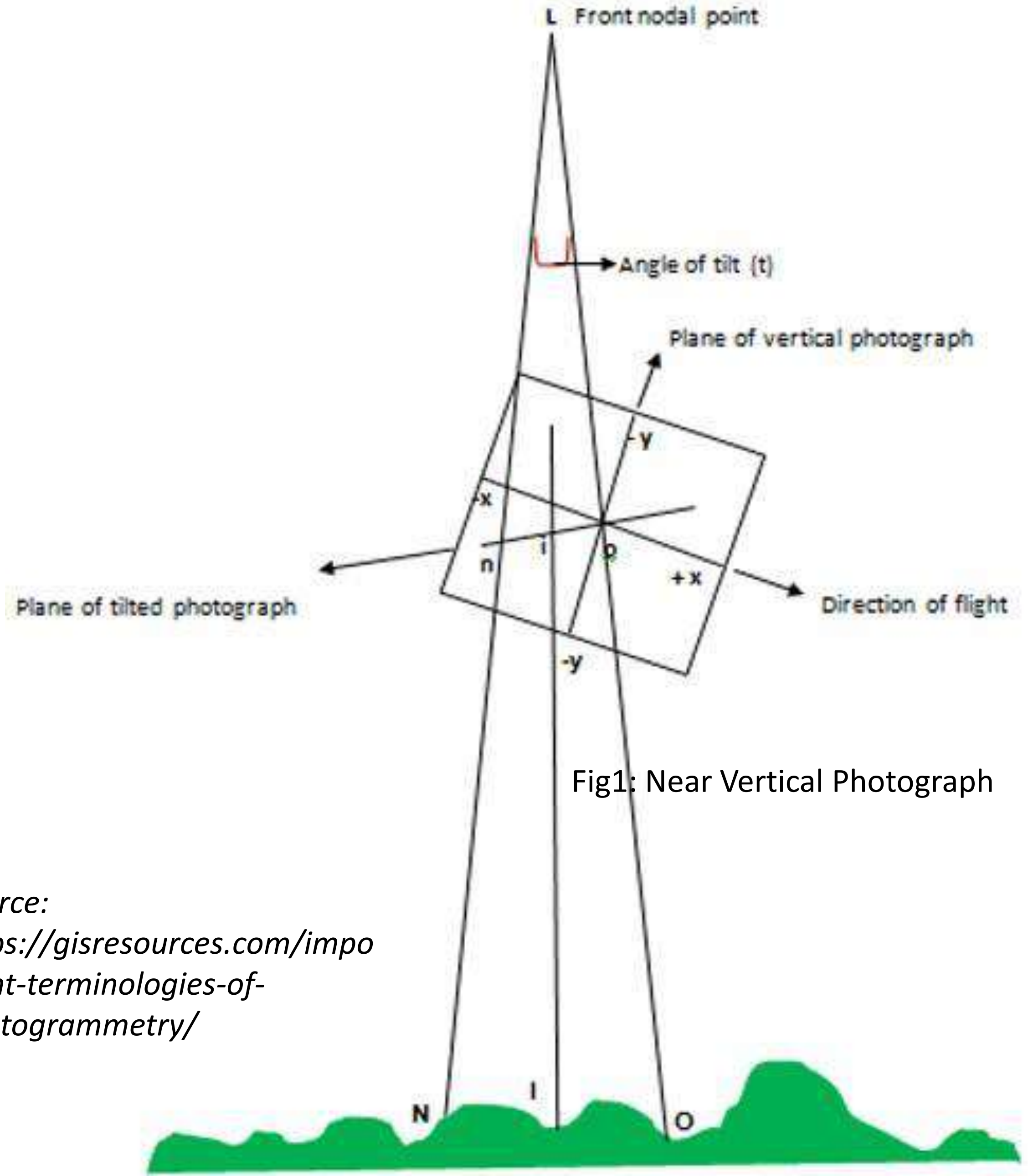


Fig1: Near Vertical Photograph

Definition of related Terminologies

3. Focal Length

- The distance from the front nodal point of the lens to the plane of photograph, as the distance Lo in the Figure 1. OR (The distance from the focal point to the center of a lens is f, the focal length of the lens).

4. Nadir Point

- The point, where the plumb line dropped from the front nodal point meets the plane of photograph, as the point n, in the Figure 1.
- It is the point on the photograph vertically beneath the exposure station.

Definition of related Terminologies

5. Tilt

- The angle formed between the optical axis of the camera and the plumb line, as the angle oLn in the Figure 1. It is also the angle which the plane of tilted photograph makes with the plane of vertical photograph.

6. Isocentre

- The point where the bisector of angle of tilt meets the plane of photograph, as the point i in the Figure 1.

7. Principal Plane

- The vertical plane containing the optical axis, as the plane Lno in the Figure 1.

Definition of related Terminologies

8. Principal Point

- It is a point where a perpendicular drop from the front nodal point of the camera lens strikes the photograph it is also known as photo principal point.(see fig2 being represented as PP)

OR It is the point of intersection of the optical axis of the aerial camera with the plane of the photograph see fig2 being represented as PP)

9. Principle Distance

- The perpendicular distance from the perspective centre to the plane of the photograph.

10. Perspective Center

- A point through which all light rays pass in a camera/lens system.

11. Principle axis

- The line joining the principal point of the photograph and the point through which all rays of light are assumed to pass.

Definition of related Terminologies

12. Homologous Points

- The pairs representing ground points and their photo points, are called homologous points.

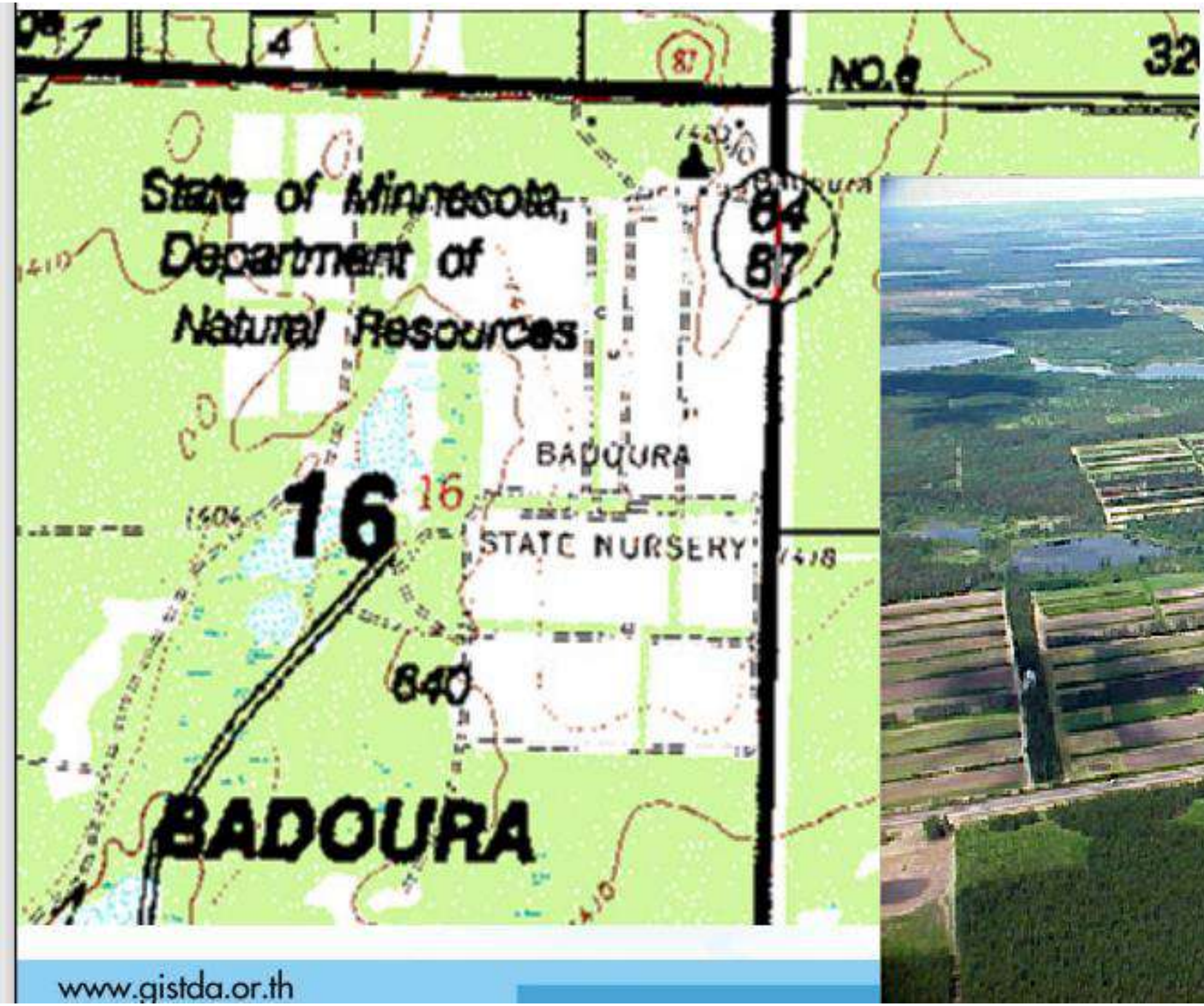
13. Camera axis

- It is the line passing through the centre of camera lens perpendicular to the both camera plate and the picture plane.

14. Photo Plane

15. Format of Photograph

Comparison of Aerial Photograph and Map



Comparison of Aerial Photograph and Map

Map

1. It has orthogonal projection.
2. Map has a uniform scale.
3. Terrain relief without distortion (contour lines).
4. Non visible object like district, ward boundary etc. are also represented along with visible objects.
5. It is an abstract representation of the earth surface.
6. Representation geometrically correct.

Comparison of Aerial Photograph and Map

Photograph

1. It has central perspective projection.
2. Photograph has variable scale.
3. Relief displacement in the image.
4. Only visible objects are represented.
5. It is a real representation of the earth surface, no legend needed.
6. Representation geometrically not correct.

Components of Photogrammetry

There are mainly three components of photogrammetry. They are:

1. Image Acquisition
2. Image Control
3. Product Compilation

Image Acquisition

a. Flight Planning
b. Selecting an appropriate camera system
c. Aerial Films
d. Image scanning
e. Digital Cameras

Components of Photogrammetry

Image Control

- It is the control that is used to establish the position and orientation of the camera at the moment of exposure.
- It involves the process of selecting areas for ground control and targeting, area surveying control details, and aerial triangulation.
- This component can get eliminate if advanced GPS methodology can solve the photo orientation difficulty without requiring ground control.

Photographs can be controlled using three different methods:

1. Ground control points

- Ground control points (or GCPs) are points on the ground with known coordinates.
- GCPs, are typically required as they can enhance the positioning and accuracy of the mapping outputs.

Components of Photogrammetry

Image Control

2. Bridging control through aerial triangulation:

- This is done by computing on the photographs common points that appear in three successive photographs or in two adjacent strips and computing their 3dimensional coordinate values.

3. Aerial photography control by kinematic GPS measurements:

- This will give the position and elevation of the camera without the use of ground control.

Components of Photogrammetry

Product Compilation

- The product compilation varies and is dependent on the nature of the final product.
- Each of these components requires the utilization of different equipment, different measurement techniques, and different data processing.
- The most commonly used photogrammetric instrument is the stereo plotter. Its main purpose is to reconstruct the original orientation and the geometric integrity of an image at the moment of exposure and to collect three dimensional data.

Advantage/Disadvantage of Photogrammetry

Advantage of Photogrammetry/Importance of Photogrammetry

- The major advantage of photogrammetry is the ease and speed at which the data can be collected.
- It is useful in any locations that are difficult, unsafe, or impossible to access.
- Data can be used for multiple use it offers a broad view of the mapped area by utilizing both topographic and cultural features of the land surface.
- It is cheap/cost effective for large area and in a long run.
- It is easy to re-process data for new information without the need for expensive fieldwork to re-survey the area.
- The road surveys can work without disturbing the traffic by closing lanes, or risking the field team.

Advantage/Disadvantage of Photogrammetry

Disadvantage of Photogrammetry

- The major disadvantage is that the photogrammetric survey is not possible in the absence of light.
- It is a complex system and requires highly trained human resource.
- It is weather dependent. Winds, clouds, haze etc. affect the aerial photogrammetry process and the image quality.
- It is costly at the time of installation/initiation as it needs heavy and complex equipments.
- Administrative procedure for getting fly permission is tedious/time-consuming.
- The accuracy of the measurement depends highly on the flight height.
- It cannot be used for accurate measurements when there are visibility restrictions such as trees, vegetation or any other obstacles.

Applications/Uses of Photogrammetry/Scope

1. Mapping

- The earliest applications of photogrammetry were in topographic mapping, and it is still the most common of photogrammetric activities.

2. Civil engineering

- It is used in road survey, cut-fill estimation, monitoring progress work of construction sites etc,.

Source: https://uavcoach.com/drones-in-construction/

Applications/Uses of Photogrammetry/Scope

3. Archaeology

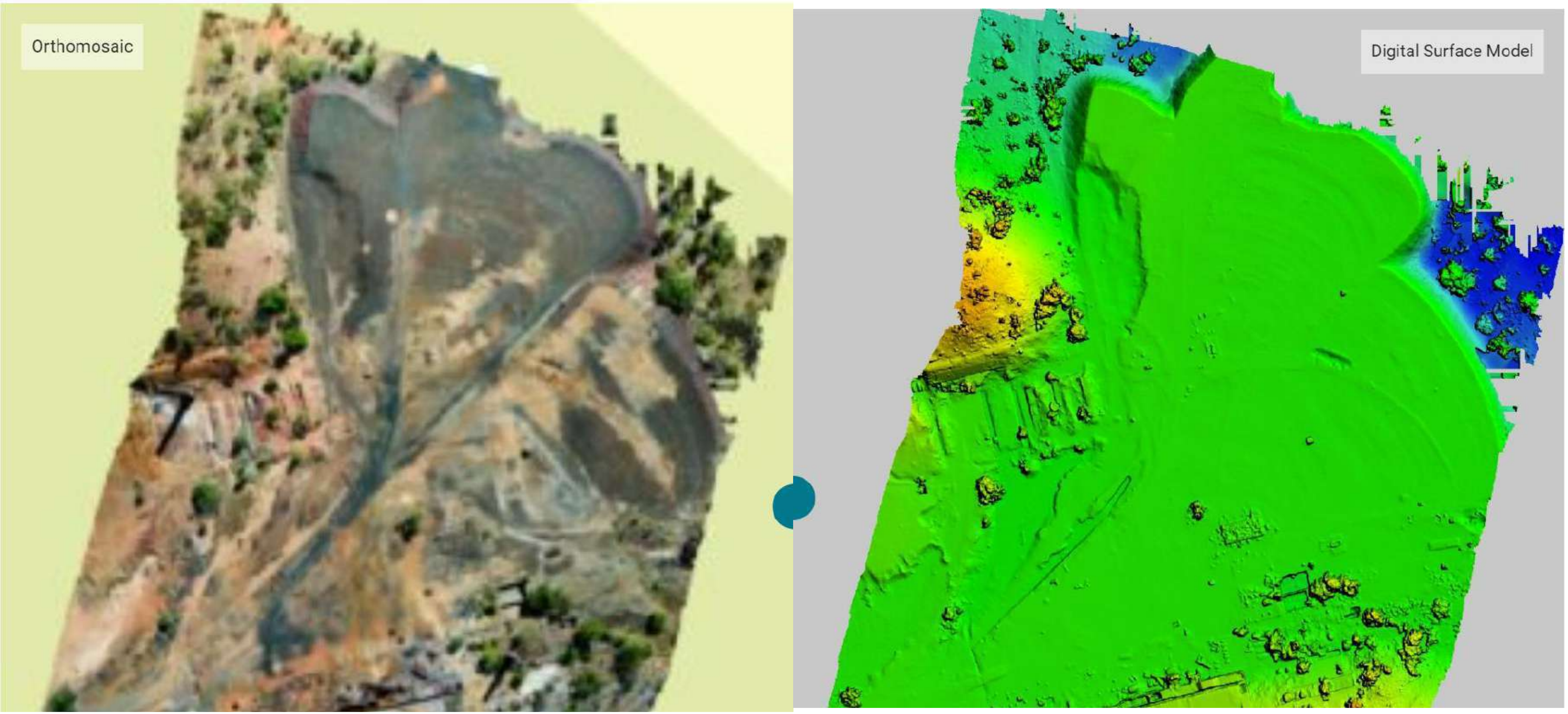
- It helps to capture the landscape and finest details of buildings, sculptures, bas-reliefs, archaeological sites and excavations
- It is used in heritage documentation of ancient buildings through 3D models/Mesh, DSM etc.

Drone used in documentation of heritage site: https://youtu.be/QztdRKS8xg0

Source: https://gistda.or.th/home.php

Applications/Uses of Photogrammetry/Scope

3. Archaeology



DSM (a photogrammetry product) giving insight about heritage site.

Source: https://geonadir.com/drone-mapping-heritage-sites/

Applications/Uses of Photogrammetry/Scope

4. Medicine

- It is also used in the fields of medicine and dentistry, measurements from X-ray and other photographs and images have been useful in diagnosis and treatment.

5. Highway planning

- Altitude photos or satellite images are used to assist in area and corridor studies and to select the best route; topographic maps are prepared for use in preliminary planning.
- DEMs are used in final design; and earthwork cross sections are taken to obtain contract quantities.

6. Real estate

- With the help of drone and photogrammetric techniques real estate agents are able to get the photographs taken from various angles with maximum accuracy within a short span of time.
- It's a cost-effective method to allow the buyer to view and decide.

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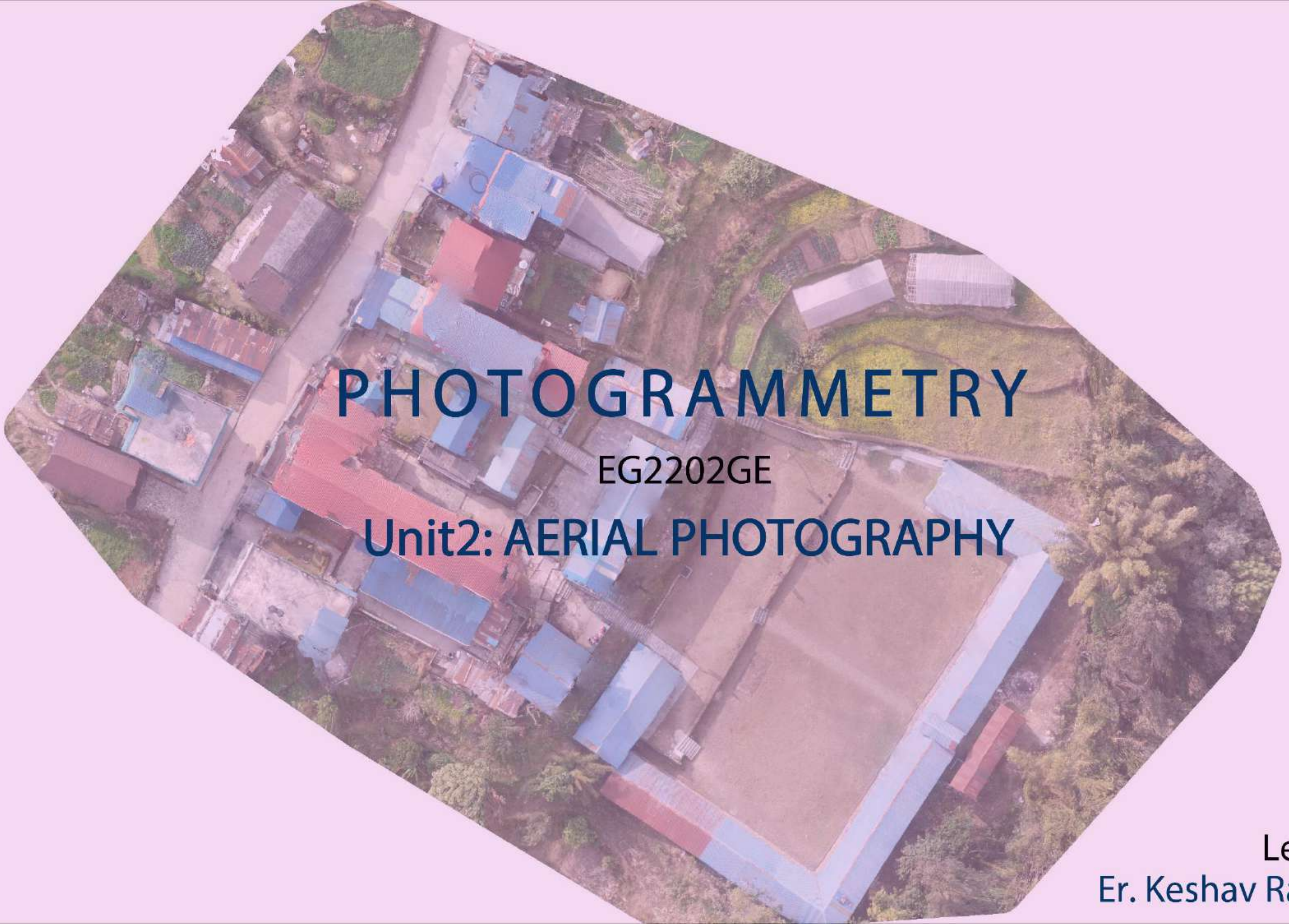

PHOTOGRAMMETRY

EG2202GE

Unit2: AERIAL PHOTOGRAPHY

Lecture by
Er. Keshav Raj Bhusal

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- Vertical
- Oblique: Low oblique and high oblique

5. Aerial Photographic process

6. Derivation of the formula for Scale of Vertical Aerial Photograph

7. Determination of Scale of a Photograph

8. Relief Displacement and Derivation of formula of relief displacement

9. Tilt Displacement

10. Related Terminology

- Overlap : Forward and Lateral
- Drift and Crab

Basic concepts and types of aerial camera

Introduction

- The most fundamental device in the field of photogrammetry is the camera(*imaging device*). It is the basic instrument which acquires images, from which photogrammetric products are produced.
- The remarkable success of photogrammetry in recent years is due in large part to the progress that has been made in developing precision cameras.
- The recent camera developments has been the perfection of lenses of extremely high resolving power and almost negligible distortion which has greatly increased the accuracy of photogrammetry.

Aerial camera

- Aerial mapping camera is the traditional imaging device used in photogrammetry.
- They are referred to as "passive sensors" because they detect and capture the natural light reflected from objects.
- It is designed for obtaining aerial photographs of the earth’s surface from an airplane or other type of aircraft.
- Aero-camera differs from ordinary camera and has specific features like fully automatic operation, shock absorbing support frame, large picture format, photographing from great distance, rapid movement and vibration during exposure etc.

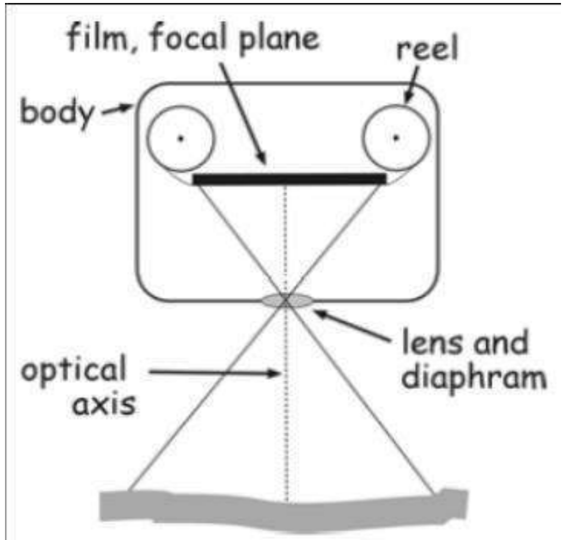

Fig: showing simple aerial camera

Source: https://www.shivajicollege.ac.in/sPanel/uploads/econtent/72c481f85b187d903efb91bbcb3402d3.pdf

Basic concepts and types of aerial camera

Types of aerial camera

1. Single lens (metric) camera
2. Multiple lenses camera
3. Panoramic camera
4. Digital camera

Types of aerial camera

On basis of lens

1. Single lens (metric) camera

- It provides the highest geometric and radiometric quality of aerial photography .
- They are exclusively used in obtaining aerial photos for remote sensing in general and photogrammetric mapping purposes in particular.

2. Multiple lenses camera

- Each of the lenses (camera) simultaneously records photographs of the same area using different film and filter combination. This creates multiple band photographs.

Types of aerial camera

On basis of lens

2. Multiple lenses camera

Fig: Multiband Aerial Photo of Multiband Aerial Photo of Waterfront Area, Cape Town Waterfront Area, Cape Town

Source: https://pdfs.semanticscholar.org/9d9a/63a99f78285d3ada4464c79d891e3e424ed7.pdf

Basic concepts and types of aerial camera

Types of aerial camera

3. Panoramic camera

- This type of camera uses a rotating lens (or prism) to produce a narrow strip of imagery perpendicular to the flight line. This allows the panoramic camera to record a much wider area of ground than either frame or strip cameras
- Panoramic cameras are most advantageous for applications requiring the resolution of small ground detail from high altitudes.

4. Digital camera

- Advantage with digital camera is that it records and store photographic images in digital form. These images can be stored directly in the camera or can be uploaded onto a computer or printer later on.

E.g camera used in drones

Essential parts of an aerial camera

There are three basic components of aerial camera. They are:

1. Magazine
2. Camera body
3. Lens cone assembly

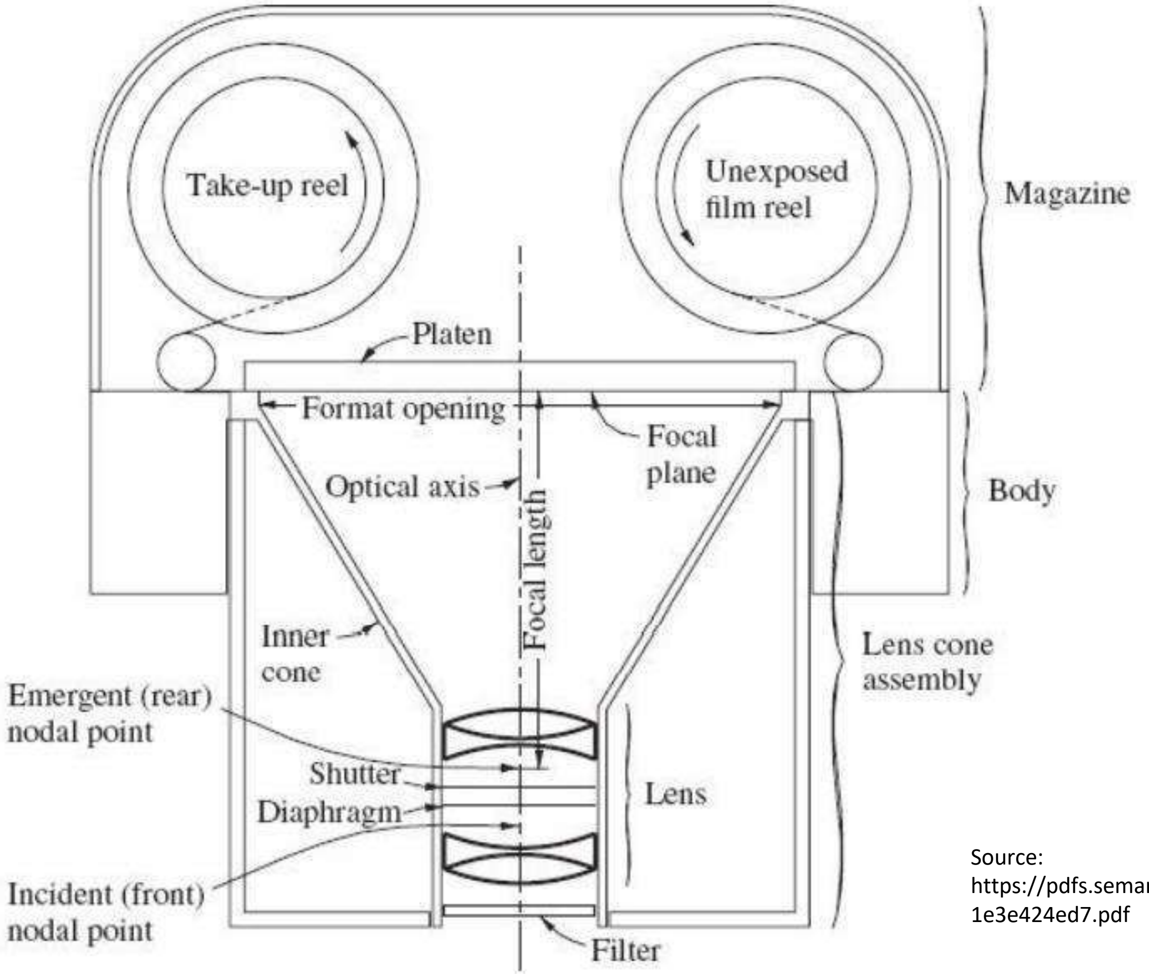

Fig: Components of Aerial camera

Source: https://pdfs.semanticscholar.org/9d9a/63a99f78285d3ada4464c79d891e3e424ed7.pdf

Essential parts of an aerial camera

Magazine consists of following parts:

i. Take-up reel
ii. Unexposed film reel
iii. Platen

Lens Cone Assembly consists of following parts:

i. Filter
ii. Lens
iii. Shutter
iv. Diaphragm

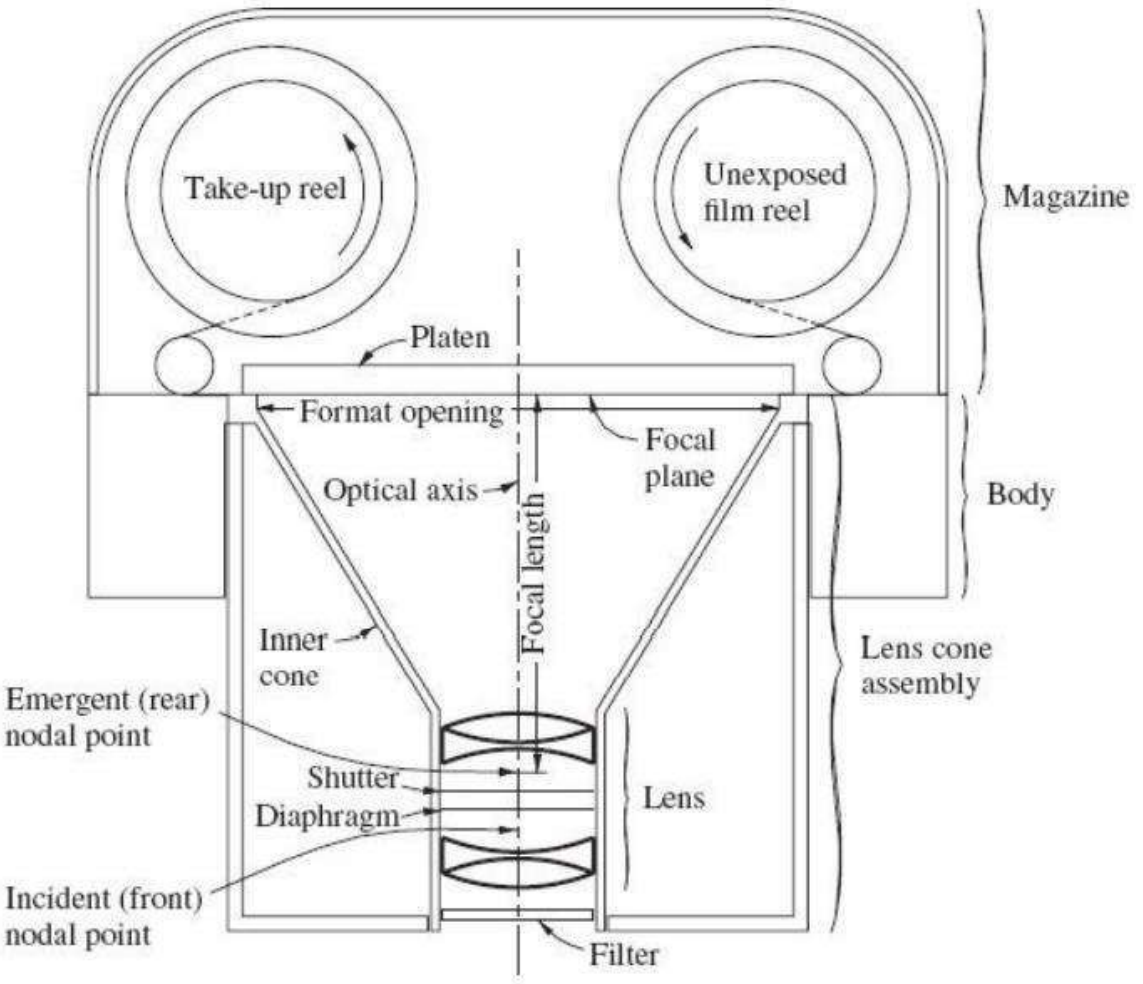

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Fig: Components of Aerial camera

Essential parts of an aerial camera

a. Lens Cone Assembly

1. The lenses :

- The camera lens is the most important (and most expensive) part of an aerial camera.
- Helps in gathering the bundle of light rays and passes through it in order to record the feature from the real ground.
- Most aerial cameras use compound lenses, formed from many separate lenses of varied sizes, shapes, and properties. To correct for the errors that may be present in any single component, so the whole unit is much more accurate than any single element.

2. Shutter:

- The shutter controls the length of time that light is permitted to pass through the lens.
- Shutters are designed to operate efficiently so that they open instantaneously, remain open the required time, and then instantaneously close, thus enabling the most uniform exposure possible over the format.
- The shutter speeds of aerial cameras typically range from about to 1/100 to 1/1000 S.

Essential parts of an aerial camera

a. Lens Cone Assembly

3. Diaphragm

- It controls the amount of light passing through the lens by varying the size of the aperture.

4. Filter

Consists of a piece of colored glass placed in front of the lens.

The filter serves three purposes:

1. It reduces the effect of atmospheric haze.
2. It helps provide uniform light distribution over the entire format.
3. It protects the lens from damage and dust.

Essential parts of an aerial camera

b. Camera Body

The camera body is a one-piece casting which usually houses the drive mechanism.

- The drive mechanism advances the film after each exposure, using electric motors activated in coordination with the shutter and the motion of the plane.
- The camera body also contains carrying handles, mounting brackets, and electrical connections.

c. Magazine

- The camera magazine houses the reels which hold exposed and unexposed film, and it also contains the film-advancing and film-flattening mechanisms.
- Operate through the drive mechanism.
- It is detachable, allowing to interchange magazines during a flight mission.

Platen

- At the time exposure the film must lie flat in the camera's focal plane. The function is performed by the platen, a small, spring-mounted, metal plate positioned to hold the film flat at the instant of exposure.

Types of lens used in Aerial Camera

Types of lens used in Aerial Camera(On basis of angular coverage)

1. Narrow Angle

- Angle of Coverage less than 20 degree (Large Focal length, higher magnification).
- It is mainly used for general interpretation, intelligence and mosaics.

2. Normal Angle

- Angle of coverage between 50 – 75 degree.
- It is used for general interpretation, mapping, ortho-photography, and mosaics.

3. Wide Angle

- Angle of coverage 85 – 95 degree.
- It is used for general interpretation, general purpose photography for normal terrain, resource mapping and mosaics.

4. Super-wide angle

- Angle of coverage more than 110 degree.
- It is used for general purpose mapping of flat areas.

Aerial Photograph

Aerial Photograph

- An aerial photograph is any photograph taken from an airborne vehicle (aircraft, drones, balloons or satellites) using a precision camera.
- It is one of the most common, versatile and economical forms of remote sensing.

Characteristics of Aerial Photographs:

1. Synoptic view:

- Recording or taking aerial photographs spatially over large area is like birds eye view from the top.
- These technologies allows discriminating and detecting small scale features and spatial relationships among them.

2. Time freezing ability

- They are defined as virtually permanent records of the existing conditions on Earth’s surface at one point of time, and further can be used as past document.

Aerial Photograph

Characteristics of Aerial Photographs:

3. Three-dimensional perspective

- Aerial photographs provide a stereoscopic view of the Earth’s surface where one can make horizontal and vertical measurements.

4. Availability

- Airborne photographs can be taken on user specific time and make permanent record at a range of scales for any area.

Aerial Photograph

Uses of Aerial Photographs:

1. Topographical Mapping: In this field photogrammetry is now replacing the traditional and classical methods of ground surveys. All topographical mapping on scales 1:10000,1:25000,1:50000 are being done photogrammetrically.

2. Civil Works: Aerial photos are now a must for a highway engineer for the planning , alignment and execution of highway project. Similarly for telephone , power transmission , drainage and sewerage and irrigation canals the use of aerial photos and subsequent mapping for engineering and civil project is helpful in reducing the cost and time.

3. Geological Mapping : Aerial Photos have been used widely to carry out geologic interpretation and preparation of base map.

Aerial Photograph

Uses of Aerial Photographs:

4. Forest Evaluation: The evaluation of forest wealth such as for tree height, forest area, tree density combined with photo-interpretation studies such as types and classification of trees, areas of diseased and disease-free are a great help in preparing forest inventory by the photogrammetric techniques.

5. War-time studies: Aerial Photos helps in making effective planning and decision making during war by watching all enemy locations, movements and supply lines etc.

Classification of Aerial Photographs

Aerial Photographs can be classified on the basis of parameters:

A. Scale
B. Camera orientation
C. Angular coverage
D. Film

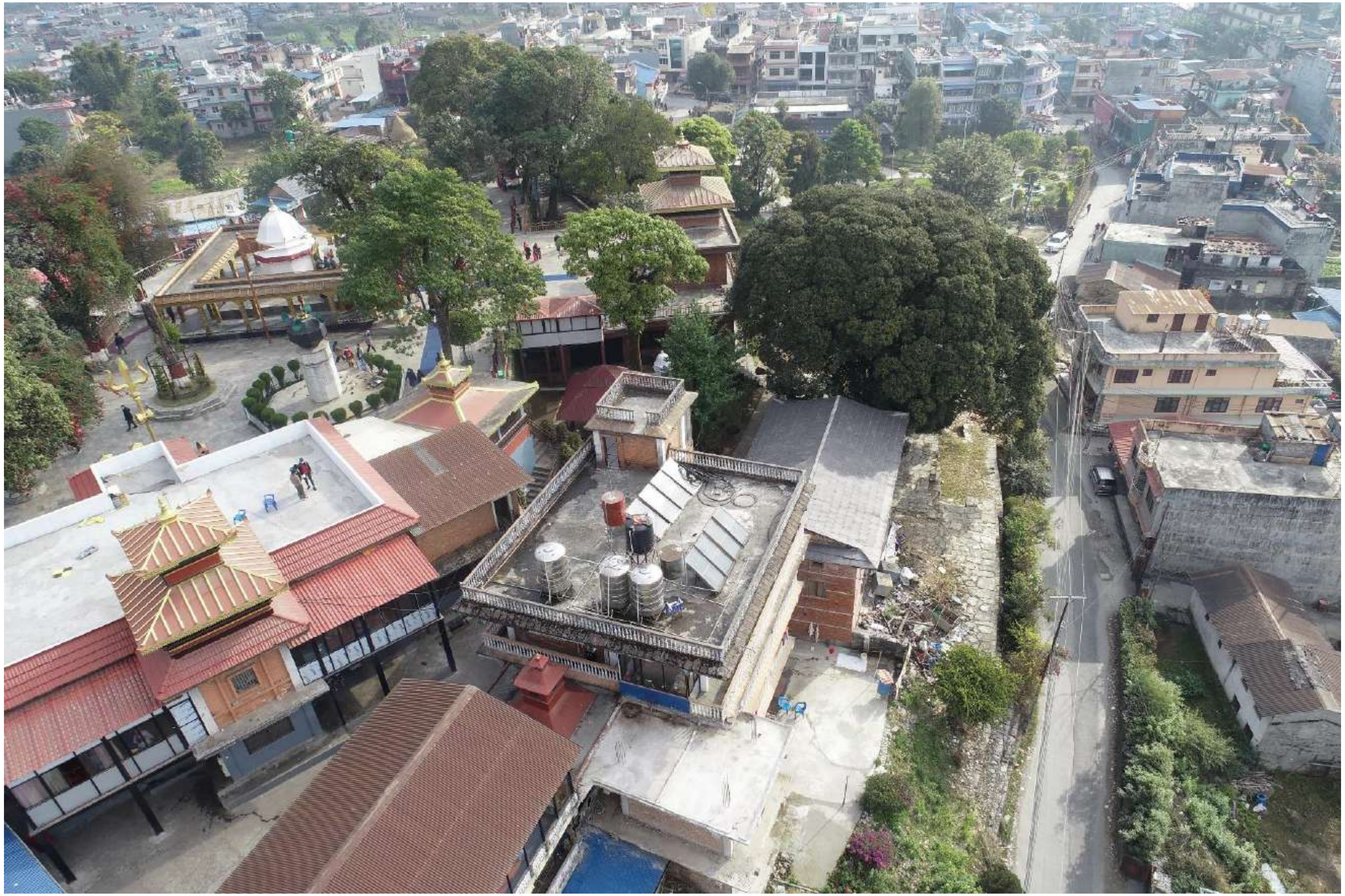


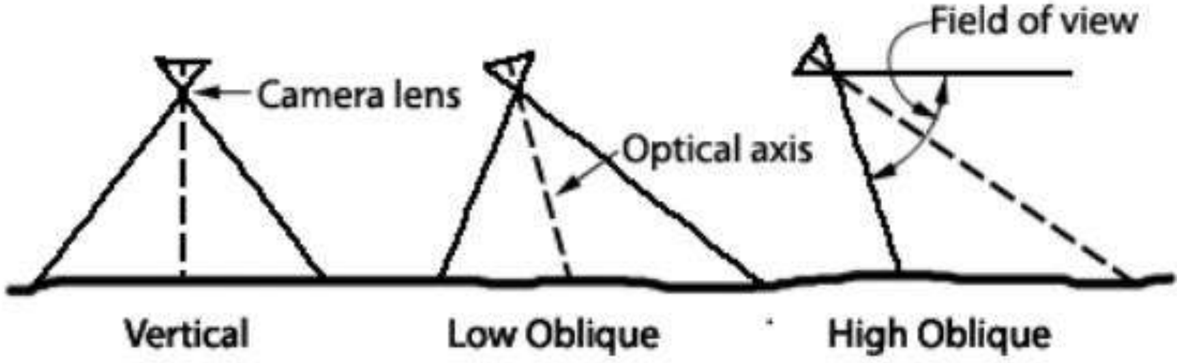
Fig: Aerial image of Bindhyabasini site

Source: https://thespatialtalk.blogspot.com/

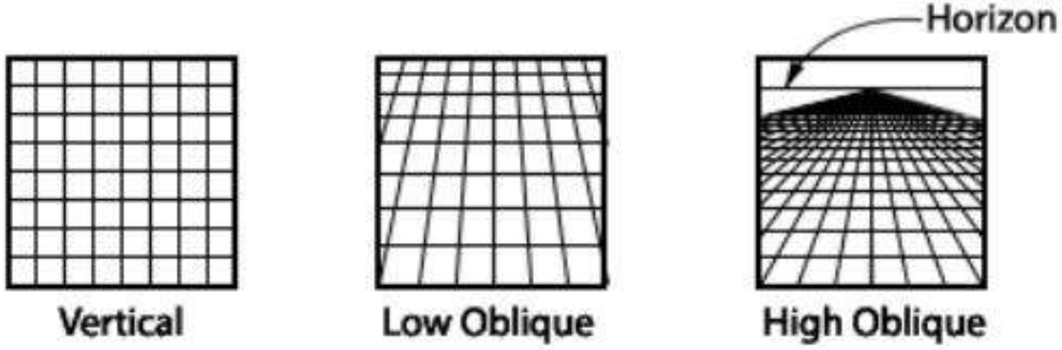
Types of Aerial Photographs

On the basis of camera orientation(Mainly two types)

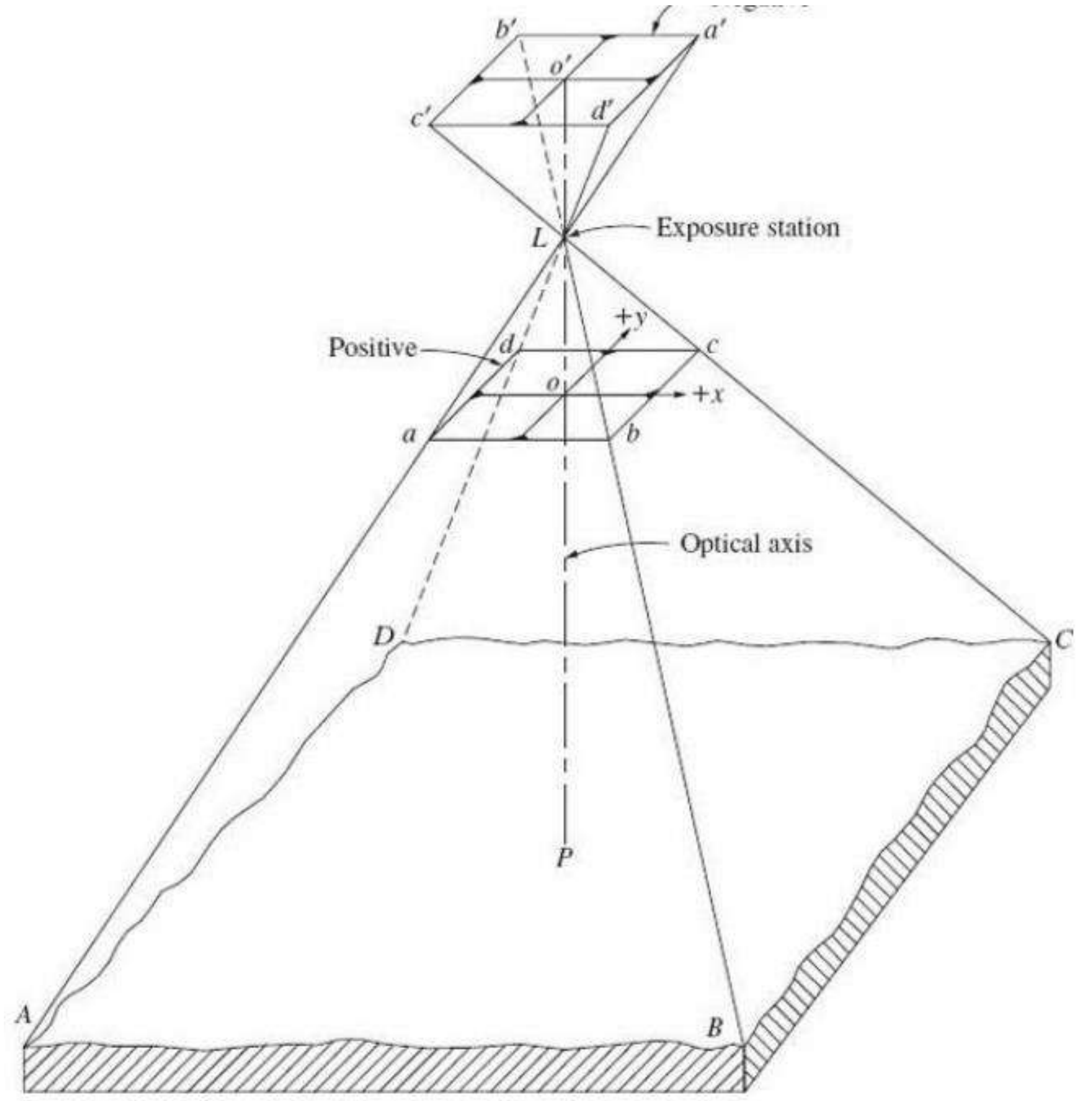
1. Vertical
2. Oblique



Camera orientation for various types of aerial photographs



How a grid of section lines appears on various types of photos.



6-1 The geometry of a vertical photograph.

Types of Aerial Photographs

On the basis of camera orientation

Vertical

- A vertical photograph is taken with the camera pointed as straight down as possible.

A vertical photograph has the following characteristics:

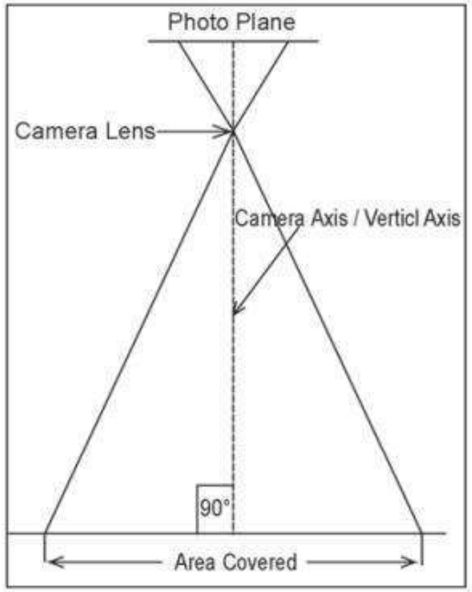
a. The lens axis is perpendicular to the surface of the earth.

b. It covers a relatively small area.

c. The shape of the ground area covered on a single vertical photo closely approximates a square or rectangle.

d. Tilt is within 3°.

* Useful in topographical Survey and thematic mapping.



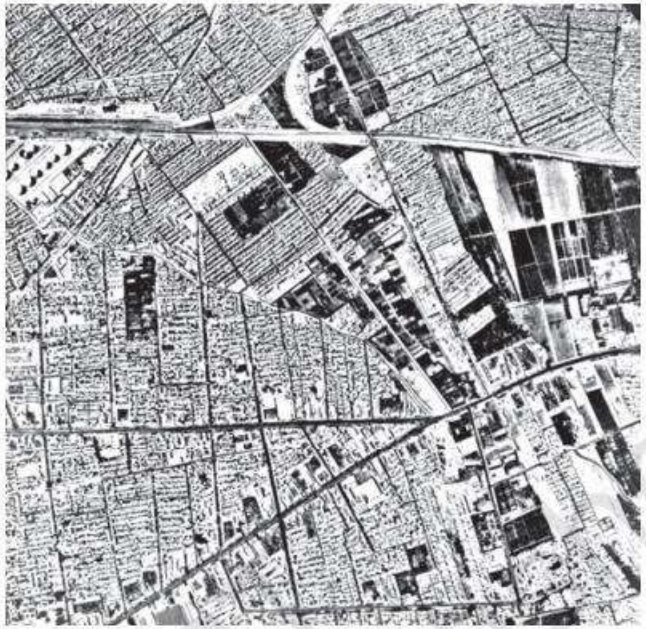


Figure 6.3 Vertical Aerial

Source: https://ncert.nic.in/textbook/pdf/kegy306.pdf

On the basis of camera orientation

Oblique

a. Low oblique

- This is a photograph taken with the camera inclined about 30° from the vertical.

A low oblique has the following characteristics:

i. It covers a relatively large area.

ii. The ground area covered is a trapezoid, although the photo is square or rectangular.

- It is used in reconnaissance survey.

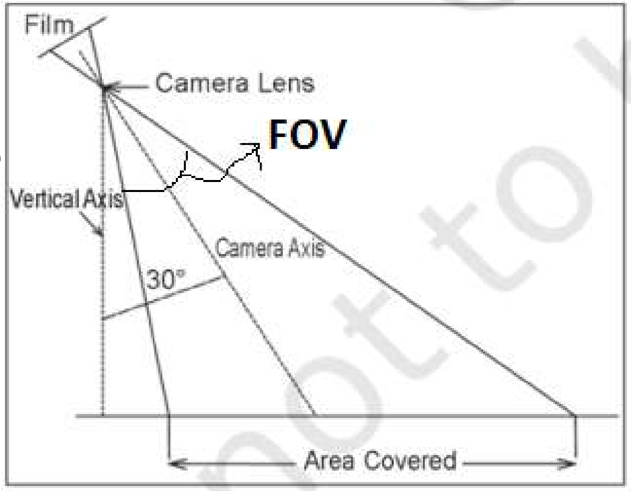


Figure 6.5 Low-Oblique Photograph

Source: https://ncert.nic.in/textbook/pdf/kegy306.pdf

Types of Aerial Photographs

On the basis of camera orientation

b. High oblique

- The high oblique is a photograph taken with the camera inclined about 60° from the vertical.

A high oblique has the following characteristics:

i. It covers a very large area.

ii. The ground area covered is a trapezoid, but the photograph is square or rectangular.

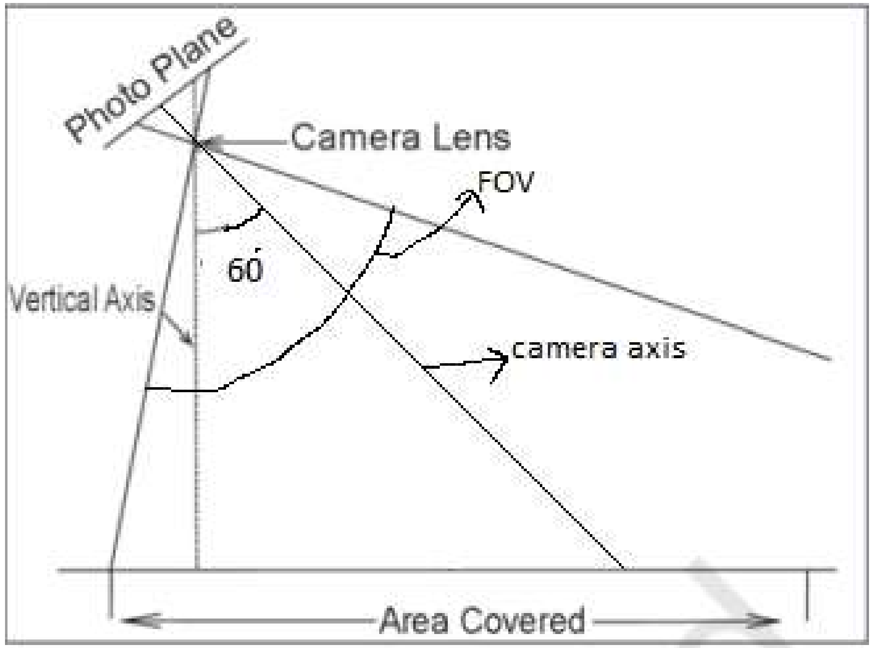


Figure 6.7 High Oblique Photograph

- It is also useful in reconnaissance surveys.

Source: https://ncert.nic.in/textbook/pdf/kegy306.pdf

Types of Aerial Photographs

On the basis of scale

The aerial photographs may also be classified on the basis of the scale of photograph into three types. They are:

i. Large scale photograph

ii. Medium scale photograph

iii. Small scale photograph

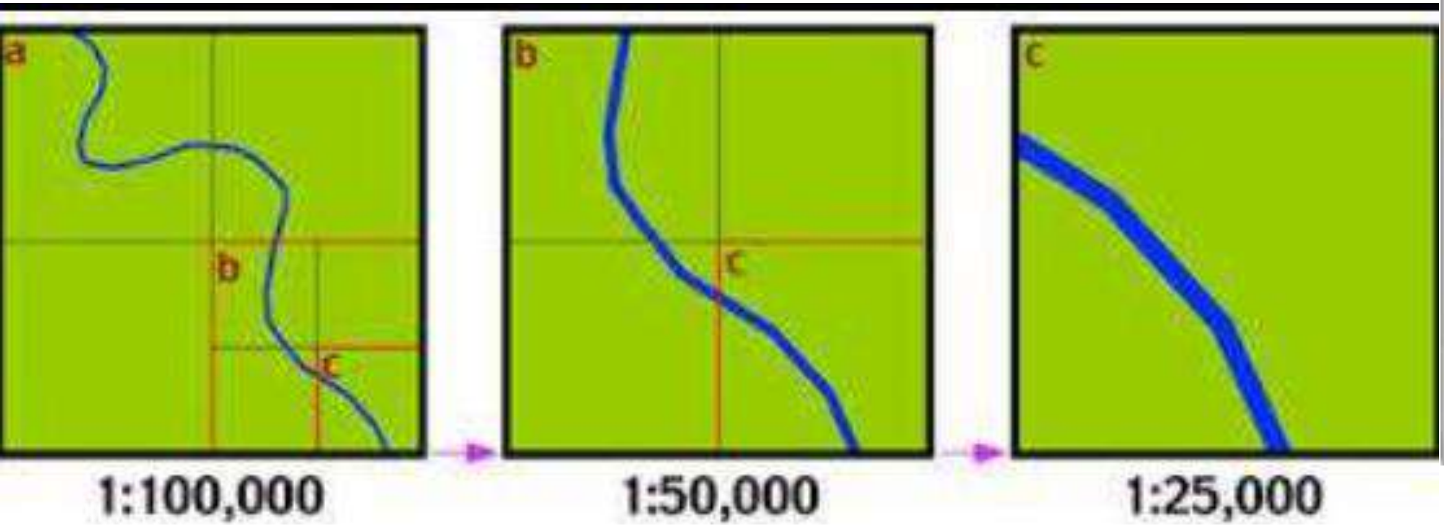
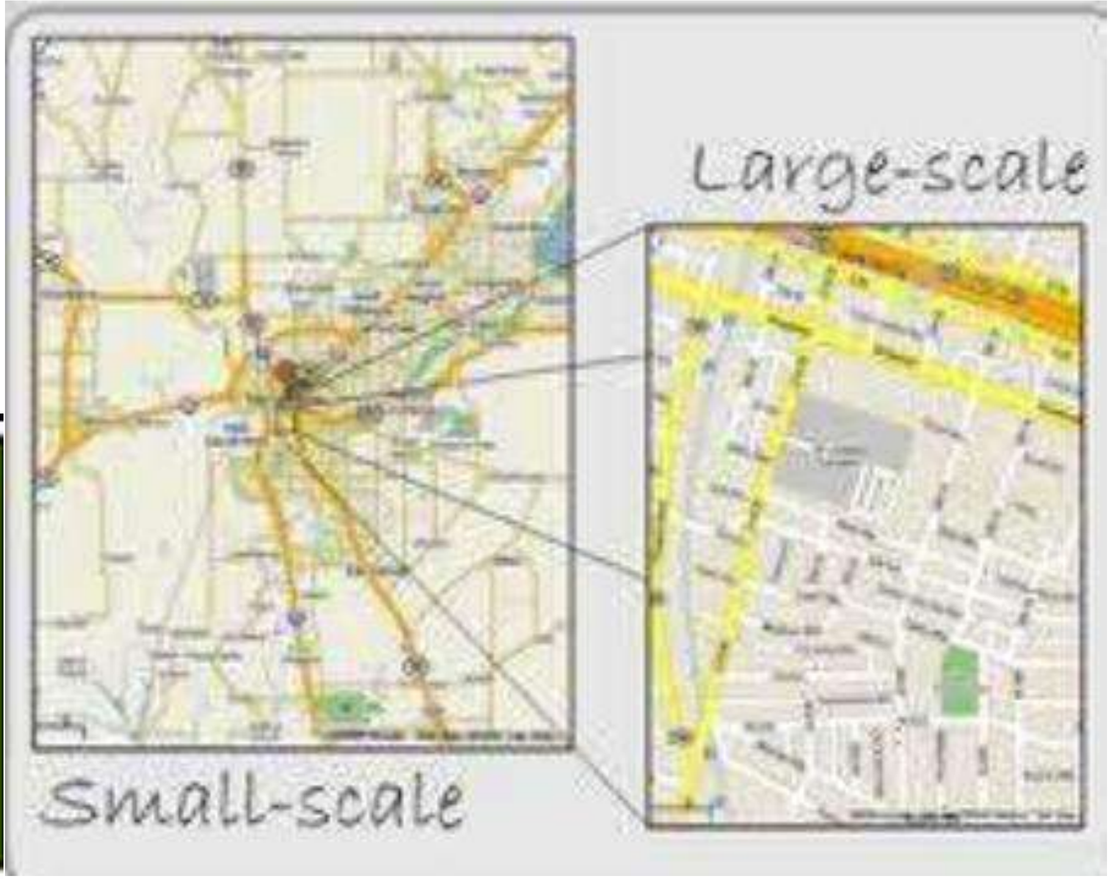


Fig: small, medium and large scale map respectively



Source: https://giscommons.org/chapter-2-input/

Types of Aerial Photographs

On the basis of scale

1. Large scale photograph

- When the scale of an aerial photograph between 1:5,000 and 1:20,000, the photography is classified as large-scale photograph.

2. Medium scale photograph

- The aerial photographs with a scale ranging between 1:20,000 and 1:50,000 are usually classified as medium-scale photograph.

3. Small scale photograph

- The photographs with the scale being smaller than 1:50,000, are referred to as small scale photographs.

Types of Aerial Photographs

On the basis of scale

Figure 6.8 1 : 5000 Photograph of Arnehem

Figure 6.9 1 : 20,000 Photograph of Arnehem

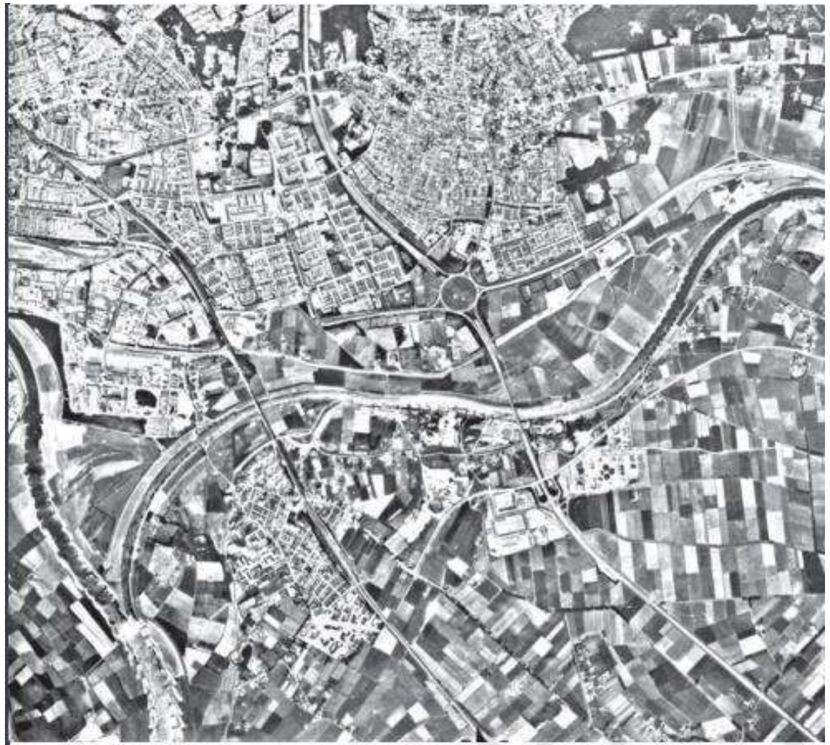


Figure 6.10 1 : 40,000 Photograph of Arnehem

Fig: showing large, medium and small scale photograph respectively

Aerial photographic process

It involves the following steps:

1. Developing
   - Exposed emulsion is placed in a chemical solution called developer
   - The silver halide grains reduced to free black silver
   - The free silver produces blacks and shades of gray of which the image is composed
   - The characteristics and strength of developer varies
   - The required time and quality of produced image varies according as the characteristics of emulsion and developer

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2. Stop Bath
   - Stop the developing process after a required contrast and darkness is attained
   - Acetic acid solution
   - Neutralizes the effects of developer solution
   - Just a few seconds are sufficient in stop bath

Aerial photographic process

3. Fixing

- during developing, not all silver halide grains are changed in free black silver, many grains remain undeveloped
- If they were not removed, they also change into black
- To prevent further developing which can ruin the quality of image, the undeveloped silver halide grains are dissolved in the fixing solution
- It also harden the emulsion

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4. Washing

- Emulsion is washed out in water to remove the chemicals
- If not removed, the chemicals may cause haziness
- A detergent can also be used for washing

5. Drying

- Finally, the emulsion is dried
- It can be done by air drier or heater drier

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Aerial Photography

Scale of the photograph

- Ratio of a distance on the photo to the corresponding distance on the ground .

Mathematically,

$$\text{Scale of the photograph} = \frac{\text{distance on the photo}}{\text{distance on the ground}}$$

- A aerial photograph is a perspective projection and its scale varies with variations in terrain elevation.
- Scales may be represented as unit equivalents, unit fractions, dimensionless representative fractions, or dimensionless ratios.

Scale of the photograph

Representation of scale

1. Unit equivalents: 1 in = 1000 ft
2. Dimensionless Unit fraction: 1 in/1000 ft
3. Representative fraction: 1/12,000
4. Dimensionless ratio: 1:12,000

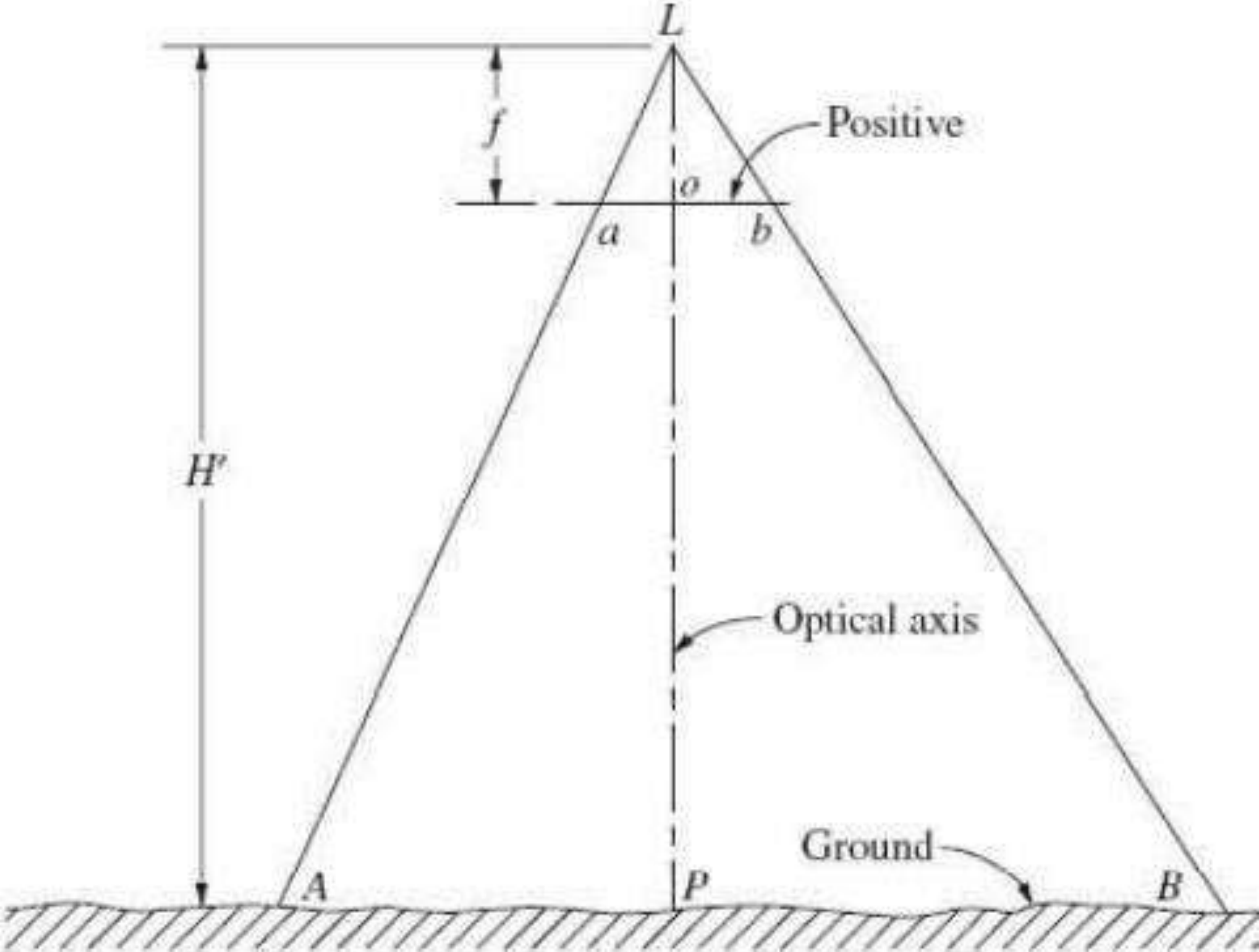
Derivation of the formula for Scale of Vertical Aerial Photograph

Case I: (if terrain is flat)

- The scale of a vertical photograph over flat terrain is simply the ratio of photo distance ab to corresponding ground distance AB.
- That scale may be expressed in terms of camera focal length f and flying height above ground H′ by equating similar triangles Lab and LAB as follows:

$$S = \frac{ab}{AB} = \frac{f}{H'} \quad \text{.......................(i)}$$

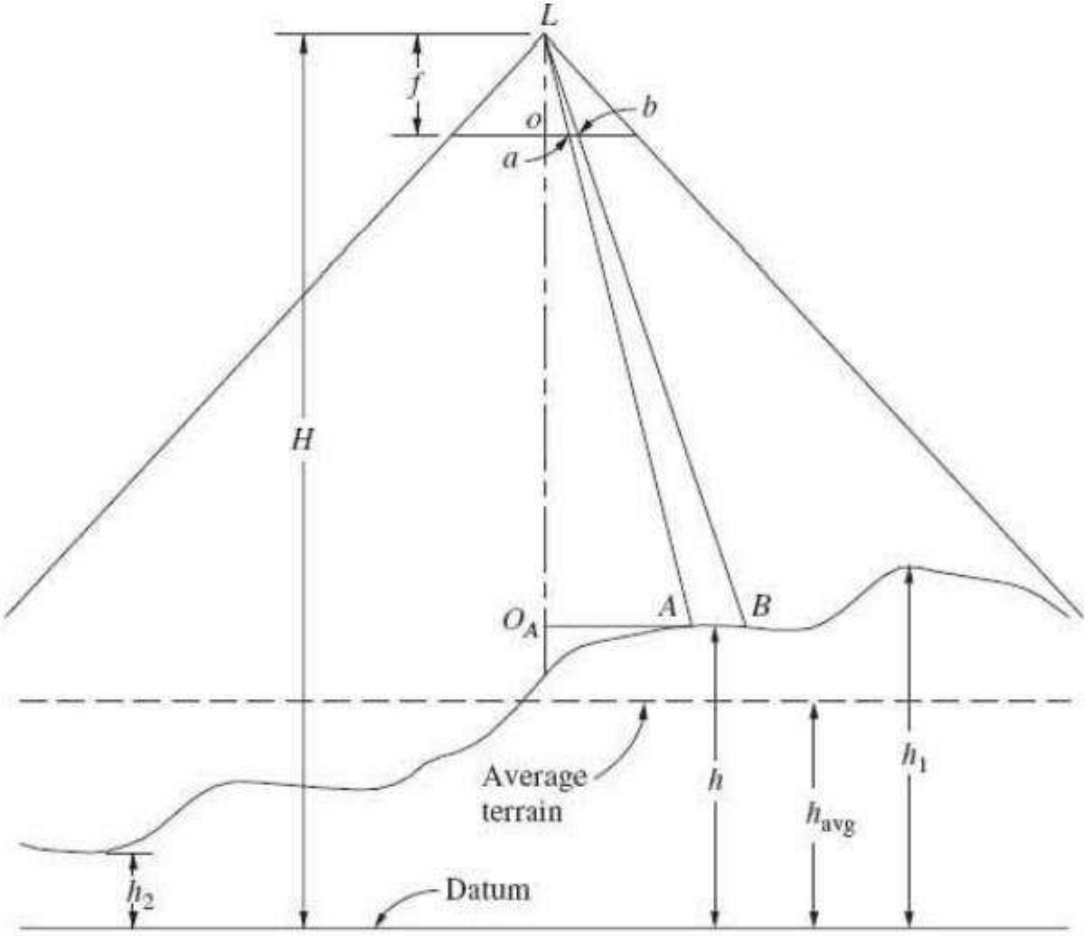
- It is seen that the scale of a vertical photo is directly proportional to camera focal length (image distance) and inversely proportional to flying height above ground (object distance).



Derivation of the formula for Scale of Vertical Aerial Photograph

Case II: (if terrain is Variable)

- If the photographed terrain varies in elevation, then the object distance—or the denominator of Eq. (i)—will also be variable and the photo scale will likewise vary.
- For any given vertical photo scale increases with increasing terrain elevation and decreases with decreasing terrain elevation.



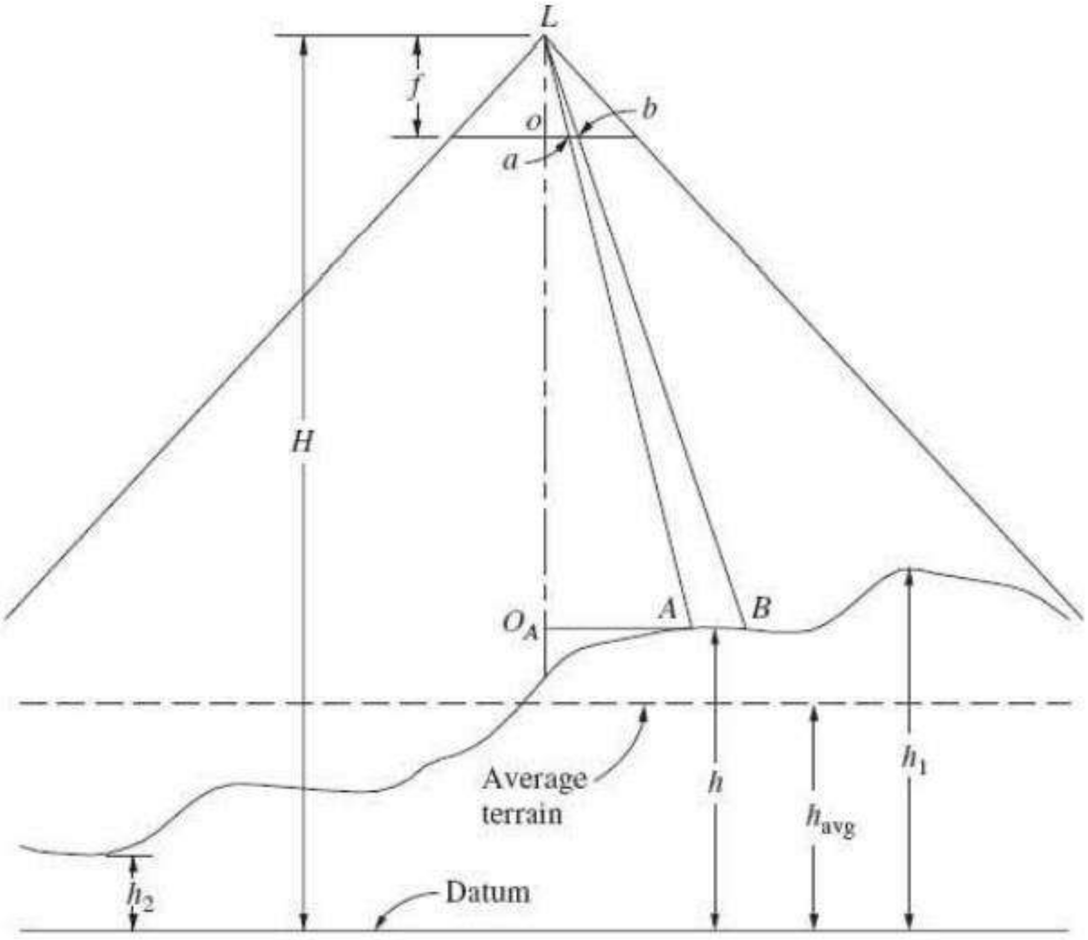
Derivation of the formula for Scale of Vertical Aerial Photograph

Case II: (if terrain is Variable)

- Suppose a vertical aerial photograph is taken over variable terrain from exposure station L of. Ground points A and B are imaged on the positive at a and b, respectively. Photographic scale at h, the elevation

of points A and B, is equal to the ratio of photo distance ab to ground distance AB. By similar triangles Lab and LAB, an expression for photo scale S_{AB} is

$$S_{AB} = \frac{ab}{AB} = \frac{La}{LA} \qquad \text{......................(a)}$$



Aerial Photography

Derivation of the formula for Scale of Vertical Aerial Photograph

Case II: (if terrain is Variable)

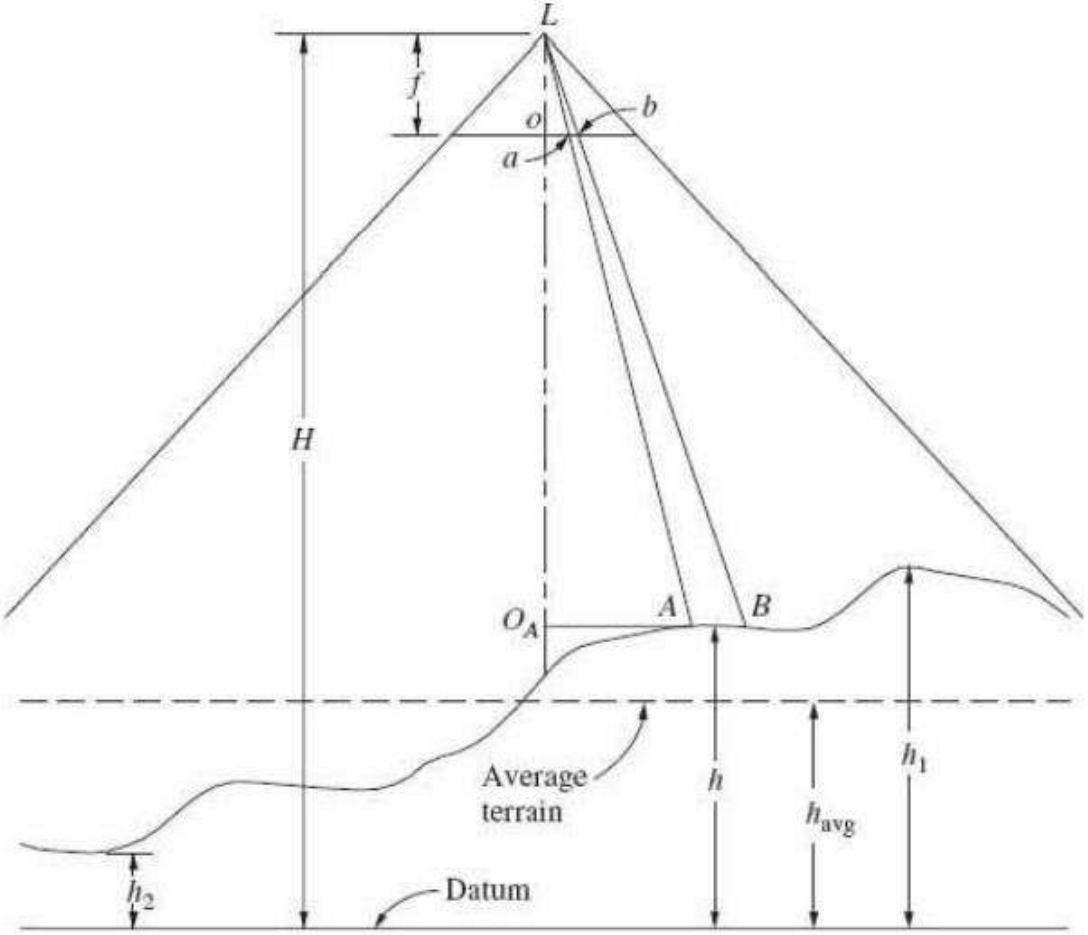
Also, by similar triangles LO_AA and Loa,

$$\frac{La}{LA} = \frac{f}{H-h}$$ …………………..(b)

Equating equation (a) and (b)

$$S_{AB} = \frac{ab}{AB} = \frac{La}{LA} = \frac{f}{H-h}$$ …………………..(c)

Here the denominator H - h is the object distance. In this equation as in Eq. (c), scale of a vertical photograph is seen to be simply the ratio of image distance to object distance.



Derivation of the formula for Scale of Vertical Aerial Photograph

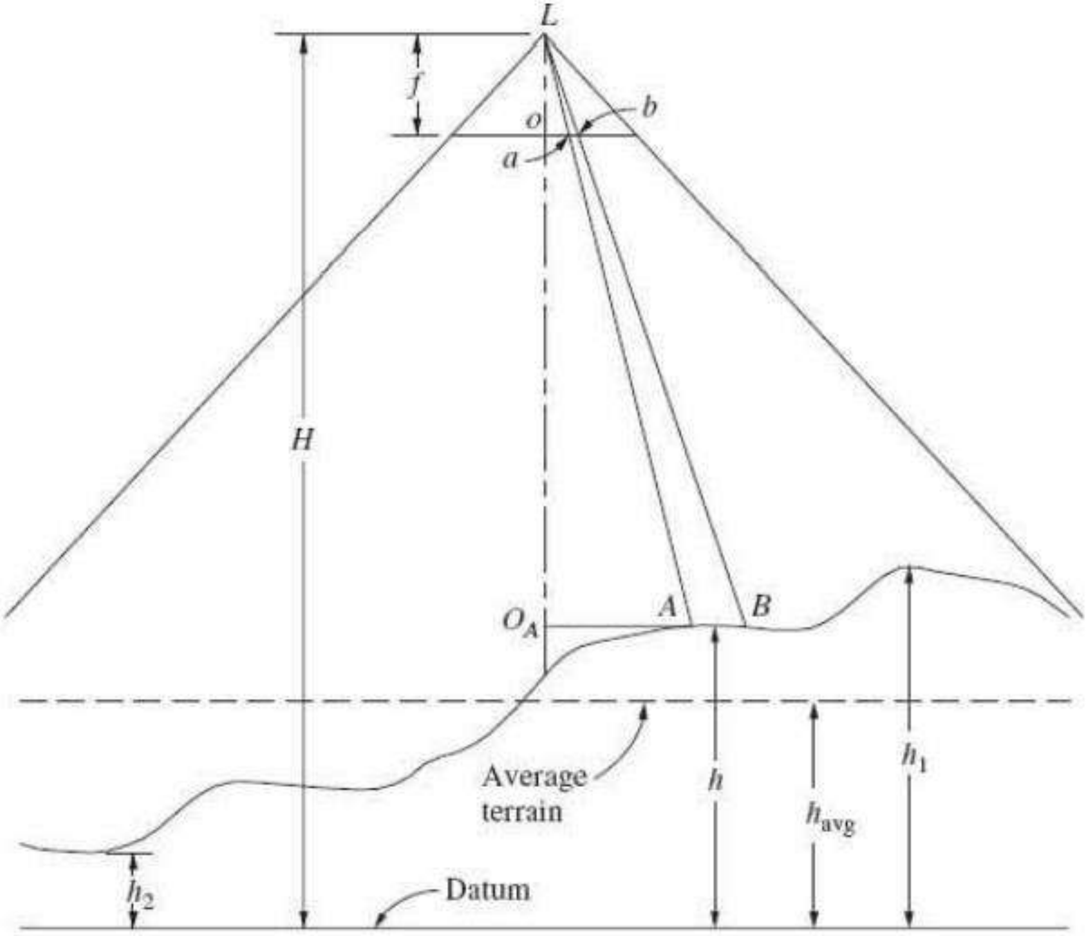
Case II: (if terrain is Variable)

- The shorter the object distance, the greater the photo scale, and vice versa. For vertical photographs taken over variable terrain,

there are an infinite number of different scales.

This is one of the principal differences between

a photograph and a map.



Derivation of the formula for Scale of Vertical Aerial Photograph

Case II: (if terrain is Variable)

Average Photo Scale:

- Average scale is the scale at the average elevation of the terrain covered by a particular photograph and is expressed as

$$S_{avg} = \frac{f}{H - h_{avg}}$$

2.7 Determination of Scale of a Photograph

There are several methods for calculating the scale of an aerial photo. Some of them are:

a. Feature of Known Size:

- The scale of an aerial photo can also be determined if an object of a known ground size appears in the image.
- One method is to find a feature of a known size (e.g. football field or standard event field) in the photograph to calculate the scale. The scale can be determined by measuring the distance or length of the feature on the photo and comparing it to the real-life or ground distance.

For eg: If a 1 km stretch of highway covers 4 cm on an air photo, the scale is

calculated as follows:

$Photo\ distane/\ Ground\ distance$ = 4 cm/1 km = 4 cm/100000 cm = 1/25000

So the scale is: 1/25000

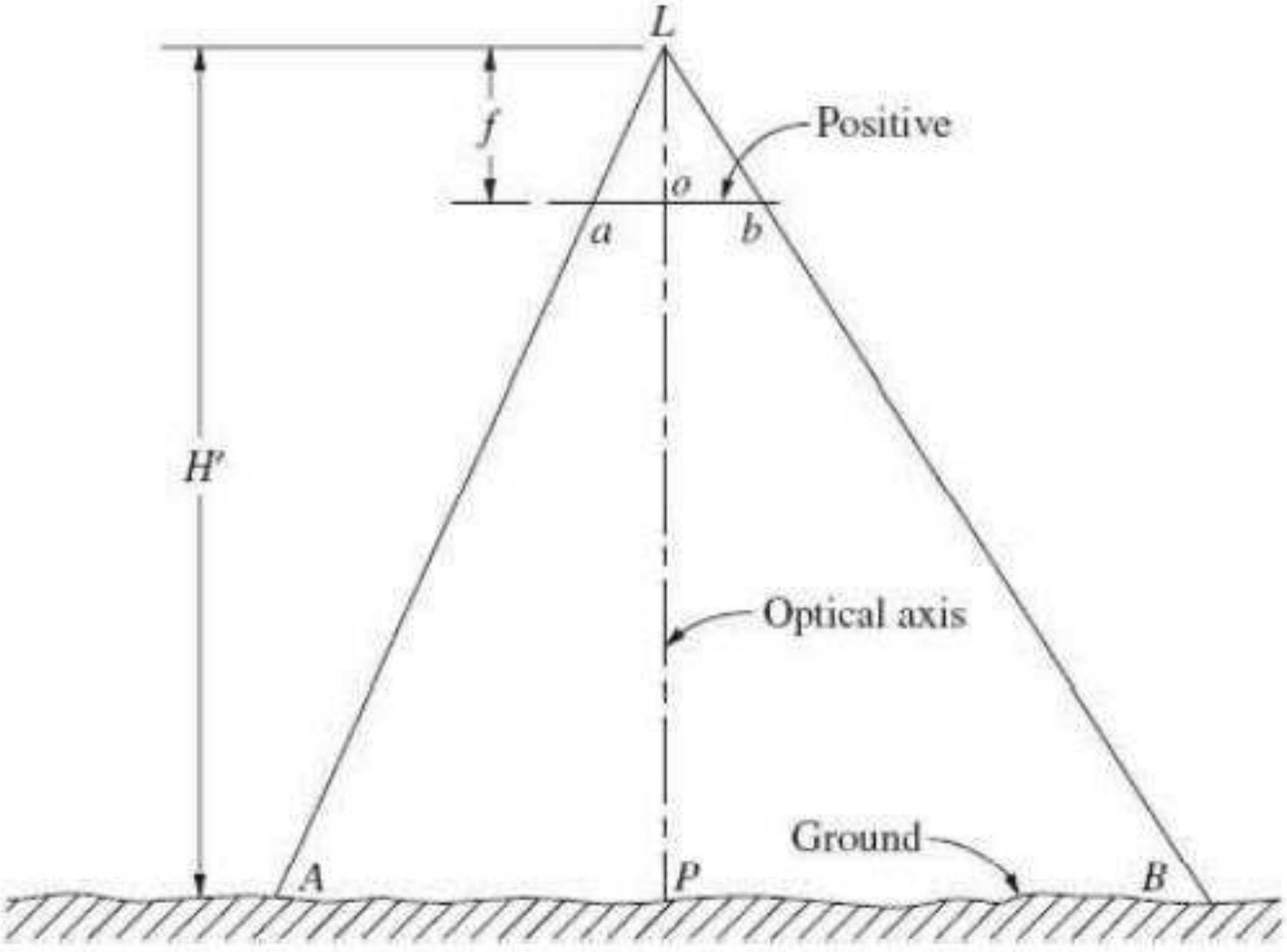
2.7 Determination of Scale of a Photograph

There are several methods for calculating the scale of an aerial photo. Some of them are:

b. Focal length of the camera and the flying height

- If the focal length and flying altitude above the surface is known, the scale can be calculated using the following formula:

$$S = \frac{f}{H'}$$



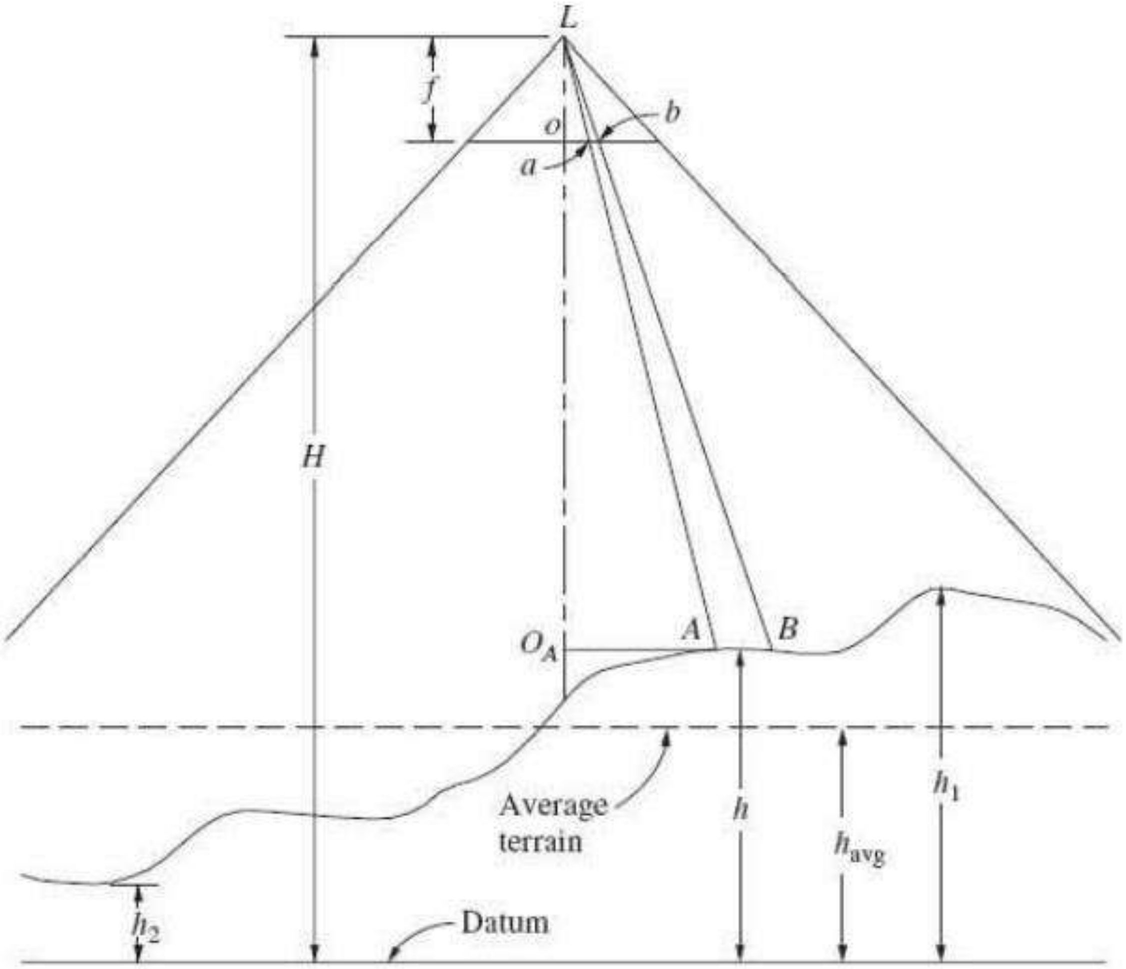
2.7 Determination of Scale of a Photograph

There are several methods for calculating the scale of an aerial photo. Some of them are:

c. Focal length of the camera, flying height and altitude above sea level or MSL

- If the focal length and flying altitude above the surface is known, the scale can be calculated using the following formula:

$$S_{AB} = \frac{f}{H - h}$$



Numericals related to scale

1. A vertical aerial photograph is taken over flat terrain with a 152.4 mm-focal-length camera from an altitude of 1830 m above ground. What is the photo scale? (Ans: 1/12000)
2. On a vertical photograph the length of an airport runway measures 160mm. On a map that is plotted at a scale of 1:24,000, the runway is measured as 103 mm. What is the scale of the photograph at runway elevation? (Ans: 1:15,400)
3. A vertical photograph was exposed with a 150mm focal length camera at a flying height of 5000m above the sea level. (a)What is the scale at a point if the elevation of a point a on the ground level is 800 m above datum? (b)What is the scale if the elevation of point B in the ground is 1250 m above datum? (c) For this photo if the average terrain is 950 m above datum, what is the average photo scale? (Ans: 1:28000, 1:25000, 1:27000)

2.8 Relief Displacement and Derivation of formula of relief displacement

Relief Displacement

- Relief displacement is the shift or displacement in the photographic position of an image due to object's elevation above or below datum.
- With respect to a datum, relief displacement is outward for points whose elevations are above datum and inward for points whose elevations are below datum.

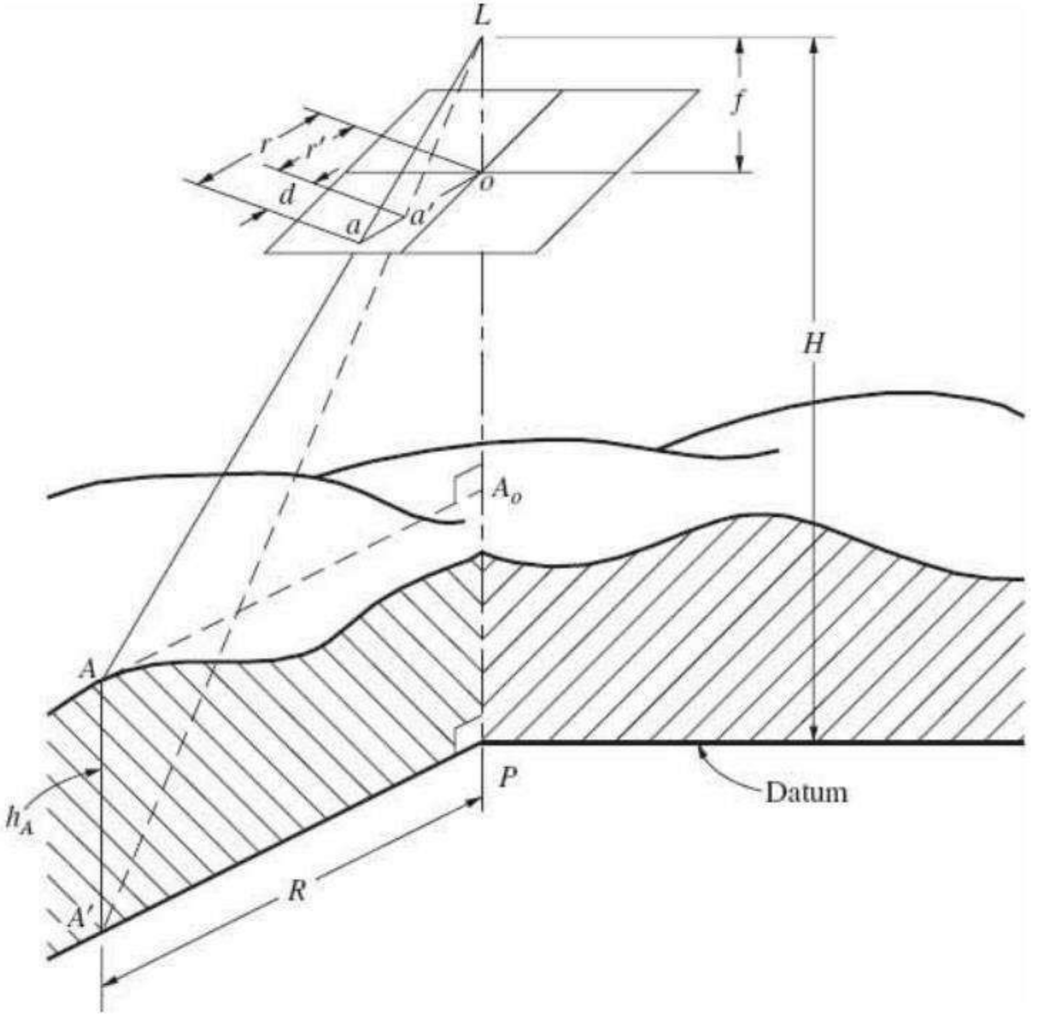


Fig: showing Relief displacement on a vertical photograph

2.8 Relief Displacement and Derivation of formula of relief displacement

Relief Displacement

- An increase in the elevation of a feature causes its position on the photograph to be displaced radially outward from the principle point.
- Hence, when a vertical feature is photographed, relief displacement causes the top of the feature to lie farther from the photo center than its base. As a result, vertical features appear to lean away from the center of the photograph.

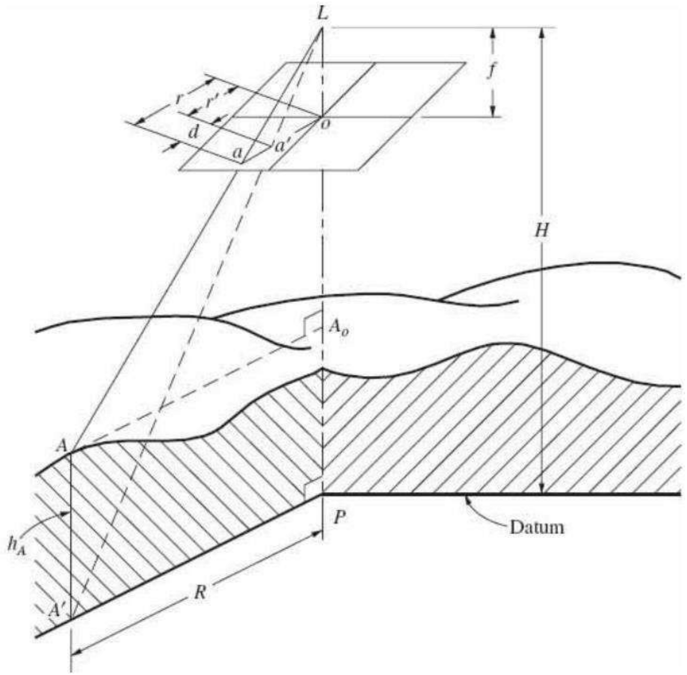
Fig: showing cooling towers at the edge of photo with greater radial displacement

2.8 Relief Displacement and Derivation of formula of relief displacement

Derivation of formula of relief displacement

Let us consider a vertical photograph is taken from flying height H above datum. Camera focal length is f, and o is the principal point. The image of terrain point A, which has an elevation h_A above datum, is located at on the photograph. An imaginary point A′ is located vertically beneath A in the datum plane, and its corresponding imaginary image position is at a′.

On the figure, both A′A and PL are vertical lines, and therefore A′AaLoP is a vertical plane. Plane A′a′LoP is also a vertical plane which is coincident with A′AaLoP. Since these planes intersect the photo plane along lines oa and oa′, respectively, line aa′ (relief displacement of point A due to its elevation h_A) is radial from the principal point.

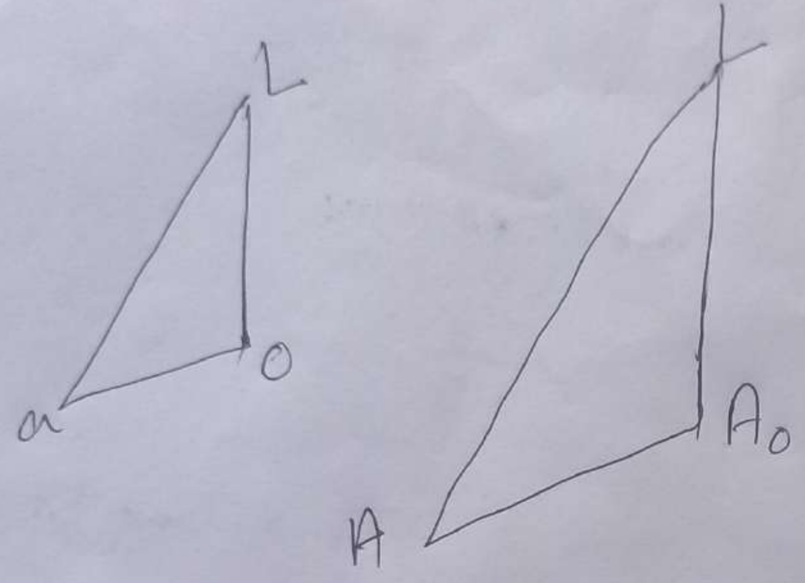


Derivation of formula of relief displacement

For similar triangles Lao and LAA_o

Here (ao=image distance and

LAA_o = object distance)



Using concept of similar triangles

$$\frac{ao}{AA_o} = \frac{aL}{AL} = \frac{LO}{LA_o}$$

~~Also~~, or, $\dfrac{f}{H-h_A} = \dfrac{r}{R}$

or, $fR = r(H-h_A)$ ... (a)

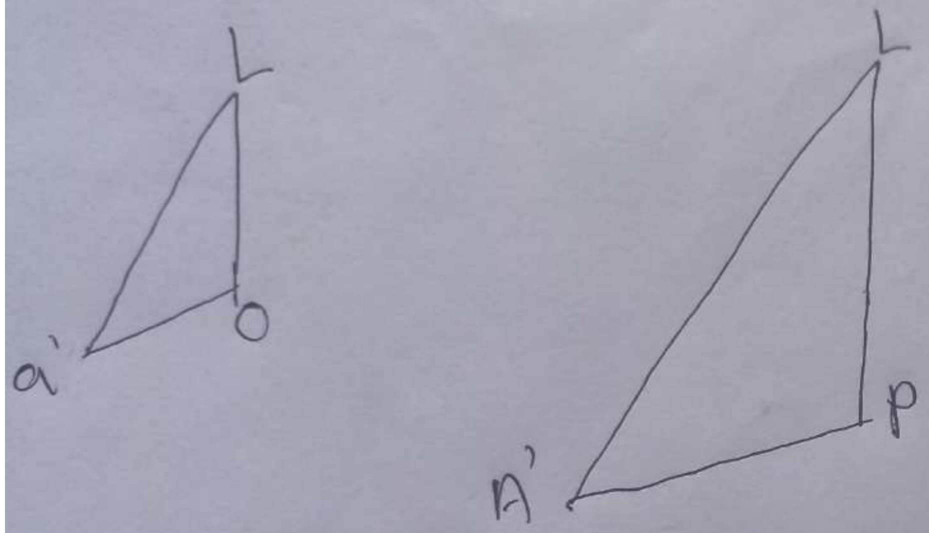
2.8 Relief Displacement and Derivation of formula of relief displacement

Derivation of formula of relief displacement

For similar triangles La'o and LA'P

Here (a'o=image distance and

A'P = object distance)



From similar triangles

$$\frac{a'o}{A'P} = \frac{a'L}{A'L} = \frac{Lo}{LP}$$

$$\text{or, } \frac{f}{H-o} = \frac{r'}{R} \quad \text{or, } fR = r'H \quad \cdots (b)$$

2.8 Relief Displacement and Derivation of formula of relief displacement

Derivation of formula of relief displacement

From equation (a) and (b)

$$r(H - h_A) = r'H$$

Rearranging the above equation, dropping subscripts, and substituting the symbol d for r - r' gives

d= (rh/H) ……………..(d)

where, d = relief displacement

h = height above datum of object point whose image is displaced

r = radial distance on photograph from principal point to displaced image; here of point A (The units of d and r must be the same.)

H = flying height above same datum selected for measurement of h

Thus, equation (d) gives the basic relief displacement equation for vertical photos.

Numericals related to scale

1. A vertical photograph taken from an elevation of 535 m above mean sea level (MSL) contains the image of a tall vertical radio tower. The elevation at the base of the tower is 259 m above MSL. The relief displacement d of the tower was measured as 54.1 mm, and the radial distance to the top of the tower from the photo center was 121.7 mm. What is the height of the tower? (Ans: 123m)
2. Radial distances to the top and bottom of a chimney are 63.57mm and 60.83mm respectively. If the flying height above the datum is 1500m and the ground elevation is 450m, what is the height of the chimney above the ground? (45.26 m above ground)

2.9 Tilt Displacement

Tilted Photograph

- It is a photograph obtained when the optical axis is inclined unintentionally to the vertical at an angle not greater than 3°.
- A tilted photograph presents a slightly oblique view rather than a true vertical record. All photos have some tilt. The perfect gyro stabilization unit, like the perfect lens, has yet to be built.

Tilt Displacement

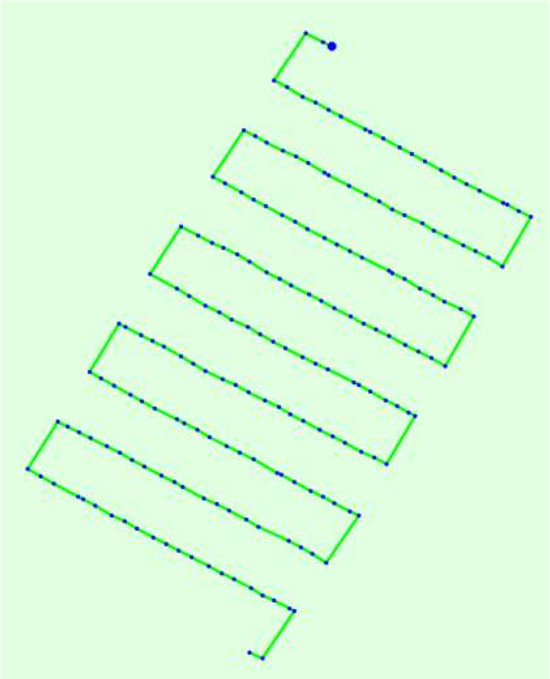
- Defined as the difference between the distance of the image of a point on the tilted photograph from the isocentre and the distance of the image of the same point on the photograph from the isocentre if there had been no tilt.
- Tilt is caused by the rotation of the platform away from the vertical. This type of displacement typically occurs along the axis of the wings or the flight line.
- An error in the position of a point on the photograph due to indeliberate tilting of the aircraft may be due to instability of aircraft, tilting of the aircraft along the flight etc.
- Tilt displacement radiates from the isocenter of the photo and causes objects to be displaced radially towards the isocenter on the upper side of the tilted photo and radially outward on the lower side.

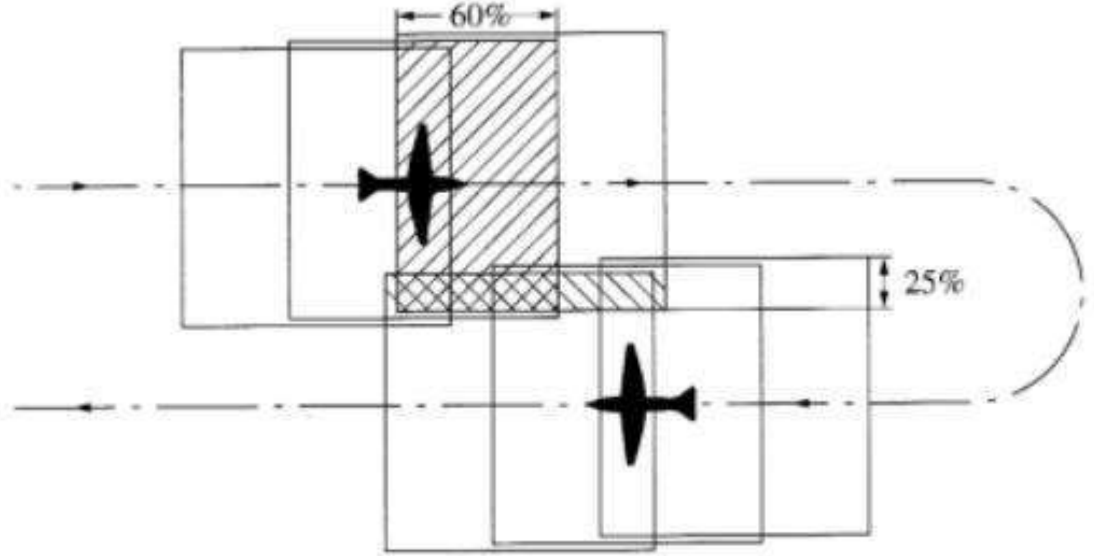
2.10 Overlap

Overlap

- Overlap is the amount by which one photograph includes the area covered by another photograph, and is expressed as a percentage.
- The photo survey is designed to acquire 60% forward overlap (between photos along the same flight line) and 30% lateral overlap (between photos on adjacent flight lines).
- When an area is to be a mapped, vertical aerial photograph are taken along a series of parallel passes called flight stripes.

Fig: showing flight stripes with green color; blue showing camera position where photo was taken.



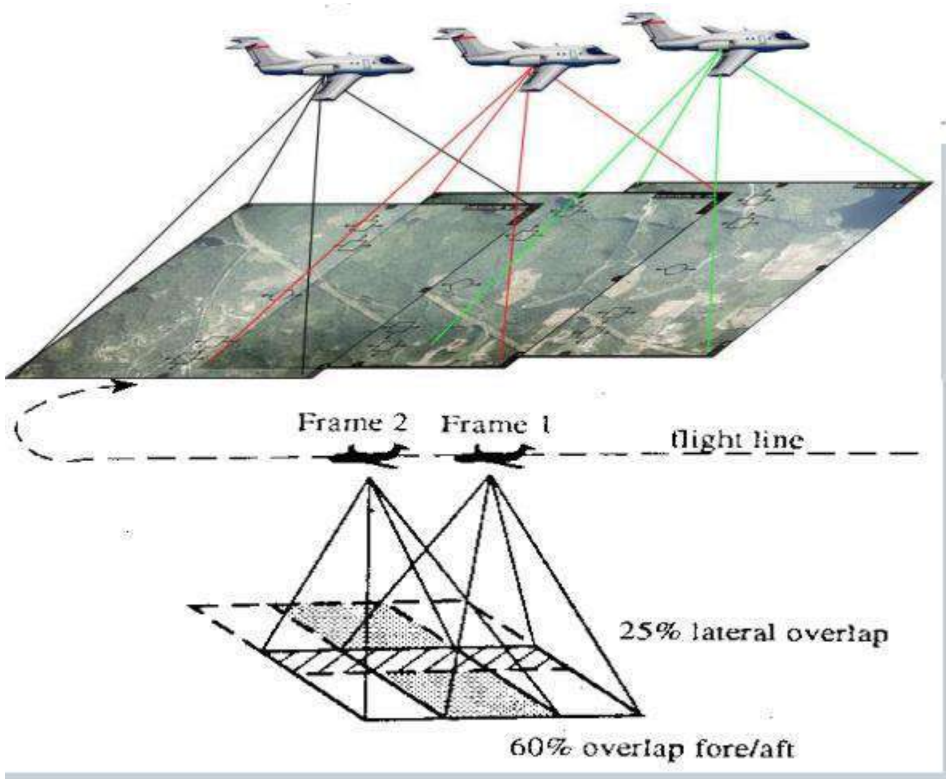


Source: https://www.geavis.si/en/2018/09/typical-causes-for-anomalies-in-the-overlap-of-aerial-photo-stereo-pairs/#:~:text=Drift%20is%20the%20lateral%20shift,between%20adjoining%20strips%20of%20photographs.

2.10 Overlap

Reasons for overlap

1. Arrangement of Mosaic.
2. Remove errors due to distortion , displacement & tilt.
3. For view in stereoscope-3D vies.
4. Avoid repetition of Aerial survey.

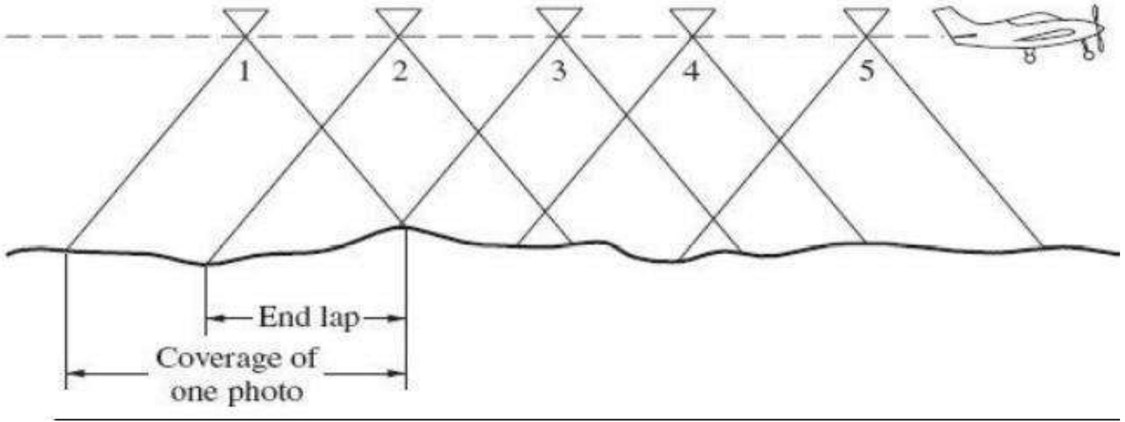


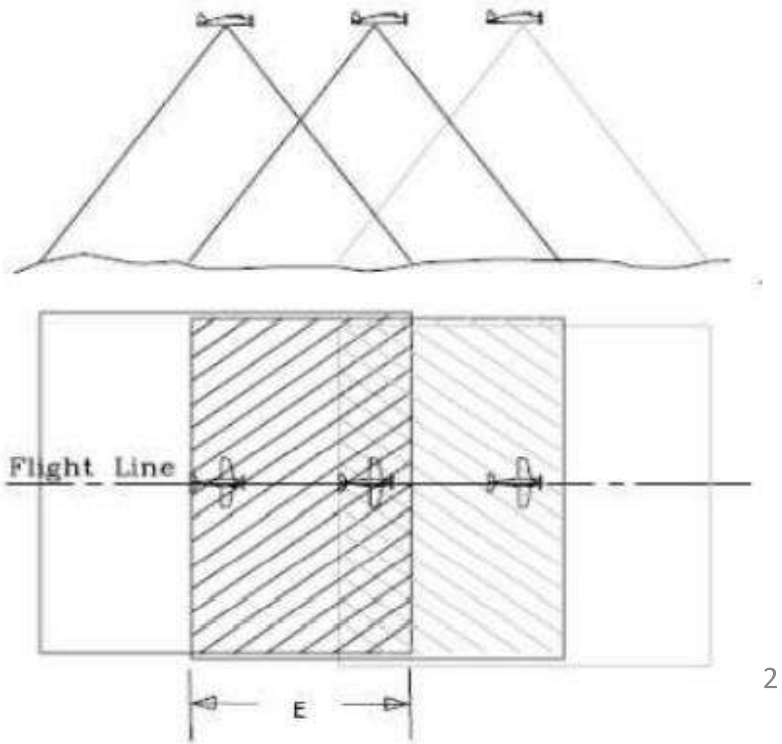
Source: https://arts.nprcolleges.org/site/download?file=unit+2-aerial+surveying.pdf

2.10 Overlap

Forward Overlap(End lap)

- Forward overlap is the amount by which one photograph includes the area covered by another photograph along the same flight line.
- In order to prevent gaps due to terrain variation, flying height variations, tilt crab; end laps greater than 50% are used.
- Sometimes aerial photographs are required with more than 80% endlap in mountainous terrain.

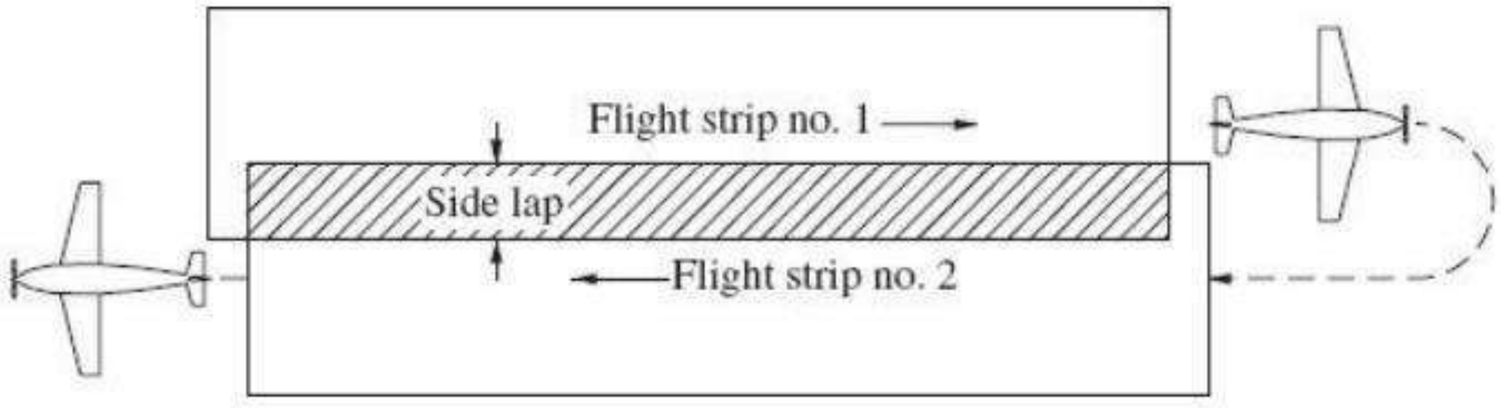




2.10 Overlap

Lateral Overlap(Side lap)

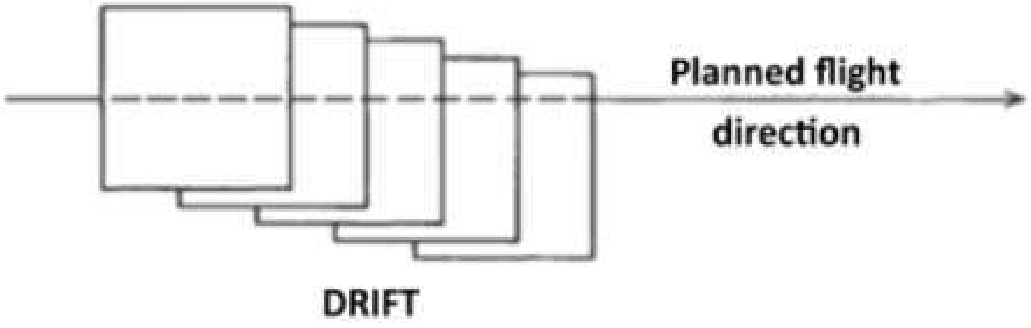
- Side overlap is the amount by which one photograph includes the area covered by another photograph on adjacent flight lines.
- Sidelap is required in aerial photography to prevent gaps from occurring between flight strips as a result of drift, crab, tilt, flying height variation and terrain variations.



2.10 Drift and Crab

Drift

- Drift is the *lateral shift* or displacement of the aircraft from the planned flight lines that may be caused by the *blowing wind* or by the *navigational errors*.
- It may cause a serious *gap* between adjoining **strips of photographs**.
- Uncorrected drift results in subsequent photos covering more area in the prevailing wind direction.
- Drift is the result of *unmanned* aircraft not being able to keep the planned navigation bearing.



Crab

- During side winds, if the pilot tries to maintain the original path, he has to *turn* the nose of the aircraft slightly against the wind. This makes the aircraft to rotate on its vertical axis. In this case, the original path is maintained, but the area covered by the aerial photo is much different from that planned originally. The photograph is rotated in the direction opposite to wind direction here. This defect is called as crab.
- It occurs when the aircraft is not oriented with flightline. It causes a reduction in a stereoscopic coverage of the terrain.

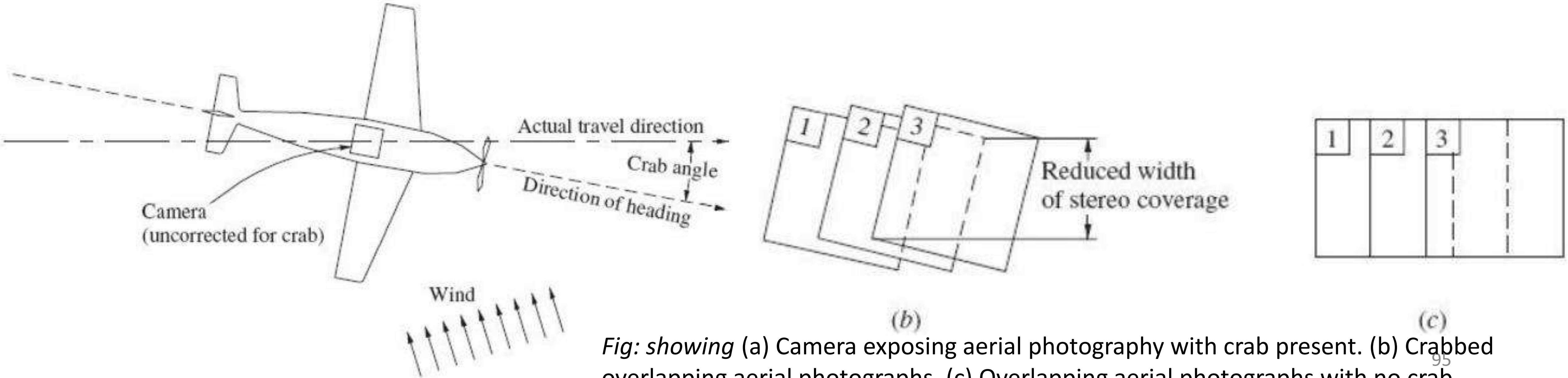


Fig: showing (a) Camera exposing aerial photography with crab present. (b) Crabbed overlapping aerial photographs. (c) Overlapping aerial photographs with no crab.

2.10 Drift and Crab

Crab

- It can be corrected by rotating the camera around the vertical axis.
- It is the result of being able to keep the planned navigation bearing but because of side winds, it doesn’t have an alignment yaw position with the bearing.

References

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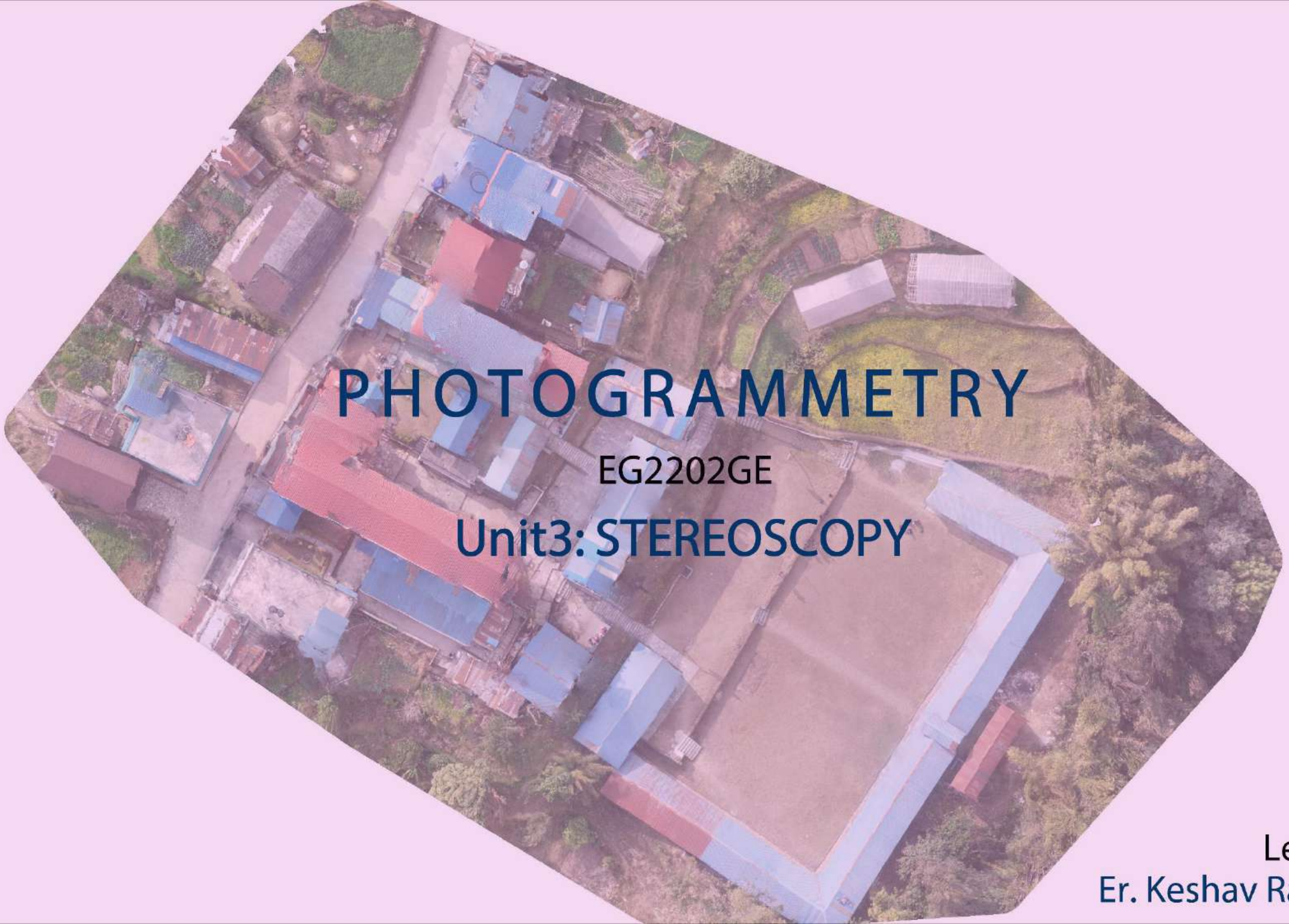
- https://arts.nprcolleges.org/site/download?file=unit+2-aerial+surveying.pdf
- https://staff.ui.ac.id/system/files/users/dodi.sudiana/material/ch.03-photographicsensors.pdf : Parts of aerial camera



PHOTOGRAMMETRY

EG2202GE

Unit3: STEREOSCOPY

Lecture by
Er. Keshav Raj Bhusal

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Stereoscopic Vision

Depth Perception

- In our normal process of vision, consciously or unconsciously, we perceive depth to objects around us with the help of our eyes.
- Depth perception is the ability to perceive the world in three dimensions (3D) and to judge the distance of objects.
- Depth perception can be classified as either monoscopic or stereoscopic.

1. Monoscopic or monocular vision is the term which refers to viewing with only one eye and judging distance.

- Depth perception is poor with monoscopic vision and distance estimation can be different.

Stereoscopic Vision

- Stereoscopic vision is a characteristic, possessed by most persons of normal vision (those capable of viewing with both eyes simultaneously; binocular vision) to conceive objects in three dimensional effects and to judge distances.
- With stereoscopic viewing, a much greater degree of accuracy in depth perception and distance estimation can be achieved.
- Stereoscopic vision is the basic prerequisite for photogrammetry and photo interpretation.
- The concept of stereoscopic vision can also be applied to view stereo pair (overlapping pair of photographs) by viewing the left photograph with the left eye, and the right photograph with the right eye, a 3D view of the terrain can be obtained. Here, the third dimension is obtained by using the principle of parallax.
- Stereoscopic viewing makes it possible to measure elevations and plot contours and planimetric features from the photographs oriented in stereoscopic plotting instruments.

Stereoscopic Vision

- With binocular vision, when eyes are focused on a certain point, the optical axes of the two eyes converge on that point intersecting at an angle called parallactic angle.

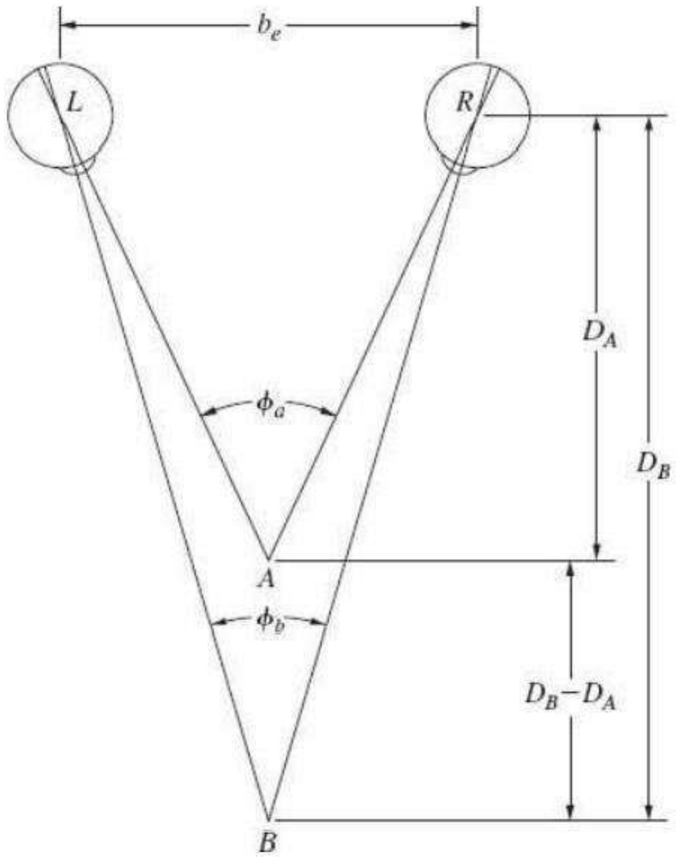


Fig: The depth between objects A and B is $D_B - D_A$ and is perceived from the difference in these parallactic angles; optical centers of the eyes L and R separated by a distance b_e, called the eye base.

Stereoscopic Vision

Types of Stereoscopic Vision

Stereoscopic vision can be of two types:

1. Natural Stereoscopic Vision

- Binocular Vision is responsible for perception of depth. Two slightly different images, seen by two eyes simultaneously are fused into one by brain, giving the sensation of a ‘model’ with three dimensions.
- The three dimension effect is reduced beyond viewing distance of one meter.
- The distance between two eyes, called ‘Eye base, affects stereoscopic vision. Wider the eye base, better is the three dimensional effect.

2. Artificial Stereoscopic Vision

- Stereoscopic Vision obtained from stereo model.

Stereo Model

- It is the phenomenon of creating the three-dimensional or stereoscopic impression of objects by viewing identical images of the objects photographically.
- This requires photographs of the objects to be taken from 2 positions. (Image overlap)

Let's suppose a pair of photographs is taken from exposure stations L1 and L2 so that a building appears on both photographs. In the figure flying ht. above the ground is H and the distance between 2 exposure stations is B, called air base.

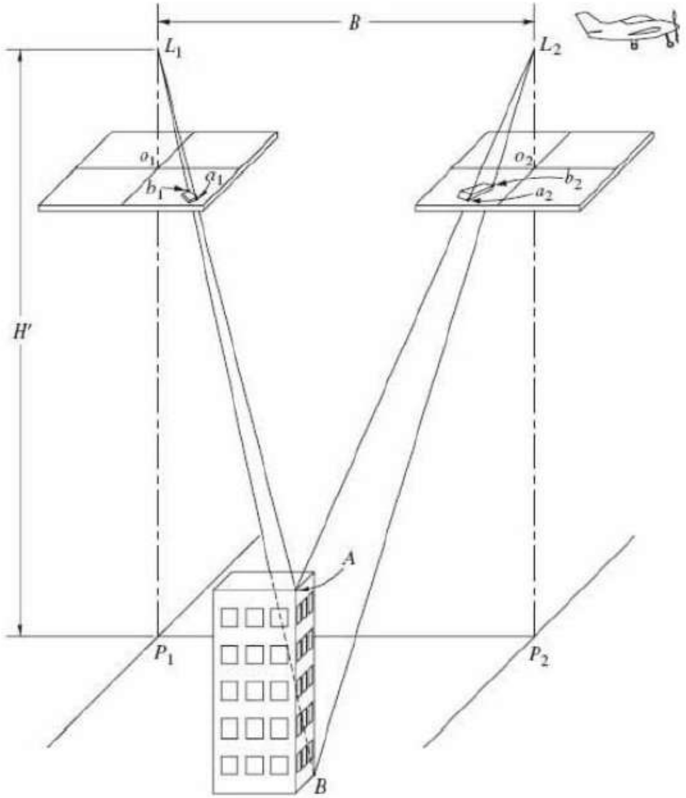


Fig: Photographs from two exposure stations with building in common overlap area.

Stereo Model

- Now if the photos are laid on the table and viewed so that the left eye sees only the left photo and the right eye sees only the right photo, a 3D impression of the building is achieved.

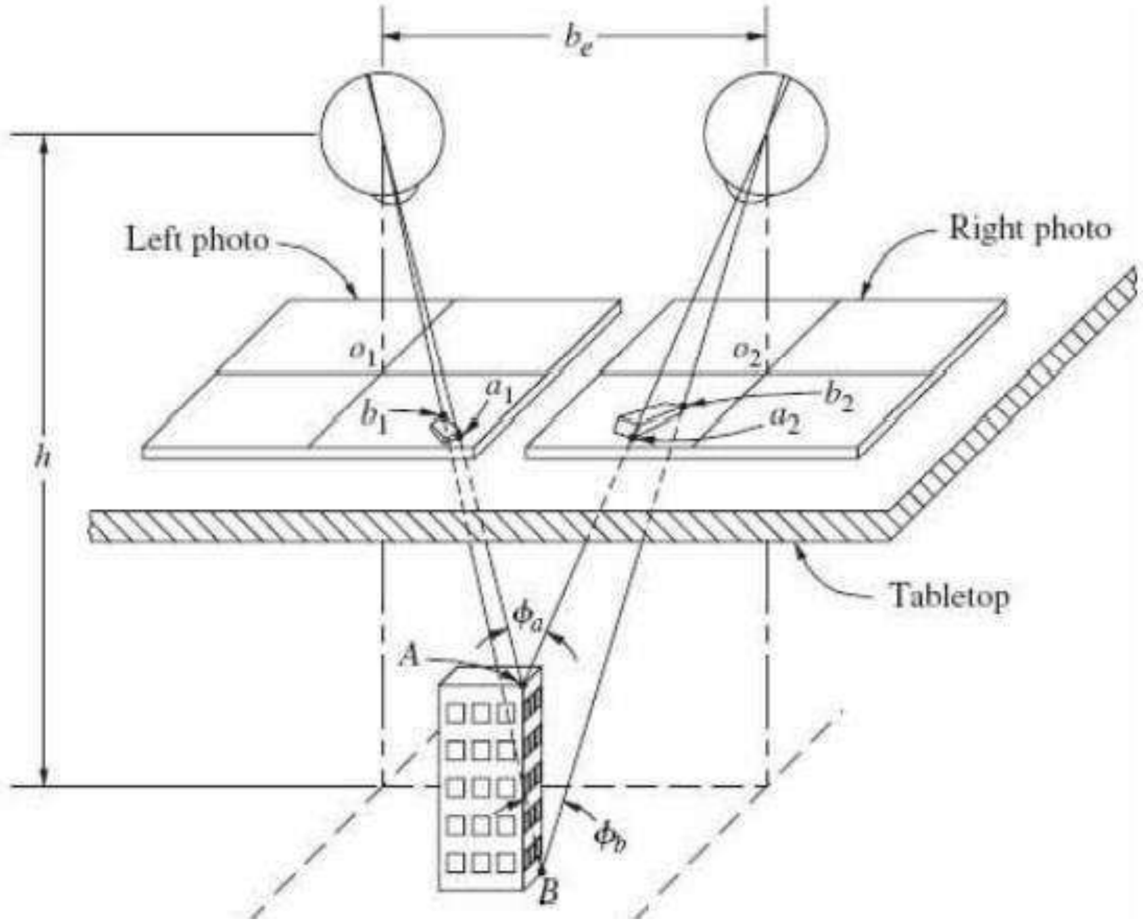


Fig: Viewing the building stereoscopically.

Conditions for viewing stereoscopic vision(Stereo Model)

1. Both photographs must cover same scene, with 60% overlap.
2. Time of exposure of both photographs must be same.
3. The scale of the two photographs should be approximately the same. Difference up to 15% may be successfully accommodated. For continuous observation and measurements, differences greater than 5% may be disadvantageous.
4. The brightness of both the photographs should be similar.

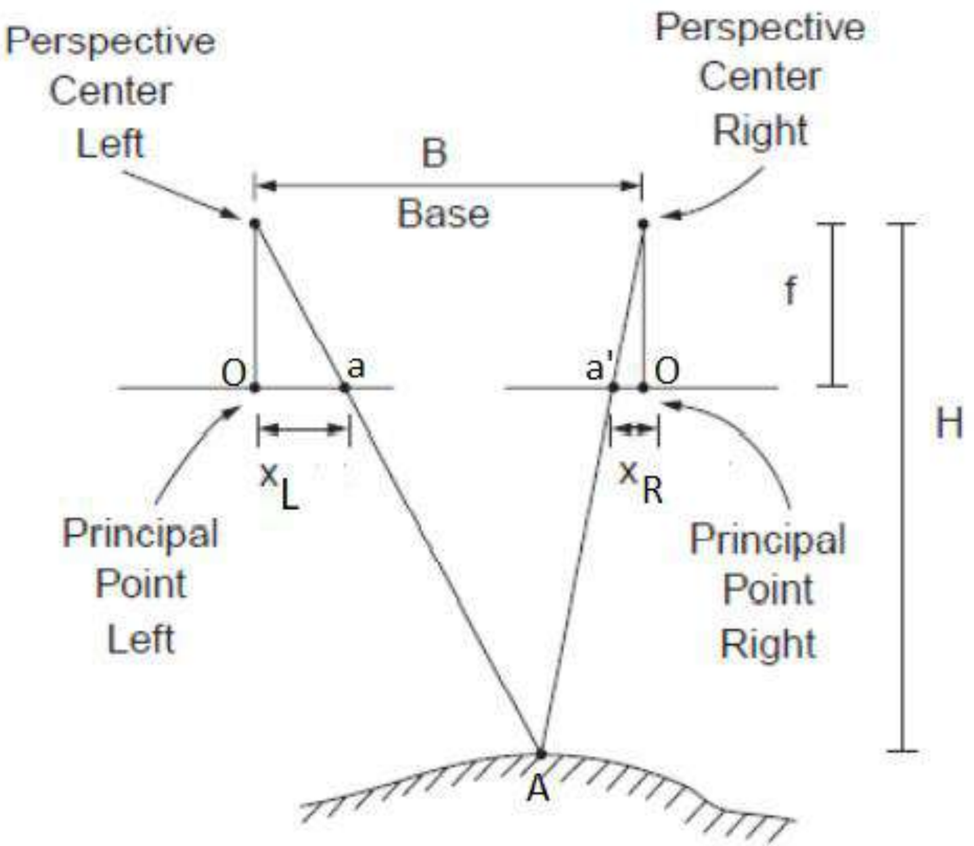
Parallax

- Parallax is the apparent shift in the position of an object caused by a shift in the position of observation.
- To demonstrate parallax hold finger in front of your eyes, while gazing at the finger, alternately close one eye and then the other. The finger will appear to move from side to side. This apparent shift of the finger is parallax, and it is caused due to the shift in the position of observation.
- Nearby objects have a larger parallax than more distant objects when observed from different positions.

Parallax bar

- In photogrammetry, a parallax bar is a tool used to measure the amount of parallax in a pair of overlapping photographs.

Parallax



- Referring to the figure, two vertical overlapping photographs are taken at the same altitude ‘H’. For a given image point ‘a’, the parallax is defined as,

$$p = x_L - x_R$$

where, x_L = measured photo distance of the point on the left image

x_R = measured photo distance of the point on the right image

Stereoscopic parallax

- The change in position of an image from one photograph to another caused by the aircraft's motion is termed as stereoscopic parallax or x-parallax or simply parallax.
- Parallax occurs for all image points appearing on successive overlapping photographs.
- The parallax of any point is directly related to the elevation of the point, and parallax is greater for high points(close to camera) than for low points (far from camera).
- Variation of parallax with elevation provides the fundamental basis for determining elevations of points from photographic measurements.

Stereoscopic parallax

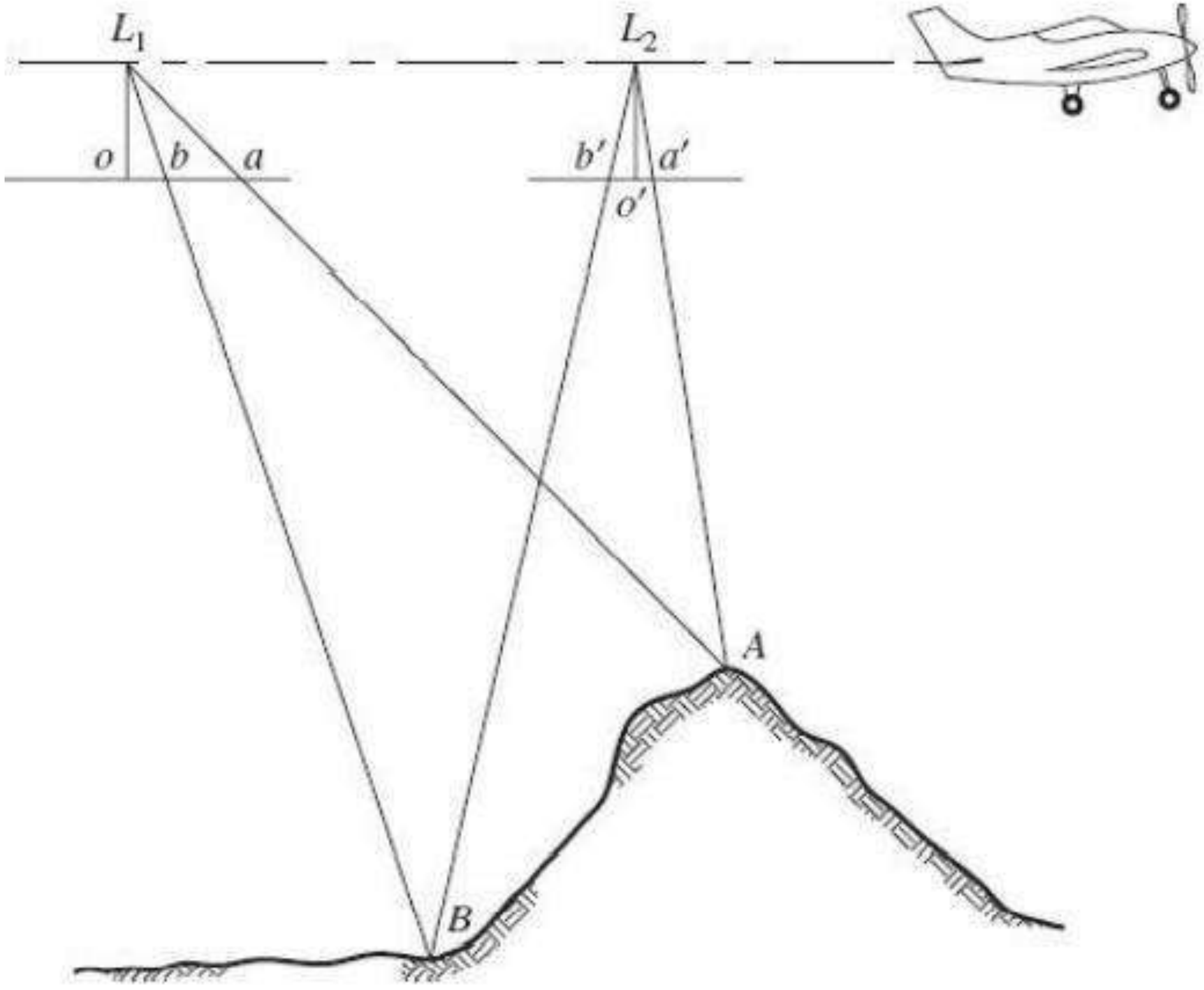
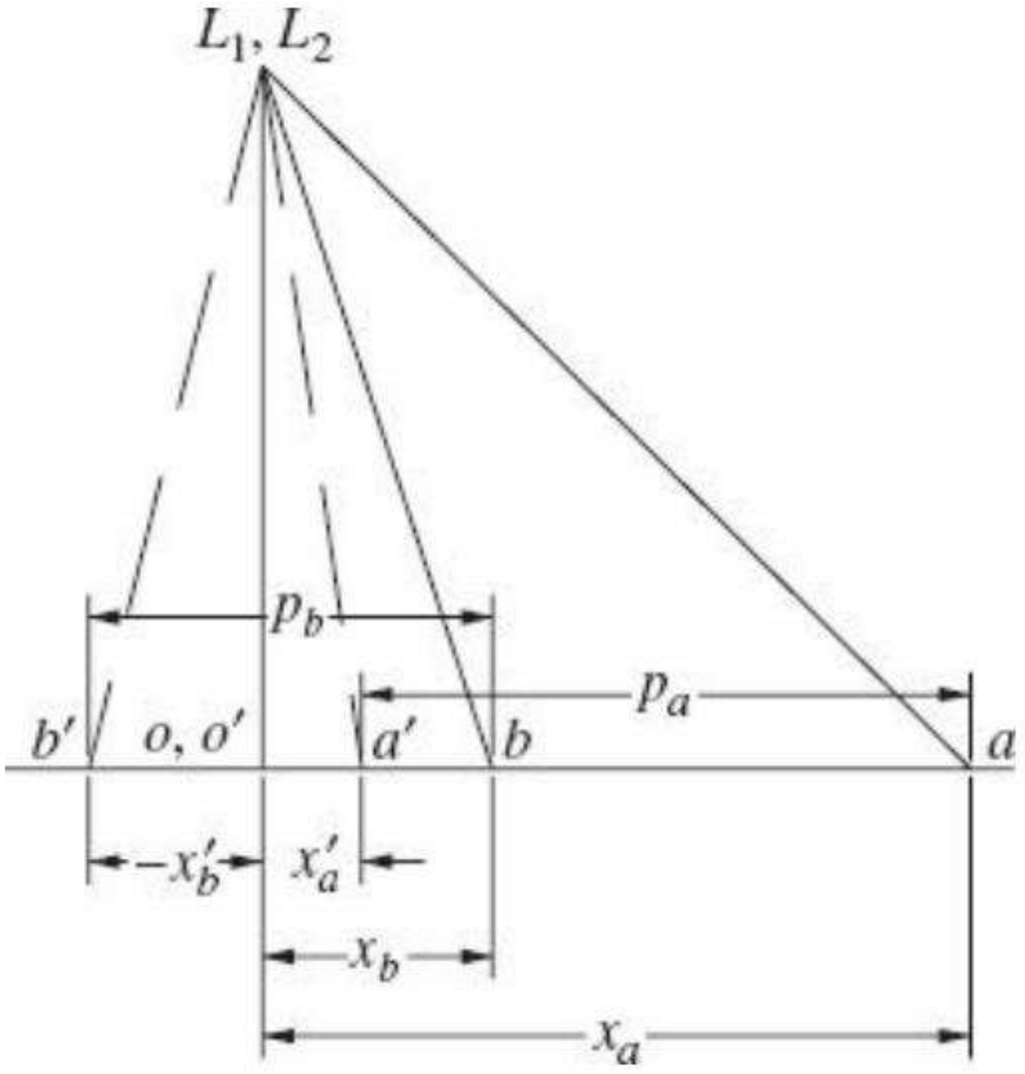


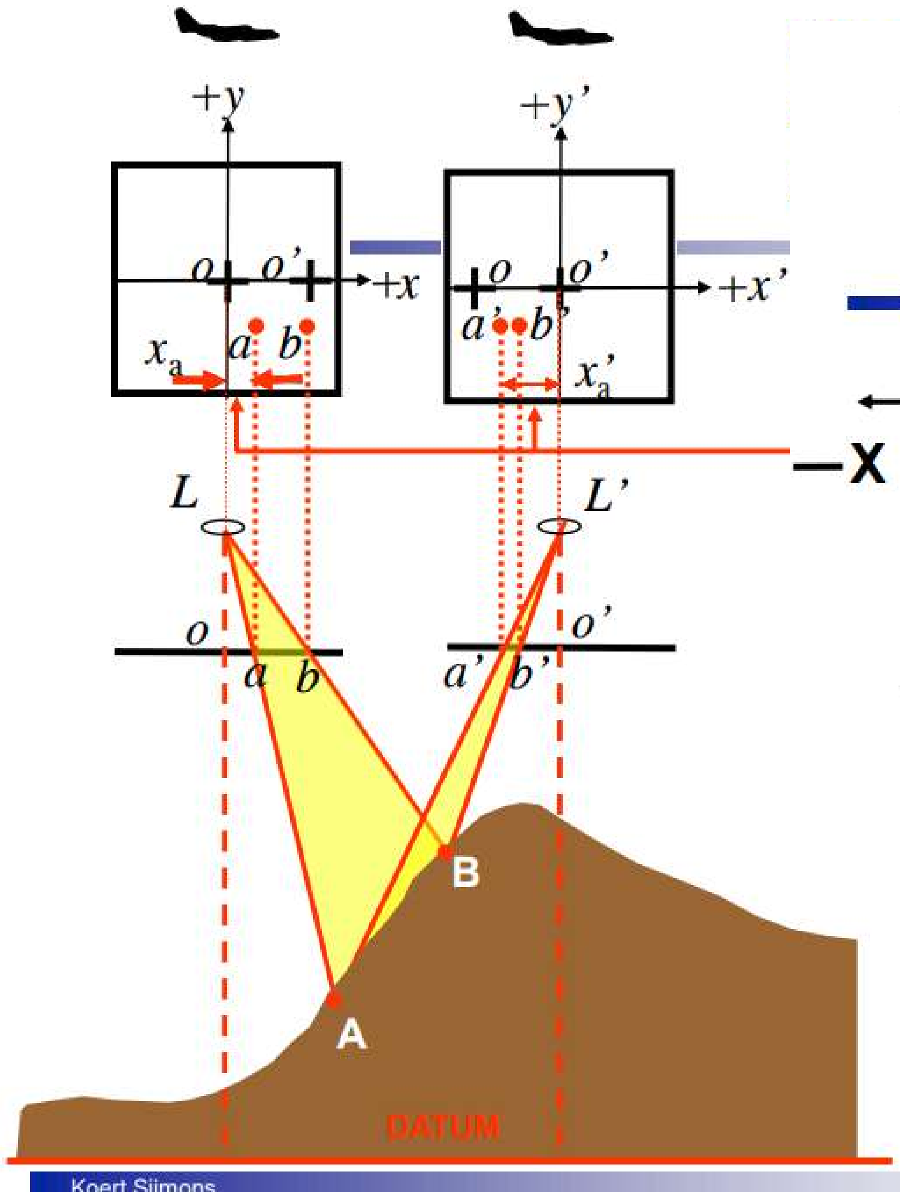
Fig: Stereoscopic parallax of vertical aerial photographs.

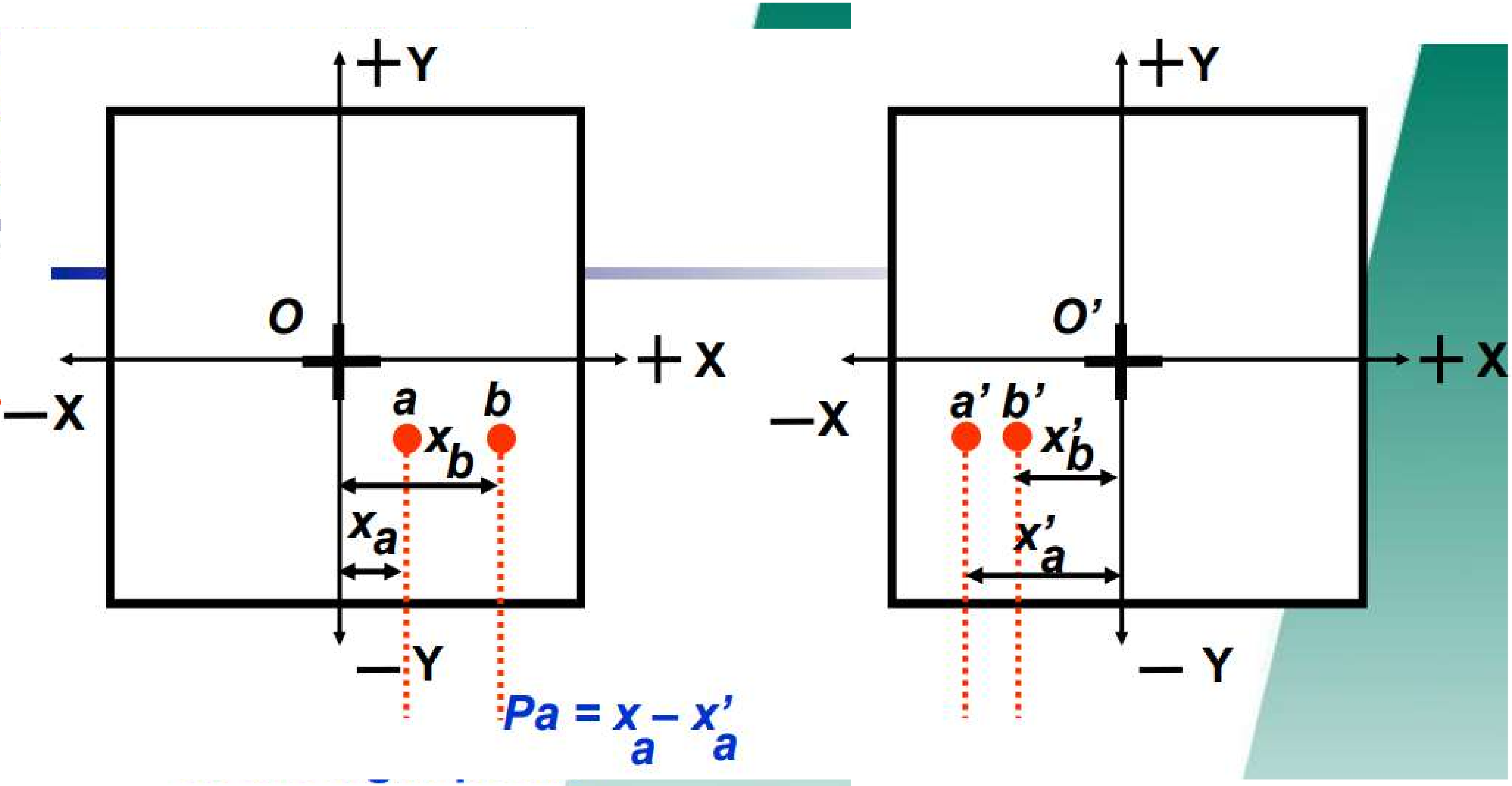


Parallax for point A = $x_a - x'_a$

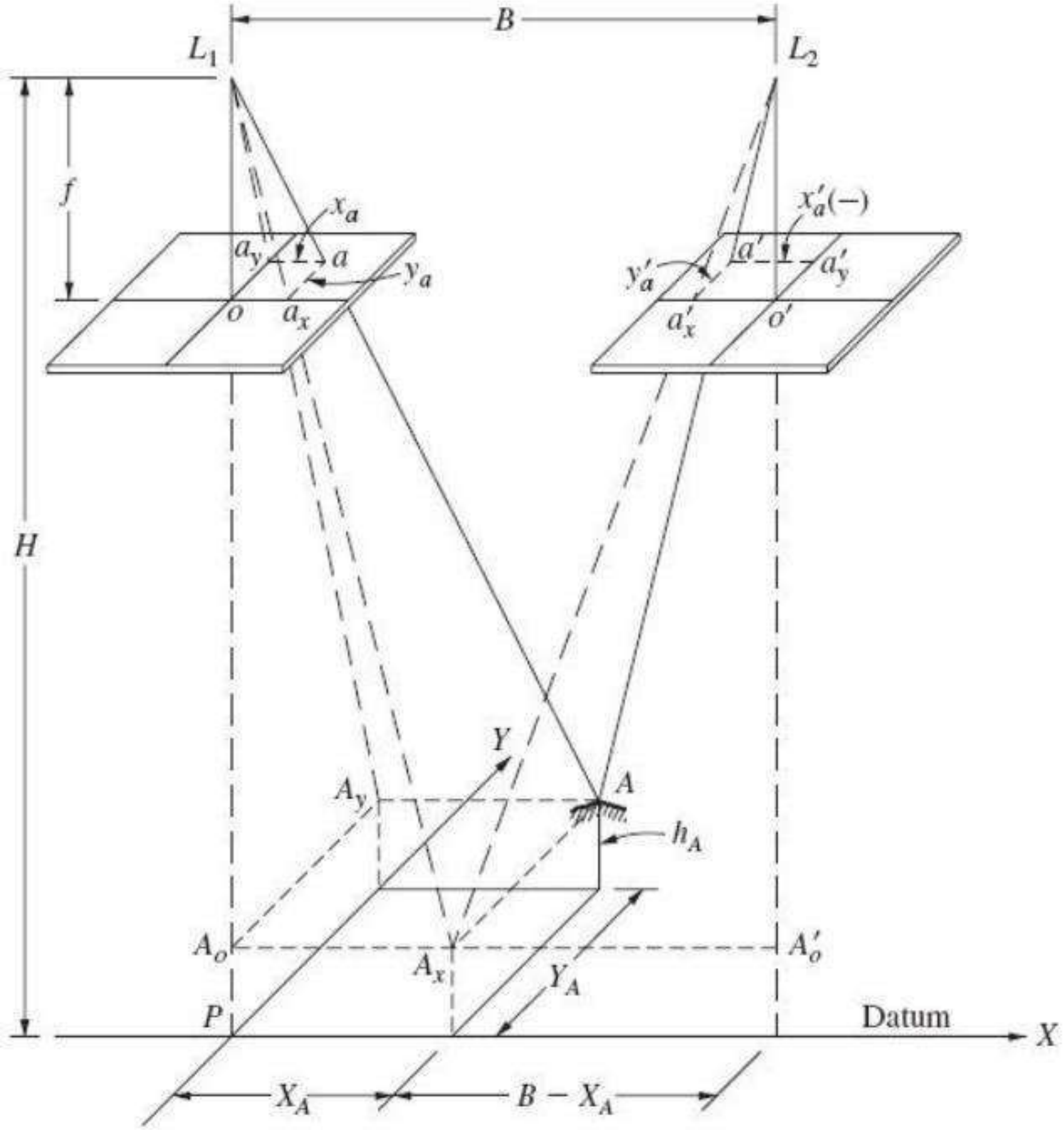
Fig: The two photographs of Fig. 8-1 are shown in superposition.

Stereoscopic parallax





Stereoscopic parallax equation



Stereoscopic parallax equation

Suppose two successive vertical overlapping photographs of a ground point ‘A’ having elevation of h_A is taken from two positions L_1 and L_2 repectively at a flying height ‘H’ from datum. Let the distance between two exposure station be ‘B’ (airbase). Also let ground Point ‘A’ appears on the left image as ‘a’ and right image as ‘a’’. If Ground coordinates of point ‘A’ is (X_A , Y_A) then repective image coordinates on left image is (x_a , y_a) and (x'_a , y'_a) on right image.

From similar triangles L_1oa_y and $L_1A_oA_y$,

$$(oa_y / A_oA_y) = (L_1o/L_1A_o)$$

$$\text{or, } (f/ H- h_A) = (y_a / Y_A)$$

$$\text{or, } Y_A = \frac{y_a (H- h_A)}{f} \text{ ………..(i)}$$

Stereoscopic parallax

Stereoscopic parallax equation

From similar triangles L_1oa_x *and* $L_1A_oA_x$ *,*

$$(oa_x / A_oA_x) = (L_1o/L_1A_o)$$

$$\text{or, } (f/ H- h_A) = (x_a / X_A)$$

$$\text{or, } X_A = \frac{x_a (H- h_A)}{f} \text{ ....(ii)}$$

Also from similar triangles $L_2o'a'_x$ and $L_2A'_oA_x$,

$$(o'a'_x / A'_oA_x) = (L_2o'/L_2A'_o)$$

$$\text{or, } (f/ H- h_A) = (-x_a / B-X_A)$$

$$\text{or, } X_A = B+ \frac{x'_a(H- h_A)}{f} \text{.........(iii)}$$

Stereoscopic parallax equation

From eq. (ii) and (iii),

$$h_A = H - \frac{Bf}{x_a - x'_a} \qquad \text{.................................(iv)}$$

Substituting p_a for $x_a - x'_a$

$$h_A = H - \frac{Bf}{p_a} \qquad \text{.................................(v)}$$

Now substituting Eq. (v) into each of Eqs. (ii) and (i) and reducing gives

$$X_A = B\frac{x_a}{p_a} \qquad \text{.................................(vi)}$$

$$Y_A = B\frac{y_a}{p_a} \qquad \text{.................................(vii)}$$

Equations (v), (vi) and (vii) are the parallax equations.

Numericals related to Stereoscopic parallax

1. A pair of overlapping vertical photographs was taken from a flying height of 1233 m above sea level with a 152.4-mm-focal-length camera. The air base was 390 m. With the photos properly oriented, flight-line coordinates for points a and b were measured as x_a = 53.4 mm, y_a = 50.8 mm, x_a' = –38.3 mm, y_a' = 50.9 mm, x_b = 88.9 mm, y_b = –46.7 mm, x'_b = –7.1 mm, y'_b = –46.7 mm. Calculate the elevations of points A and B and the horizontal length of line AB. (Ans: 585m, 614m above sea level, 427m)

Solution By Eq. (8-1)

$$p_a = x_a - x_a' = 53.4 - (-38.3) = 91.7 \text{ mm}$$

$$p_b = x_b - x_b' = 88.9 - (-7.1) = 96.0 \text{ mm}$$

By Eq. (8-5),

$$h_A = H - \frac{Bf}{p_a} = 1233 - \frac{390(152.4)}{91.7} = 585 \text{ m above sea level}$$

$$h_B = H - \frac{Bf}{p_b} = 1233 - \frac{390(152.4)}{96.0} = 614 \text{ m above sea level}$$

By Eqs. (8-6) and (8-7),

Numericals related to Stereoscopic parallax

$$X_A = B\frac{x_a}{p_a} = 390\left(\frac{53.4}{91.7}\right) = 227 \text{ m}$$

$$Y_A = B\frac{y_a}{p_a} = 390\left(\frac{50.8}{91.7}\right) = 216 \text{ m}$$

$$X_B = B\frac{x_b}{p_b} = 390\left(\frac{88.9}{96.0}\right) = 316 \text{ m}$$

$$Y_B = B\frac{y_b}{p_b} = 390\left(\frac{-46.7}{96.0}\right) = -190 \text{ m}$$

The horizontal length of line *AB* is

$$AB = \sqrt{(X_B - X_A)^2 + (Y_B - Y_A)^2} = \sqrt{(361-227)^2 + (-190-216)^2} = 427 \text{ m}$$

Assignment

Numericals related to Stereoscopic parallax

2. Overlapping vertical photograph with an airbase 650m. If the elevation of a point within the overlapping area is 283m, and the parallax of the point is 89.40mm, what is the flying height above sea level for this stereo pair? (f=152.4) [Ans:1391m above sea level]

$$H = h + \frac{Bf}{p} = 283 + \frac{650 \times 152.4}{89.4} \simeq 1391m \text{ above sea level}$$

Numericals related to Stereoscopic parallax

3. Images of the endpoints of ground line AB, whose horizontal length is 650.47 m, appear on a pair of overlapping vertical photographs. Photo coordinates measured with respect to the flight axis on the left photo were xa = 33.3 mm, ya = 13.5 mm, xb = 41.8 mm, and yb = –95.8 mm. Photo coordinates measured on the right photo were xa ′ = –52.3 mm and xb ′ = –44.9 mm. Calculate the air base for this stereopair.

Solution By Eq. (8-1),

$$p_a = x_a - x'_a = 33.3 - (-52.3) = 85.6 \text{ mm}$$
$$p_b = x_b - x'_b = 41.8 - (-44.9) = 86.7 \text{ mm}$$

By Eq. (8-9),

$$B = \frac{650.47}{\sqrt{(41.8/86.7 - 33.3/85.6)^2 + (-95.8/86.7 - 13.5/85.6)^2}} = 514 \text{ m}$$

Methods for Stereoscopic Viewing

Stereoscope

- A stereoscope is a device for viewing a stereoscopic pair of separate images, depicting left-eye and right-eye views of the same scene, as a single three-dimensional image.

There are two types of stereoscopes

i. Lens(Pocket) stereoscope

- It consists of wo simple convex lenses mounted on a frame on a stand at the normal eye separation. The lenses also serve to magnify the images, thereby enabling details to be seen more clearly.
- Lens stereoscopes are handy, cheap and are good for study of small format aerial photographs.
- It has a limited view and therefore restricts the area that can be inspected.

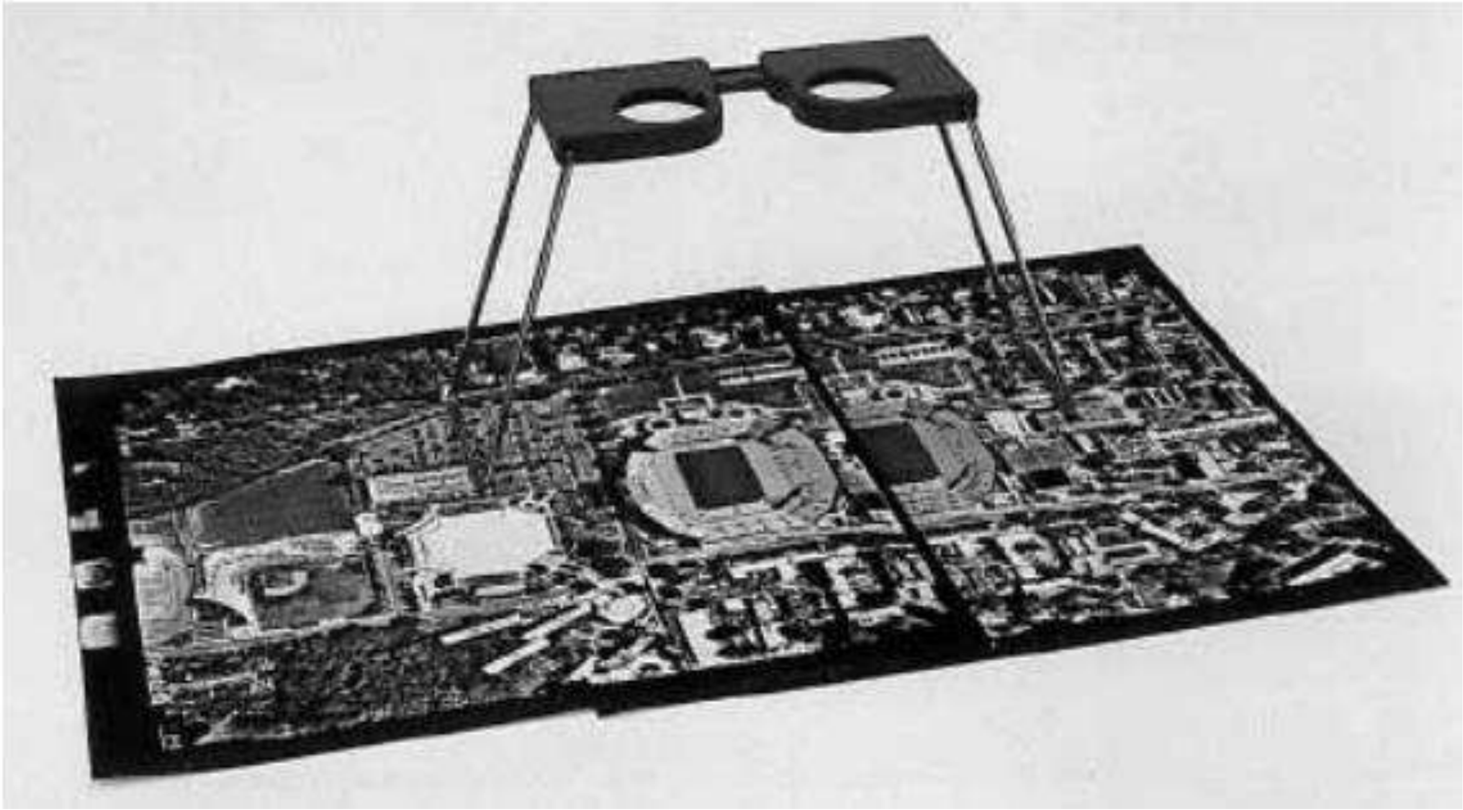
Features

- The spacing between the lenses can be varied to accommodate various eye bases.
- The legs fold or can be removed so that the instrument is easily stored or carried(a feature which renders the pocket stereoscope ideal for fieldwork).

i. Lens(Pocket) stereoscope

Disadvantage

- It requires the photo edges to be curled back to permit viewing of the larger format photographs.



Methods for Stereoscopic Viewing

ii. Mirror stereoscope

- The mirror stereoscopes are most widely used in photo interpretation and in photo measurements, in combination with parallax bar.
- A binocular viewer attachment can provide magnification.
- It also enables the entire width of the stereomodel to be viewed simultaneously.
- It consists of two large wing mirrors and two smaller eyepiece mirrors, all of which are mounted at 45° to the horizontal.

ii. Mirror stereoscope

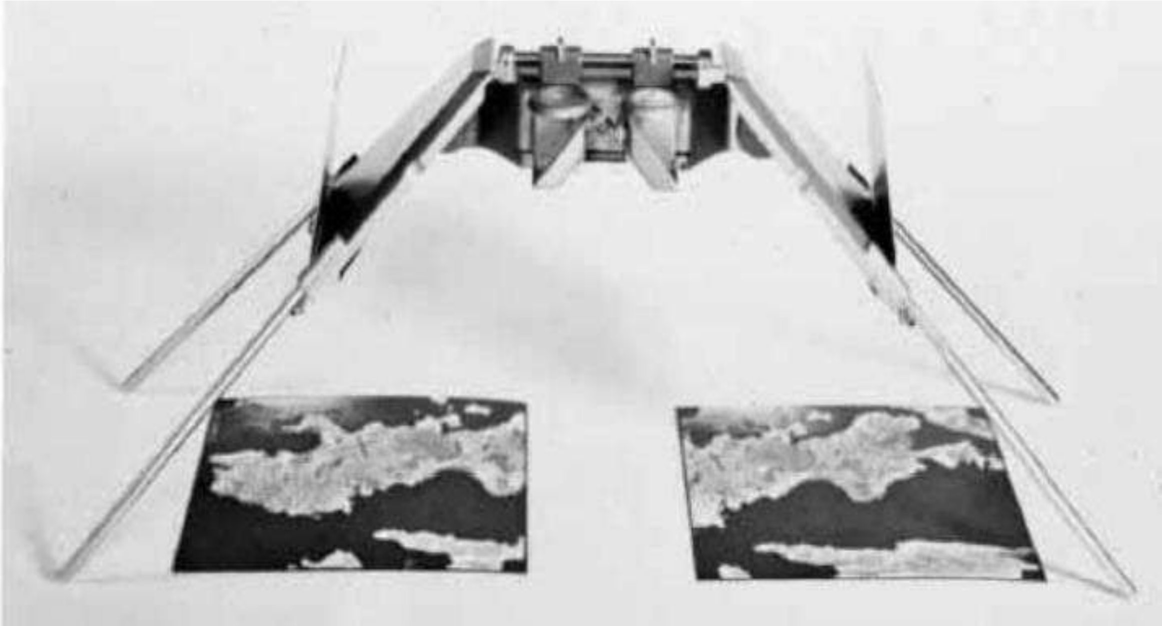
- Light rays produced from image points on the photos such as a1 and a2 are reflected from the mirror surfaces, according to the principles of reflection

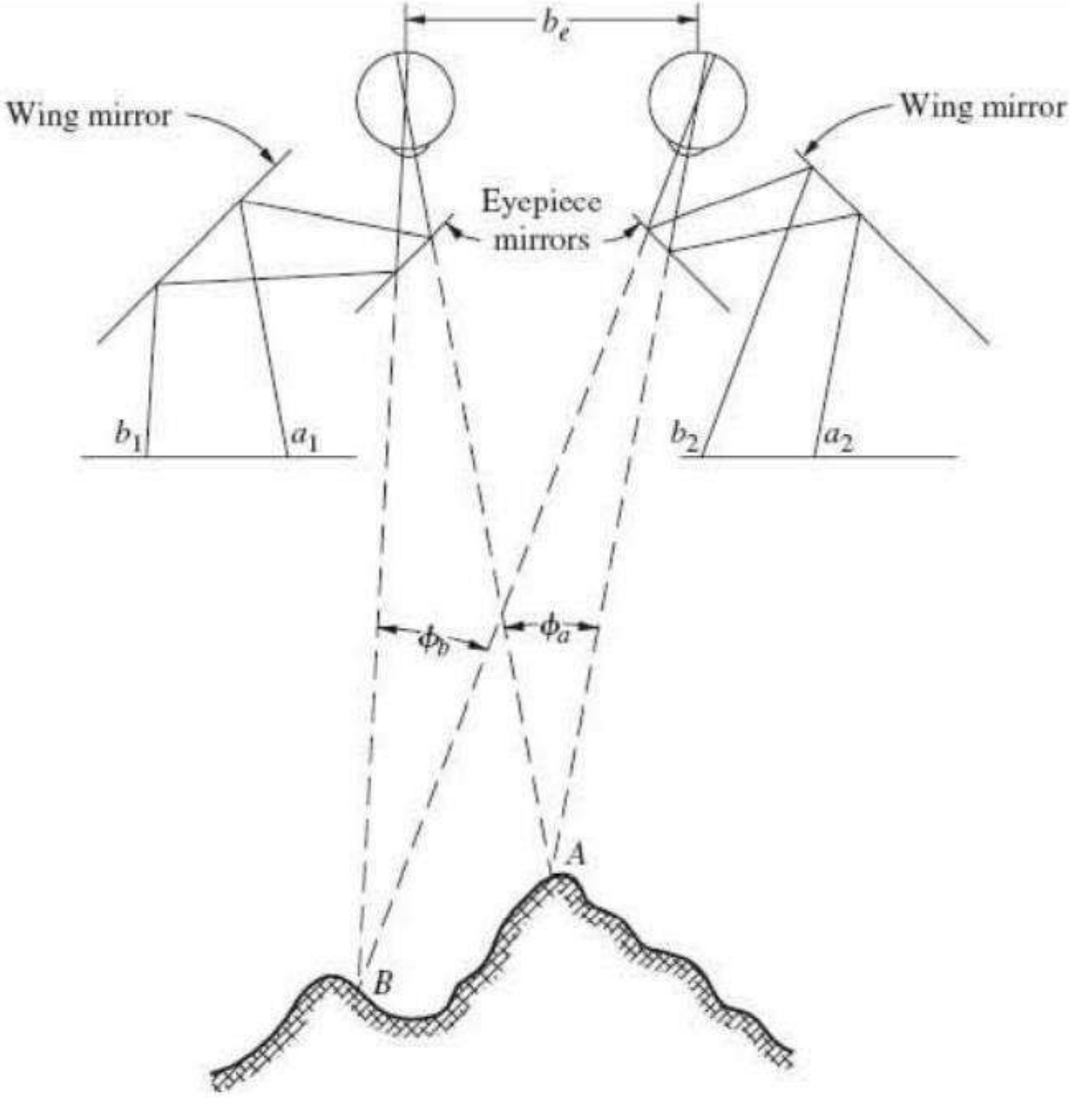
and are received at the eyes, forming parallactic angle

φa . The brain automatically associates the depth to

point A with that parallactic angle. The stereomodel

is thereby created beneath the eyepiece mirrors.





Methods for Stereoscopic Viewing

Anaglyph System

Anaglyph - are stereo pairs of images in which each image is shown using a different color. The two images are overlapped and then viewed using red/green or red/blue glasses (depending on the colors used).

- If the anaglyph image is viewed through a pair of anaglyph glasses that contain corresponding color filters, a stereoscopic image can be seen.
- Usually the image for one eye is red and the image for the other eye is a contrasting color such as blue, cyan or green. If viewed through appropriately colored glasses (see Fig. 2) each eye sees a slightly different picture.
- Video games, theatrical films, and DVDs can be shown in the anaglyph 3D process.
- This system are classified as least accurate instrument which is replaced by modern system.

Advantage:

- It is simple to create anaglyph images and the glasses are inexpensive.
- It is used to make stereoscopic hard copies.

Methods for Stereoscopic Viewing

Anaglyph System

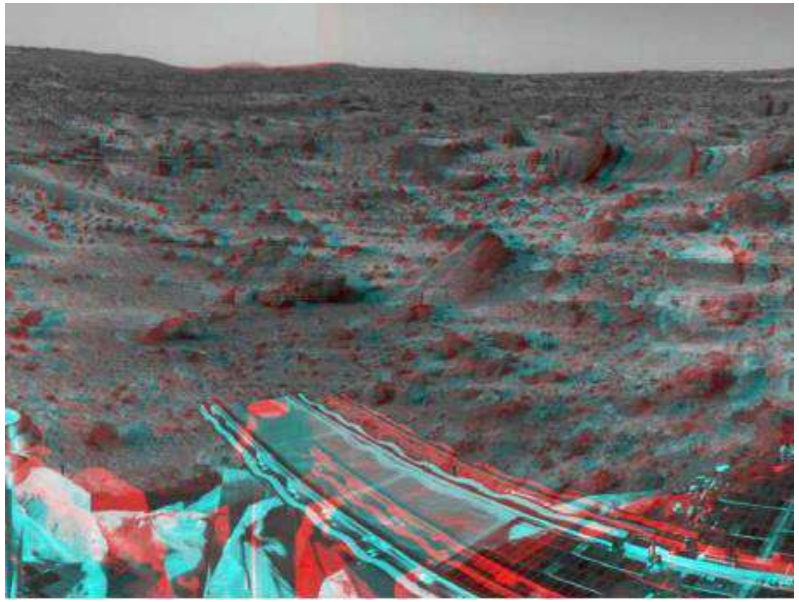


Fig2: Anaglyph glasses with red/blue filter

Fig1: Example of a anaglyph image

Source: https://www.cg.tuwien.ac.at/courses/Seminar/WS2006/stereo_techniques.pdf

Modern Methods for Stereoscopic Viewing

1. Anaglyph system

2. Polarized 3D

- Polarized 3D uses special glasses with lenses that filter light waves so that each eye sees a slightly different image. The projector or screen displays two images at once, one for the left eye and one for the right eye, with each image polarized in a different direction. The glasses then filter out the polarized light that does not match the orientation of their lenses, creating a 3D effect.

3. Active 3D:

- Active 3D glasses use LCD lenses that alternate between opaque and transparent at a very high speed, synchronized with the display. The left and right lenses are alternated so that each eye sees a different image. The viewer's brain combines these two images to create a 3D effect.

Modern Methods for Stereoscopic Viewing

4. Autostereoscopy:

- Autostereoscopy, also known as glasses-free 3D, allows users to view 3D images without the need for special glasses. This technology works by using a lenticular lens or parallax barrier to project slightly different images to each eye. This technique requires precise positioning of the viewer's eyes in order to create the 3D effect.

5. Virtual Reality:

- Virtual Reality (VR) uses a combination of computer graphics, 3D modeling, and interactive devices such as head-mounted displays to create a fully immersive 3D experience. With VR, the user is completely immersed in a 3D environment and can move around and interact with objects in a realistic way.

Methods for Stereoscopic Viewing

Process for Orientation and Use of Pair of Photographs in stereoscope

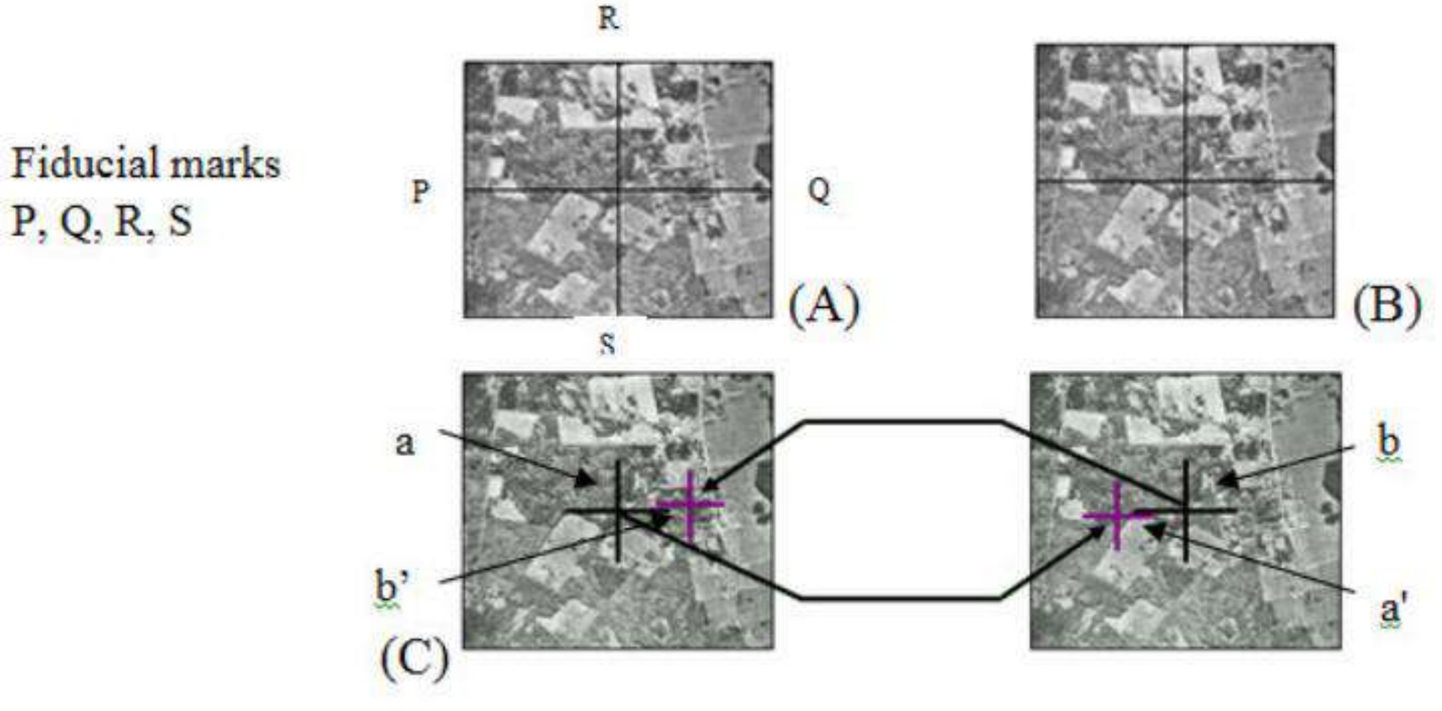
A stereo pair consists of two consecutive photographs (A, and B) having a certain percentage of overlap, and these are placed in the manner in which they were taken during the mission; otherwise a pseudo- stereoscopy is obtained.

The process of orientation of these stereo pairs involves the following steps:

1. Connect the fiducial mark(center of the each side of a photograph) of either side to obtain the principal point which is the geometric center of the photograph as shown by fig: A & B.
2. In a stereopair the principal point of a photograph can be found on the either photograph, which is known as conjugate principal point on that photograph (marked as pink in fig (C)).
3. Connect principal point and conjugate principal point on each photograph by a straight line.
4. Adjust these two photographs are in the stereoscope so that that these two straight lines are coincident.

To achieve good stereoscopic vision the distance of the two straight lines should be equal to the intraocular distance y.

Process for Orientation and Use of Pair of Photographs in stereoscope



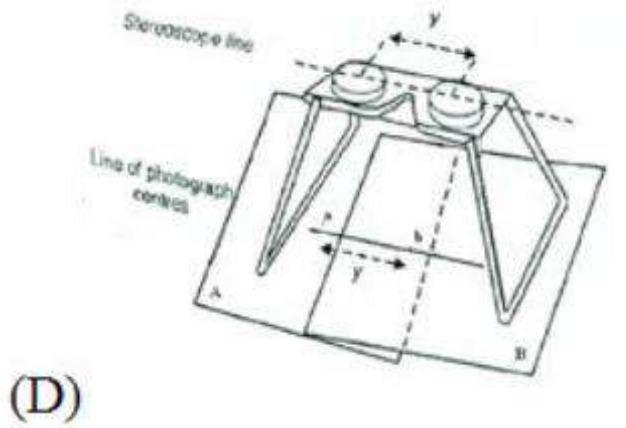


Fig1: (A), (B) are photographs makes a stereo pair, (C) principal points (a, b) are marked as black and conjugate principal points (a’, b’) are marked as pink.   (D) Stereoscope.

Source: http://ecoursesonline.iasri.res.in/mod/page/view.php?id=124945

Relation between Camera, Ground and Image in coordinate system

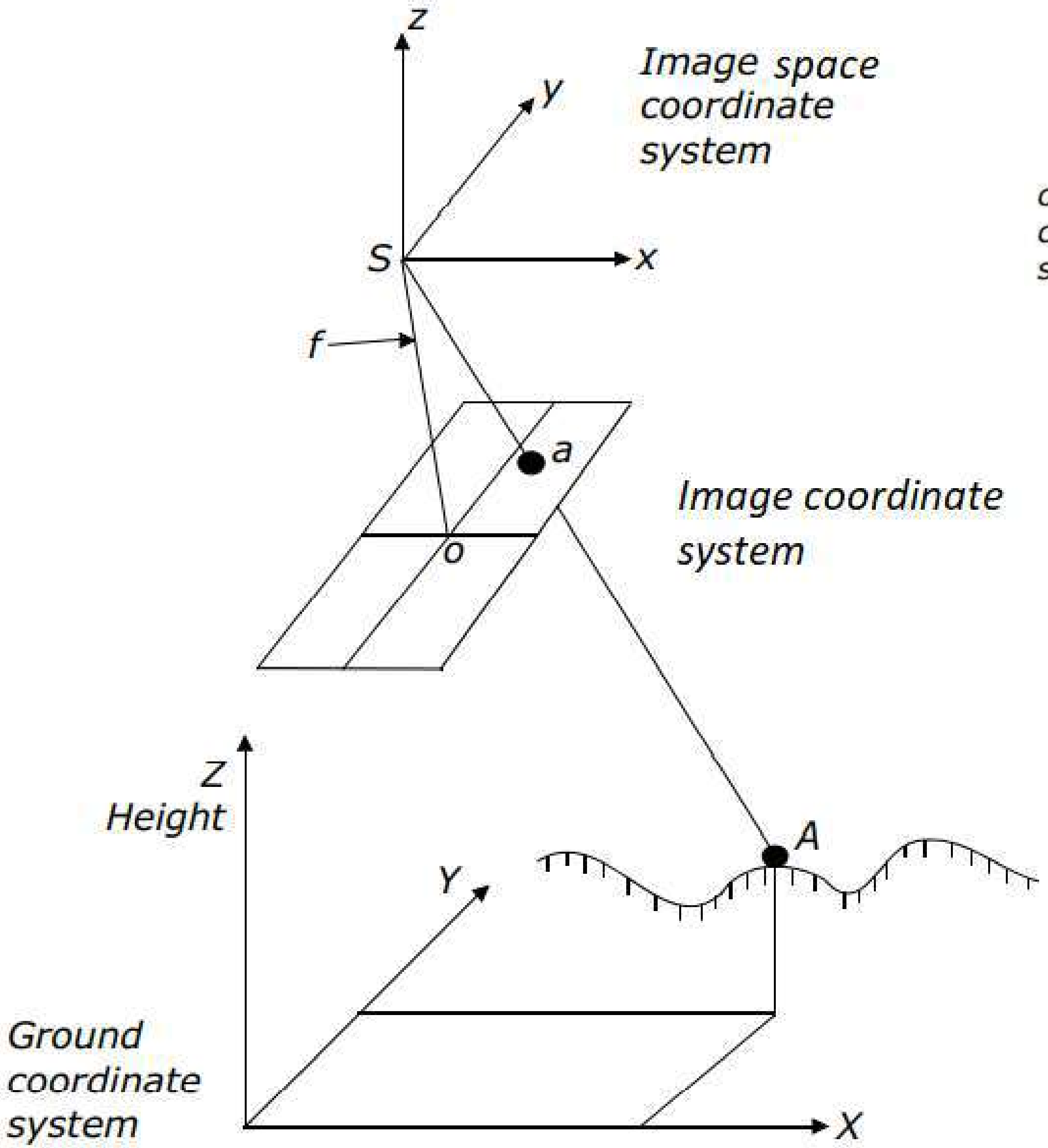


Fig1: showing relation between Camera, Ground and Image itself; here S is the lens(perspective center) of the camera, a is the position in image of ground object A

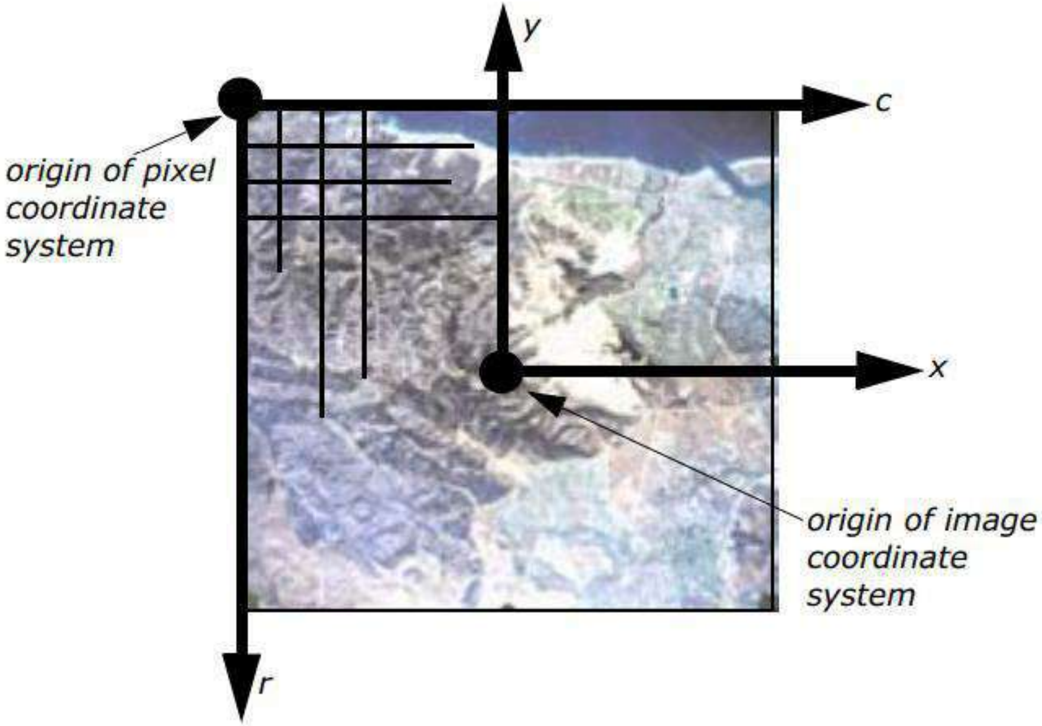


Fig2: showing relation between pixel coordinate system and image coordinate system

Concept of coordinate system

Image space coordinate system (camera coordinate system or photo coordinate system)

- Identical to image coordinate system, except it adds a third axis: z-axis.
- The origin of this system is defined at the perspective center.
- x-axis and y-axis are parallel to the x-axis and y-axis in the image coordinate system, while the z-axis is the optical axis which means, z-value of an image point in this system is usually equal to the focal length (f) of the camera as shown in fig1.
- Describe positions inside the camera, and usually measured in millimeters or microns. Therefore, it is also known as camera coordinate system.
- It is a 3D Cartesian coordinate system.

Concept of coordinate system

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 Figure 2.
- Image coordinates are used to describe positions on the film plane.

Ground coordinate system (*also called object space 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) may be local or global system and are usually expressed in feet or meters. The Z value is elevation above mean sea level for a given vertical datum. See fig1
- When it is used as global system, the origin can be the Earth's center of mass (geocentric system) or some convenient local point with respect to known map projection (topocentric system).
- Photogrammetrically compiled data or the control point coordinates are usually available in geocentric (Φ,λ,h) or topocentric (x, y, h) coordinate system, but these have to be transformed into Cartesian system to serve as object space coordinate system for photogrammetry

Photogrammetric Orientations

Stereo restitution

- Stereo restitution in photogrammetry refers to the process of obtaining three-dimensional information about an object or scene by analyzing pairs of overlapping images captured from different angles.
- It involves the use of stereo vision, which is the ability to perceive depth by combining two slightly different views of the same scene.
- Stereo restitution in photogrammetry can be performed using a variety of techniques, including manual measurement, semi-automatic feature matching, and fully automatic algorithms. The choice of method depends on factors such as the complexity of the scene, the level of accuracy required, and the availability of software tools and hardware resources.

The process comprises of the following:

i. Interior orientation

ii. Exterior orientation (Relative and Absolute orientation)

Photogrammetric Orientations

Theory of Orientation

- Orientation is the procedure through which transformation parameters from one coordinate system to a second coordinate system are determined.
- Fundamental operations in photogrammetry.
- Used to recover the geometric relationship between an object and the image captured.
- In photogrammetry, orientations are described as interior and exterior or relative and absolute.
- Interior and exterior orientations relate to the digital photogrammetry.
- Relative and absolute orientations along with interior and exterior orientations were used for operating analog/analytical stereo-plotters.

Photogrammetric Orientations

Interior(Inner) orientation

- IO is the procedure whereby the geometric characteristics of an aerial photograph are mathematically related to the geometric characteristics of the camera.
- Interior orientation is primarily used to transform the image pixel coordinate system or other image coordinate measurement system to the image space coordinate system.
- Interior orientation defines the internal geometry of a camera or sensor (camera characteristics) as it existed at the time of image capture.
- For a frame camera, the internal geometry of the camera includes:

i. Focal length

ii. Location of fiducial marks

iii. Location of principal point in the image plane

iv. Description of lens distortion

- In case of digital metric camera, the camera characteristics include.

i. Focal length

ii. Pixel size

- These information are obtained from camera calibration report.

Photogrammetric Orientations

Exterior orientation

- EO determines the mathematical relationship between image coordinates (x, y, z) and real-world ground coordinates (X, Y, Z).
- It involves defining the position and angular orientation of the camera that captured the image.
- There are six parameters(3D coordinates of the perspective center wrt ground coordinate system and 3 rotations around the image space coordinate axes) of EO that express the spatial location and angular orientation of the image.
- The positional elements of exterior orientation include Xo, Yo, and Zo. They define the position of the perspective center (O) with respect to the ground space coordinate system (X, Y, and Z). Zo is commonly referred to as the height of the camera above sea level, which is commonly defined by a datum.
- The angular or rotational elements of exterior orientation describe the relationship between the ground space coordinate system (X, Y, and Z) and the image space coordinate system (x, y, and z). Three rotation angles are commonly used to define angular orientation. They are omega, phi , and kappa.

Photogrammetric Orientations

Exterior orientation

- Unlike interior orientation, EO requires that the control points to be located in both images of stereo pair.
- Exterior orientation parameters can be derived in one of three ways: (1) direct space resection (2) relative orientation followed by absolute orientation. (3) simultaneous orientation by bundle adjustment.
- For resection, at least 3 controls are required and shall be well distributed in each image.
- Knowing the six exterior orientation parameters for an image is necessary for any photogrammetric processing aimed at creating products from such an image. Whether you perform map compilation on a stereo plotter or generate an ortho image, the six exterior orientation parameters need to be computed before you start the production process.

Exterior orientation

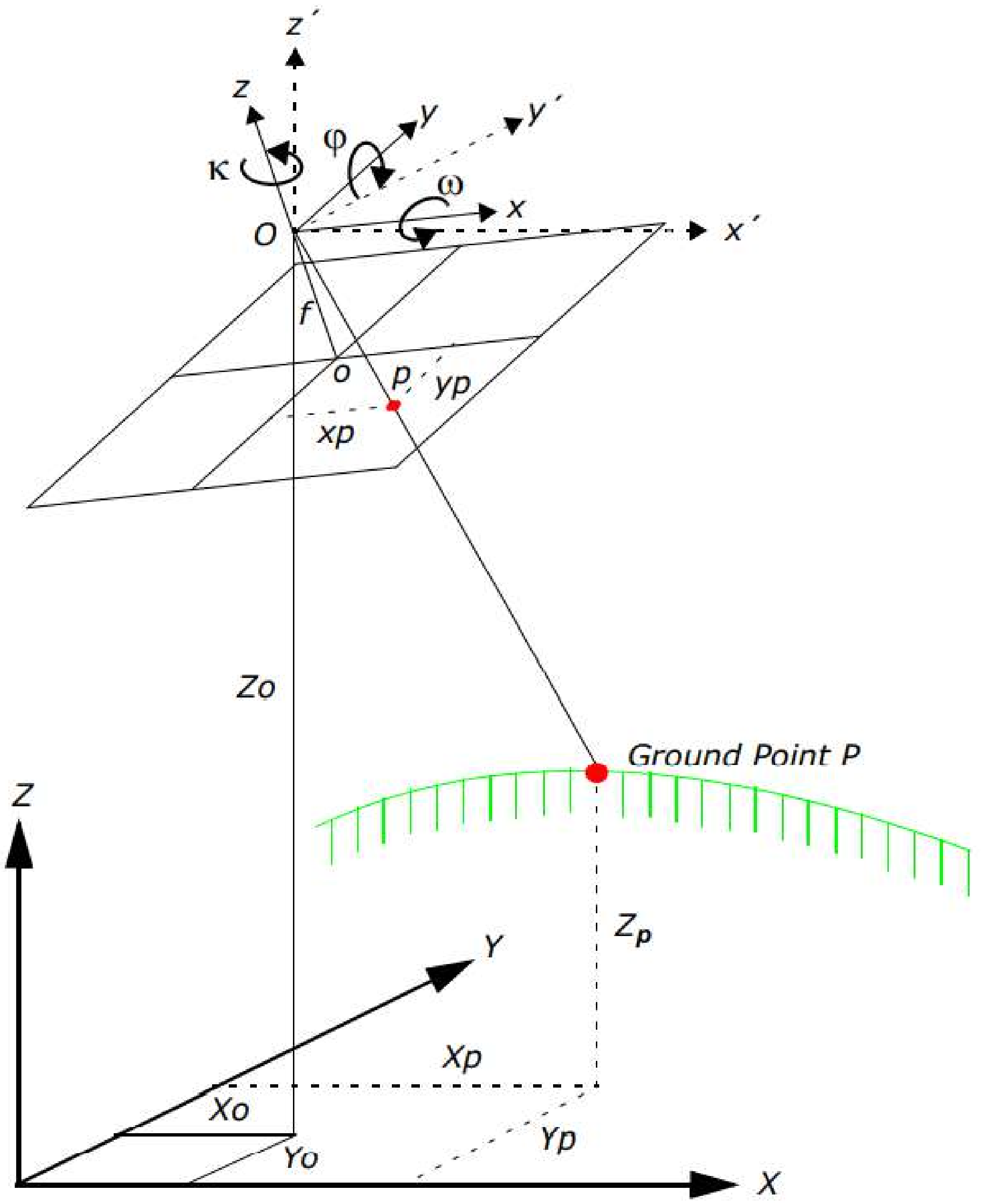


Fig: showing elements of exterior orientation; angular element: omega , phi , and kappa and positional element X_O, Y_O, Z_O

Photogrammetric control

Photogrammetric control

- Ground Control Points(GCP) or simply Ground Controls refers to physical points on the ground with known coordinates with respect to some horizontal coordinate system and/or vertical datum.
- GCP provides the means for orienting or relating aerial photographs to the ground at the time of exposure.
- Almost all phases of photogrammetric work requires some ground controls.
- Generally classified as either horizontal control or vertical control.
- Horizontal Control – position of point in object space is known in some XY coordinate system, e.g., state plane coordinate system
- Vertical control – elevation of the point is known with respect to a vertical datum e.g., mean sea level
- Total Control – points with known planimetric position and elevation and act as horizontal and vertical control.
- Cost of establishing ground control ranges between 20 to 50 % of total mapping cost.
- GCP establishment is important aspect as the accuracy of mapping entirely depends on it. Therefore it should be carefully planned and executed.

Relative Orientation (RO)

- It is the process of establishing the relationship between two consecutive photographs or images at it existed at the time of exposure to form the stereo model.
- It involves the determination of the position and attitude of one of a pair of stereo images with respect to another.
- This process orients one image relative to another image.
- Can be performed with more than 2 images in a sequential procedure, once the 1st pair of images is relatively oriented. In this process each successive image is oriented to its preceding image.
- It is the basis of independent model block adjustment.
- Relative orientation is based on the coplanarity condition that two image points on a stereopair, the perspective centers of the two images, and the object point lie on the same plane.
- Relative orientation is an important process that must be performed before we scale the imagery to the ground datum through the process of absolute orientation. To form a cohesive block, all images in the block should be relatively oriented with respect to each other through the process of relative orientation.

Relative and absolute orientation

Absolute Orientation

- Absolute orientation is a 3-D conformal transformation that converts the model coordinates obtained during the relative orientation into correctly oriented mapping coordinates.
- There are seven parameters in this 3-D conformal transformation, including three rotation angles $R\omega$, $R\varphi$, and $R\kappa$, three translation components T_X, T_Y, and T_Z, and a scale factor s.
- In this process at least three control points with known horizontal and vertical positions are necessary to achieve a result.
- The accuracy of absolute orientation depends on the quality of the relative orientation and the accuracy of the control points.
- Without performing the absolute orientation process, the generated map would not be specifically associated with a certain location in space. Generating maps that have geo-location information such as datum and coordinates systems can only happen after the process of absolute orientation is performed following relative orientation.

The relative and absolute orientations can be performed on an individual stereopair or on complete image blocks covering a large area. In the latter case, the term aerial triangulation is often used to describe the procedure.

Absolute Orientation

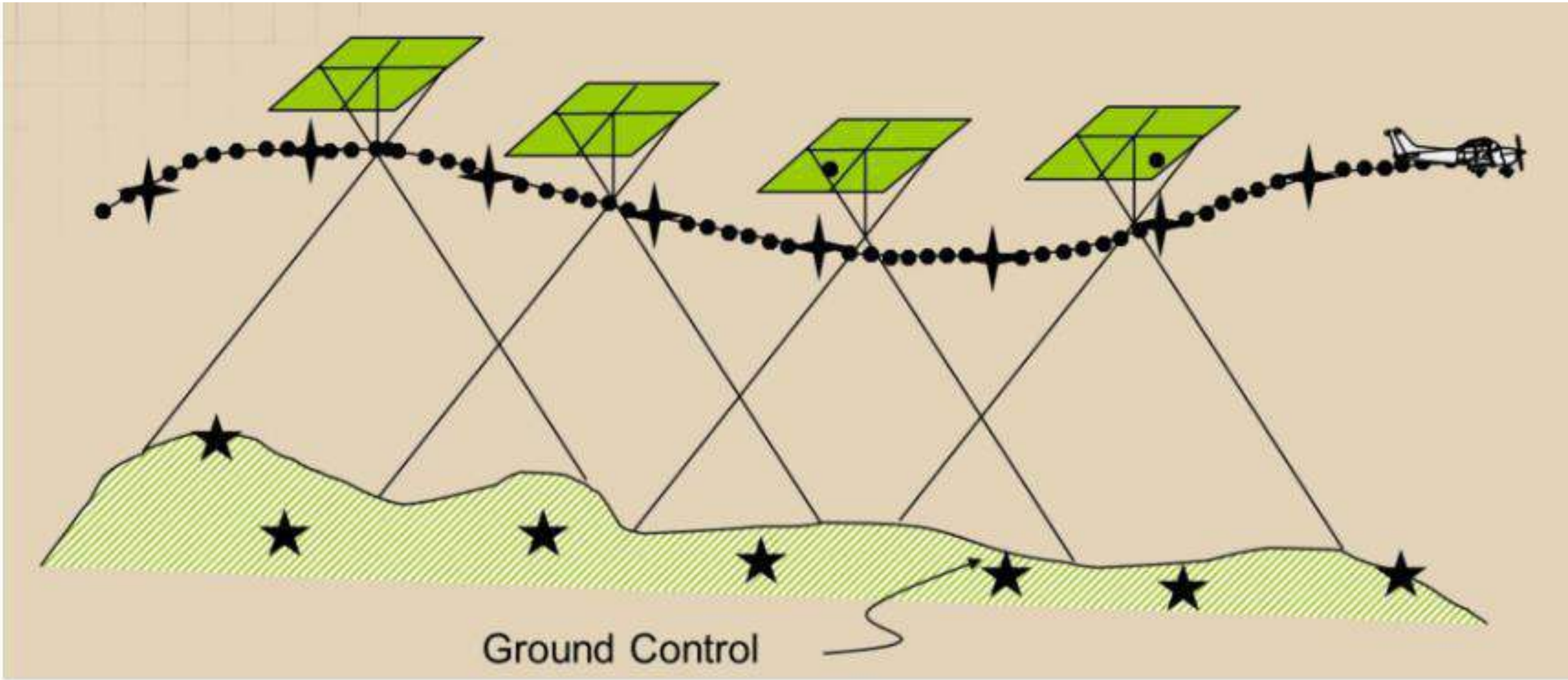


Fig: showing images being tied up to the ground with seven ground controls

Collinearity Condition

Collinearity Condition

- Fundamental condition in analytical photogrammetry.
- It is the condition in which the exposure station of any photograph(perspective center), any object point in the ground and its photographic image all lie on a straight line in 3D space.
- This condition hold true irrespective of the angular tilt of a photograph.
- The equations that express the collinearity condition are referred to as collinearity equation.
- They describe the relationships among image coordinates, ground coordinates, the exposure station position and angular orientation of a photograph as

Collinearity Condition

Collinearity Condition

$$x_a - x_o = (z_a - z_o)\left[\frac{m_{11}(X_A - X_L) + m_{12}(Y_A - Y_L) + m_{13}(Z_A - Z_L)}{m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L)}\right]$$

$$y_a - y_o = (z_a - z_o)\left[\frac{m_{21}(X_A - X_L) + m_{22}(Y_A - Y_L) + m_{23}(Z_A - Z_L)}{m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L)}\right]$$

where,

(x_a, y_a) = image coordinates, (x_o, y_o, z_o) = principal point coordinates (usually known from camera calibration);

X_A, Y_A and Z_A are ground coordinates of the corresponding object point; X_L, Y_L and Z_L are ground coordinates of the exposure station; and the m's are functions of three rotation angles omega, phi, kappa.

- Thus, if the location of the exposure station is known along with the rotation angles, then for any position on the ground, the associated image point can be computed through collinearity equations.
- This is how DEMs are used to generate digital orthophotos.

Collinearity Condition

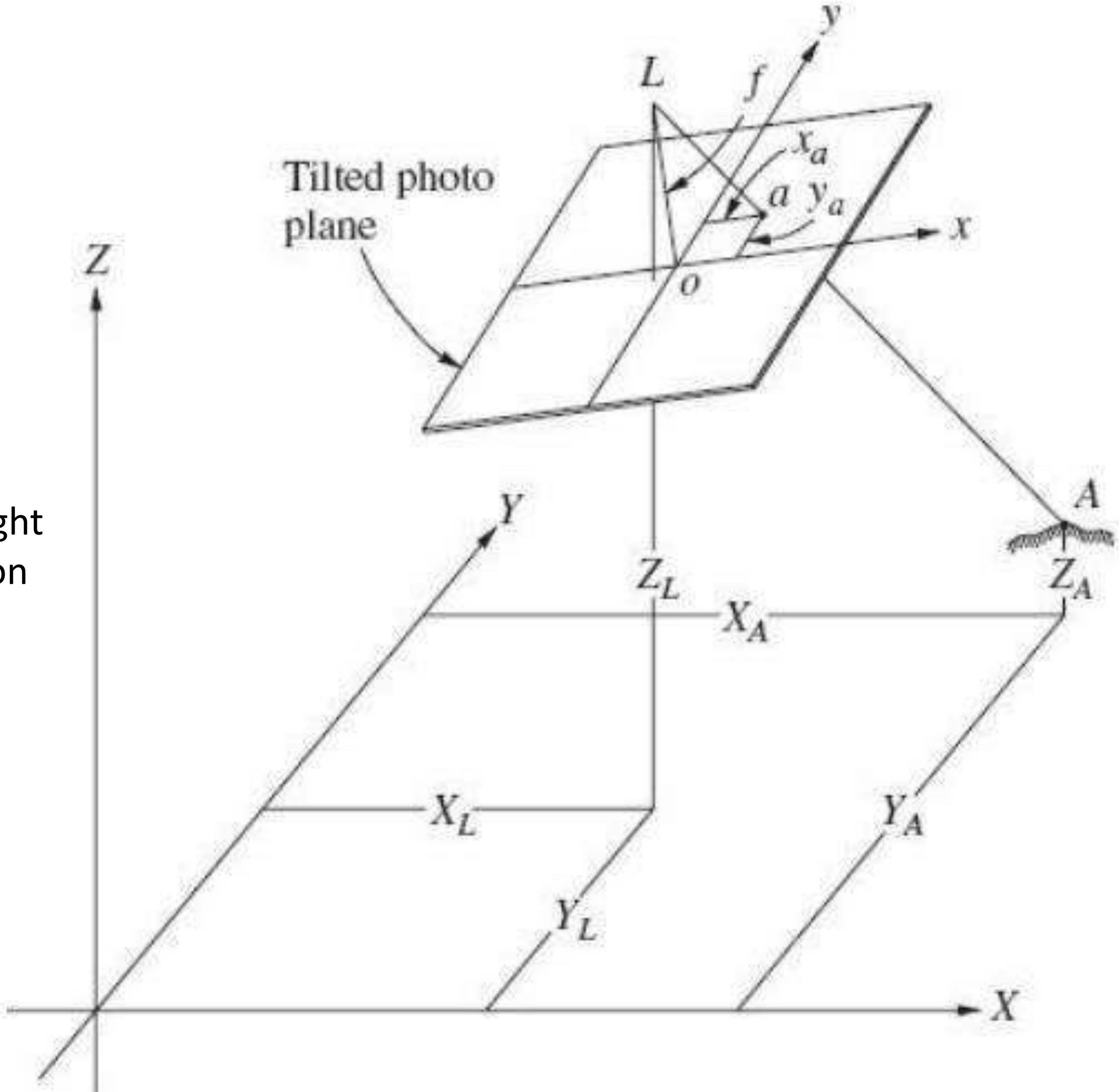


Fig: 'L', 'a', and 'A' all lie in a straight line; showing collinearity condition

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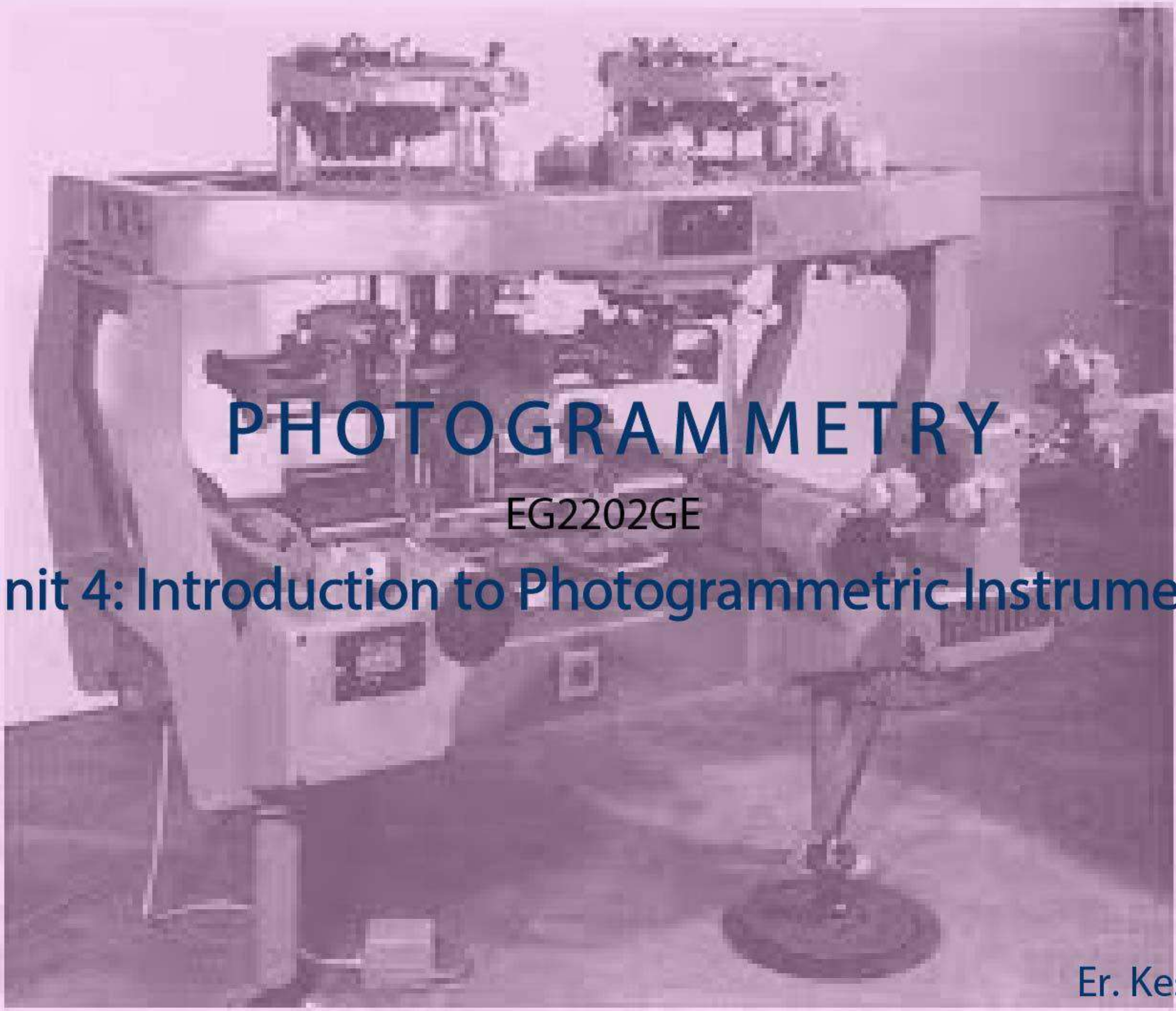

PHOTOGRAMMETRY

EG2202GE

Unit 4: Introduction to Photogrammetric Instruments

Lecture by
Er. Keshav Raj Bhusal

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4.1. Background

4.2. Point Transfer and Image Matching techniques

4.3. Technical features for the following Photogrammetric instruments:

- Stereo Plotters
- Analytical Plotters
- Digital Photogrammetric workstation

4.4. Rectifier and process of Rectification

Photogrammetric Instruments

Background

Photogrammetric Instruments were developed and manufactured mainly for the preparation of maps.

Different instruments were made on the basis of different criteria, such as: purpose, precision, efficiency, technology or method etc.

- *Purpose*: The purpose may be for transferring points, viewing the photographs, compilation of maps, etc. such as point transfer device, stereoscope, stereoplotter, etc.
- *Precision*: Some instruments were made for different accuracy of end products. Such as topographic plotter, precision plotter etc.
- *Efficiency*: Efficiency is one of the key factors for mapping, so every time attempt will be made to increase efficiency of the instrument.
- *Technology or Method*: Depending upon the technological advancement or the method to be adopted, instrument will be manufactured accordingly such as orthophoto production equipment , analytical plotter, etc.

Based on Purpose

1. Point Transfer Device
2. Stereo plotter

- Optical Projection Stereo Plotter (Analog stereo plotter or Direct Optical projection instruments)
- Mechanical Projection Stereo Plotter
- Optical-Mechanical Projection Stereo Plotter
- Analytical stereo plotter

Based on Purpose

Point Transfer Device

- It is an instrument which is used for transforming the pass points and tie points onto positive films, by observing on aerial photographs with stereoscopic vision.
- It is an instrument which was first constructed first time by Dongleman ITC, Delft.
- The development of the point transfer device was realized because the accuracy of aerial triangulation results depend upon to a larger extent upon the accuracy with which tie points are marked and transformed.
- The major feature of the point transfer device are; Photo holder, Image viewing system, Image matching mechanism, Point Drilling Device.

Based on Purpose

Stereo plotter

- It is an instrument that uses stereo photographs for map making.
- It is essentially a three-dimensional digitizer, capable of producing accurate X, Y, and Z object space coordinates when properly oriented and calibrated
- It works on the principle of floating mark.
- The primary uses of stereoplotters are:

i. compiling topographic maps and

ii. generating digital files of topographic information.

The major three components in the stereo plotter are:

i. Projection system

ii. Viewing system

iii. Measuring and tracing system.

2. Stereo plotter

Fig: Man plotting map using stereoplotter

Source: https://fab.cba.mit.edu/classes/865.21/topics/scanning/01_passive.html

Components of Stereo plotter

i. Projection System

This system mainly helps in following :

• Serves for the relative and absolute orientation.

ii. Viewing System

• The function of the viewing system of a stereoplotter is to enable the operator to view the stereomodel three-dimensionally.

• Stereoviewing is made possible by forcing the left eye to view only the overlap area of the left photo while the right eye simultaneously sees only the overlap area of the right photo.

iii. Measuring and Tracing System:

• It helps in the plotting of the 3D Stereoscopic model in case of optical projection plotter.

Stereo plotter

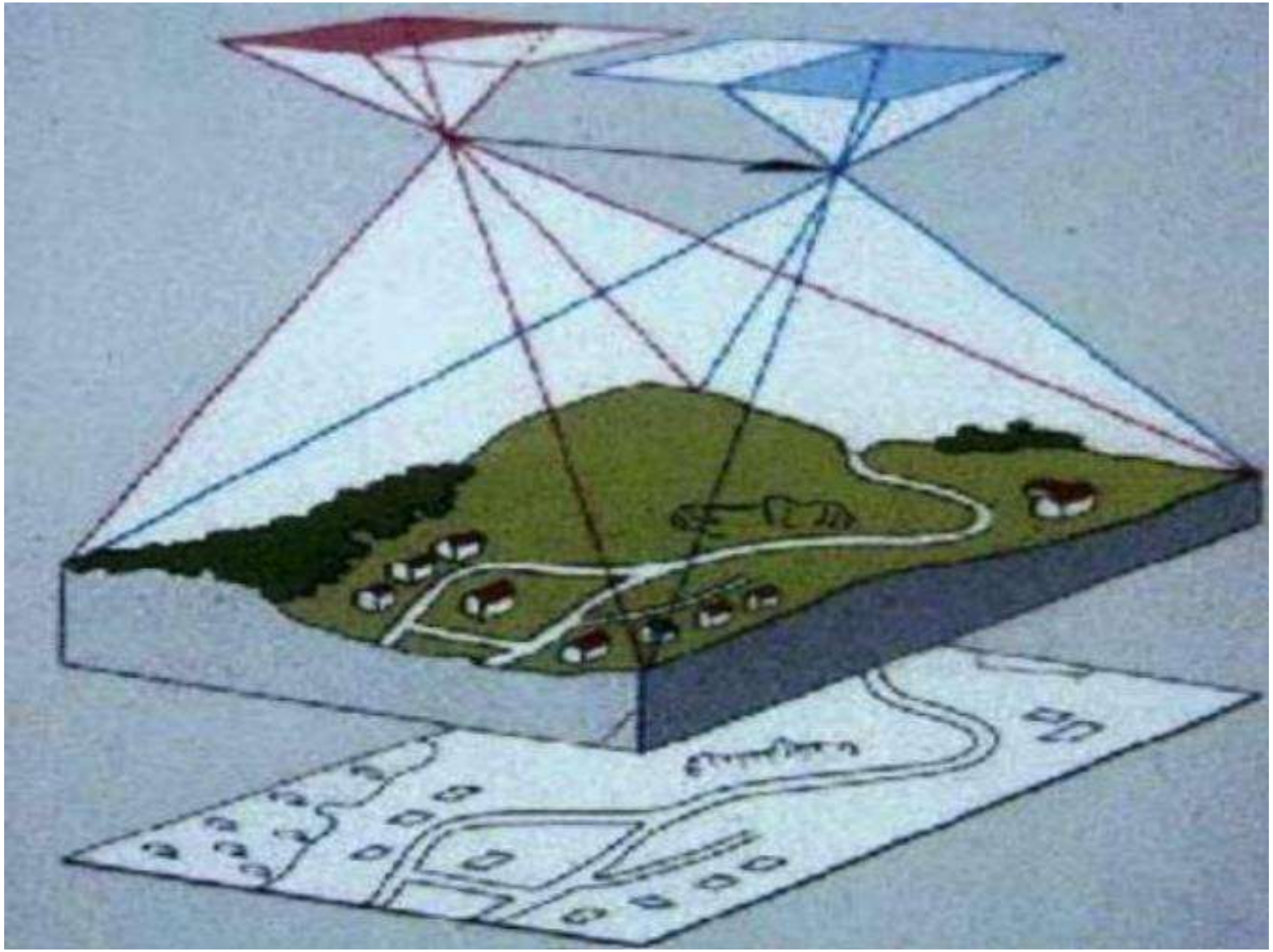


Fig: Concept of stereo plotter

Types of stereoplotter

Stereoplotters have changed as technology has improved. There are mainly three types of stereoplotters. They are:

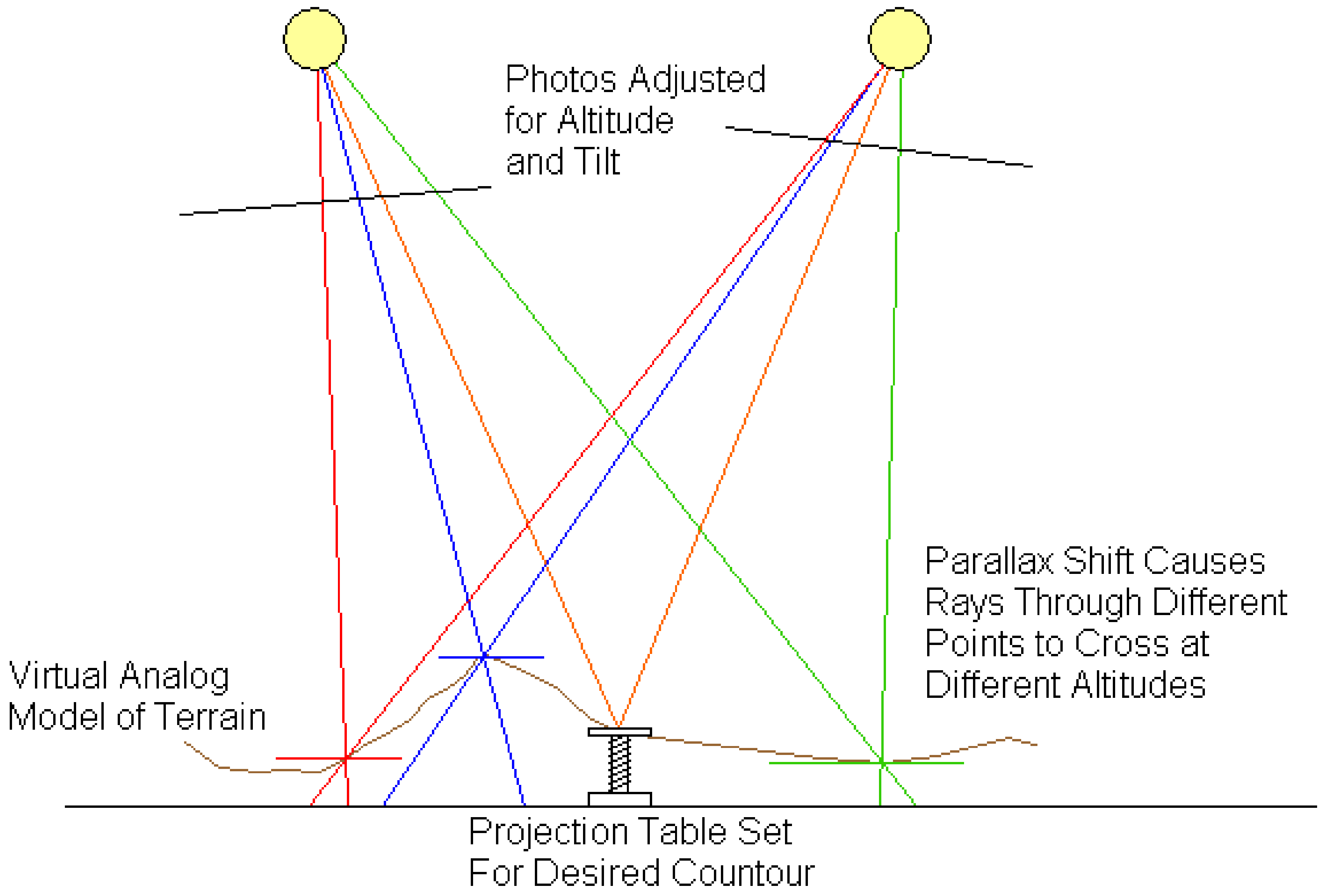
1. Optical Projection Stereo Plotter (Analog stereo plotter or Direct Optical projection instruments)

- It is the first generation of stereoplotters which used only the light rays and optics to adjust the image.
- It creates a true three dimensional stereo-model by projecting transparency images through projector lenses.
- An operator is able to view the model directly and make measurements on it by intercepting projected rays on a viewing screen (platen).

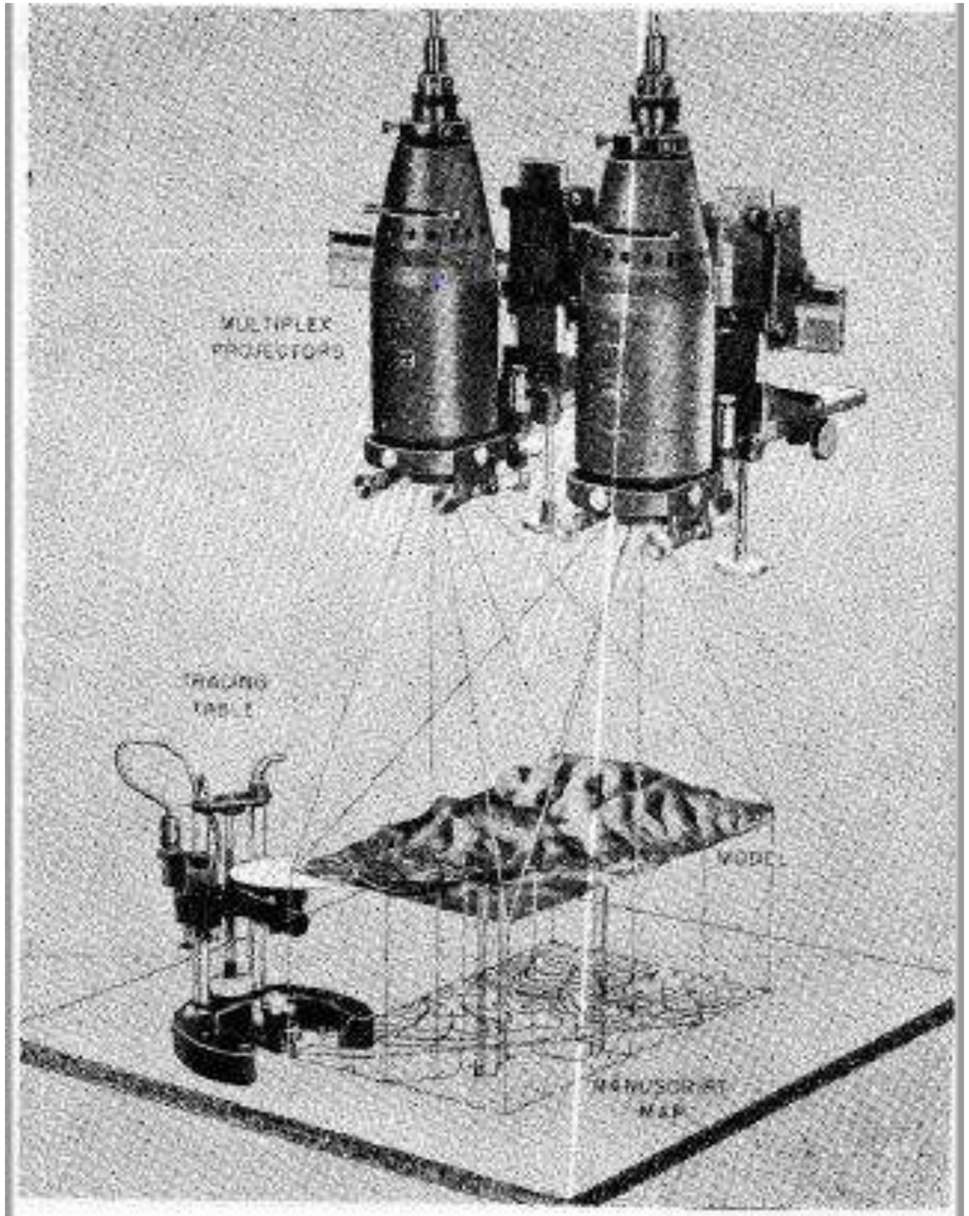
E.g Kelsh Plotter

Types of stereoplotter

2. 1. Optical Projection Stereo Plotter (Analog stereo plotter or Direct Optical projection instruments)



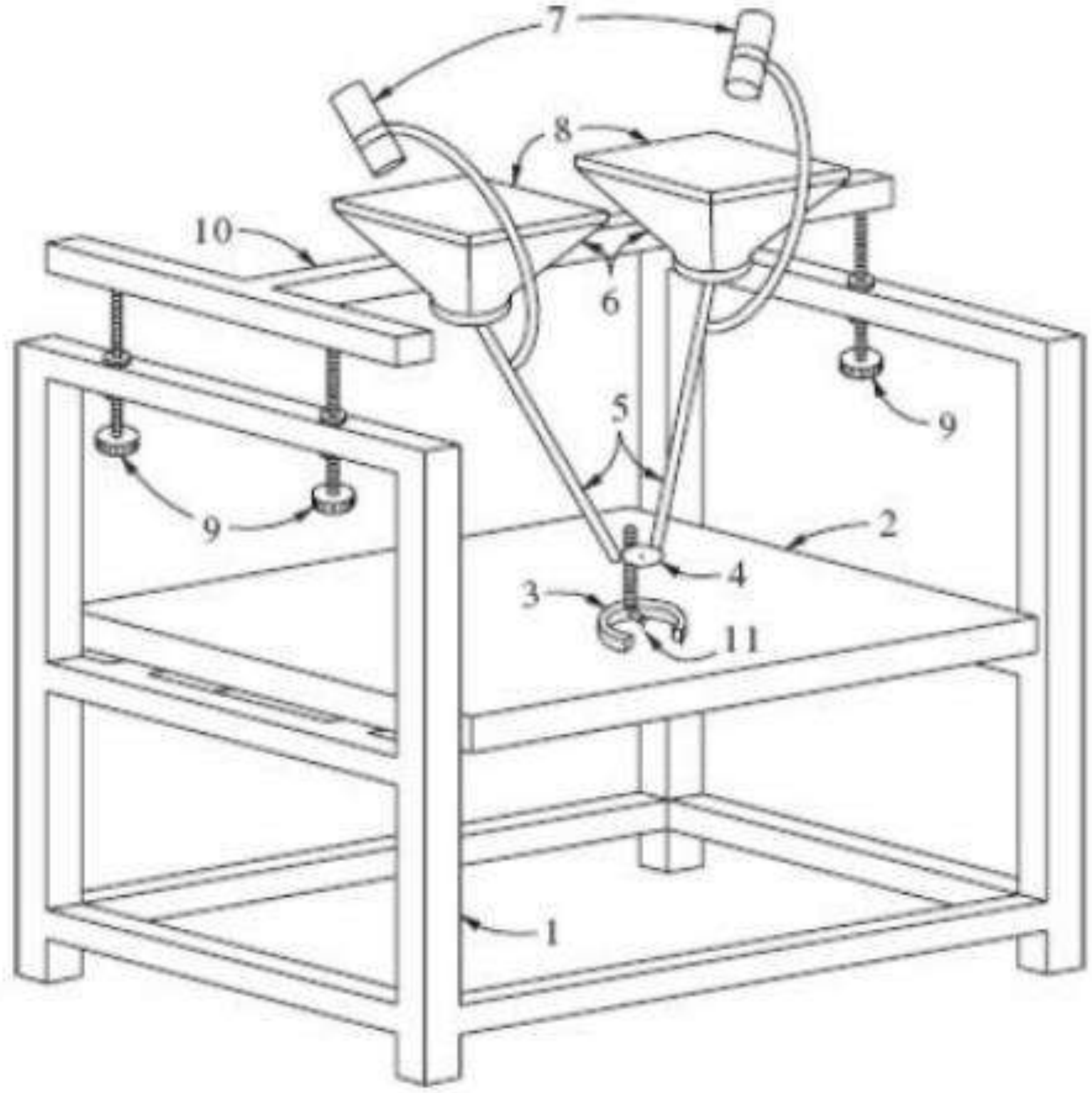
2.1 Optical Projection Stereo Plotter (Analog stereo plotter or Direct Optical projection instruments)



Types of stereoplotter

2.1 Optical Projection Stereo Plotter (Analog stereo plotter or Direct Optical projection instruments)

1. Main frame
2. Reference table
3. Tracing table
4. Platen
5. Guide rods
6. Projectors
7. Illumination lamps
8. Diapositives
9. Leveling screws
10. Projector bar
11. Tracing pencil



2.1 Optical Projection Stereo Plotter (Analog stereo plotter or Direct Optical projection instruments)

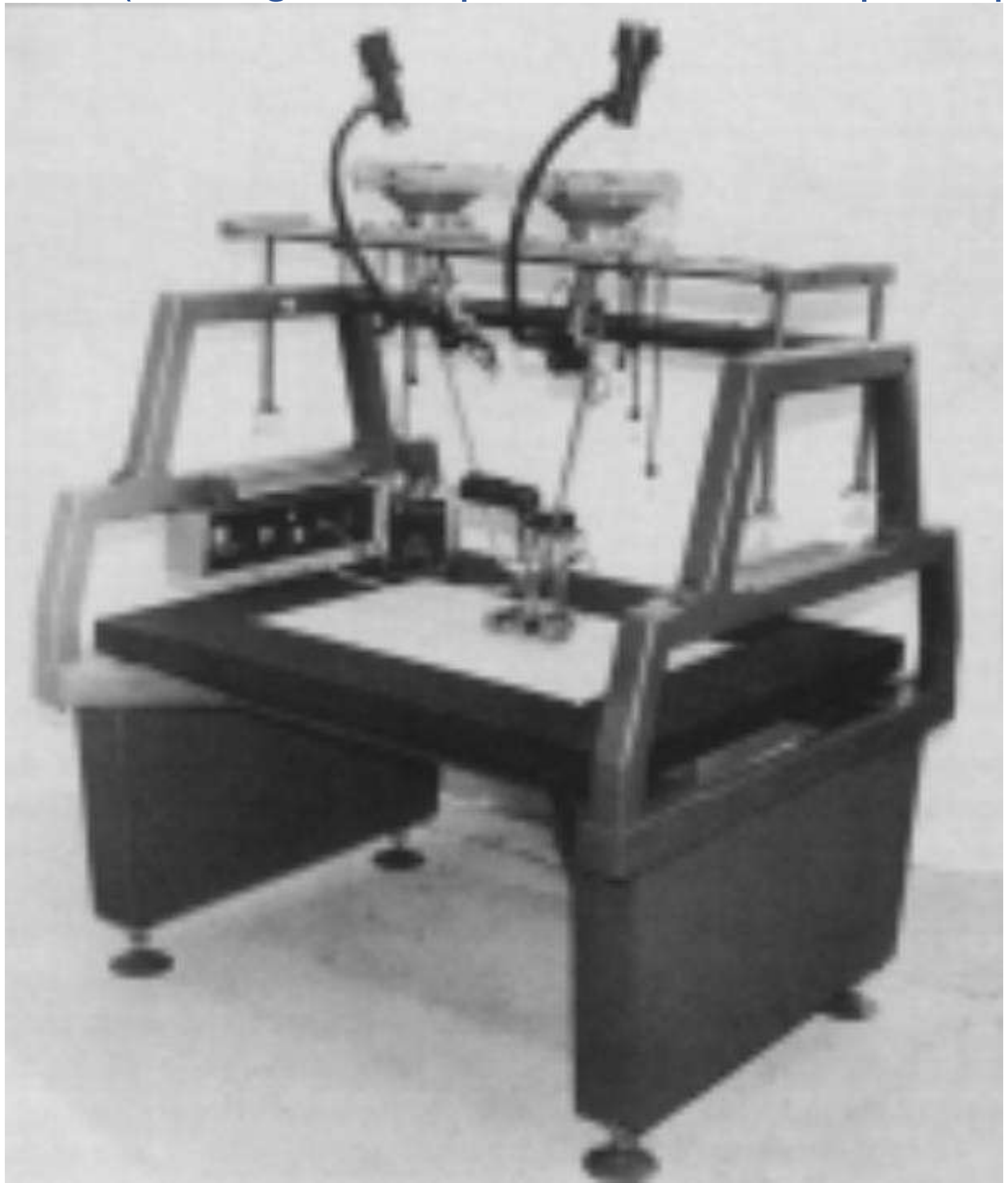


Fig: showing Kelsh Plotter

Stereo plotter

Types of stereoplotter

2.2 Mechanical Projection Plotter

- It also creates a true three dimensional stereo-model by projection of light rays through mechanical or optical-mechanical means.

Advantages of MP instrument over direct optical Plotters:

– More versatile

– Higher accuracy

– Better overall stability

E.g Wild B8

Types of stereoplotter

2.2 Mechanical Projection Plotter

Stereo plotter

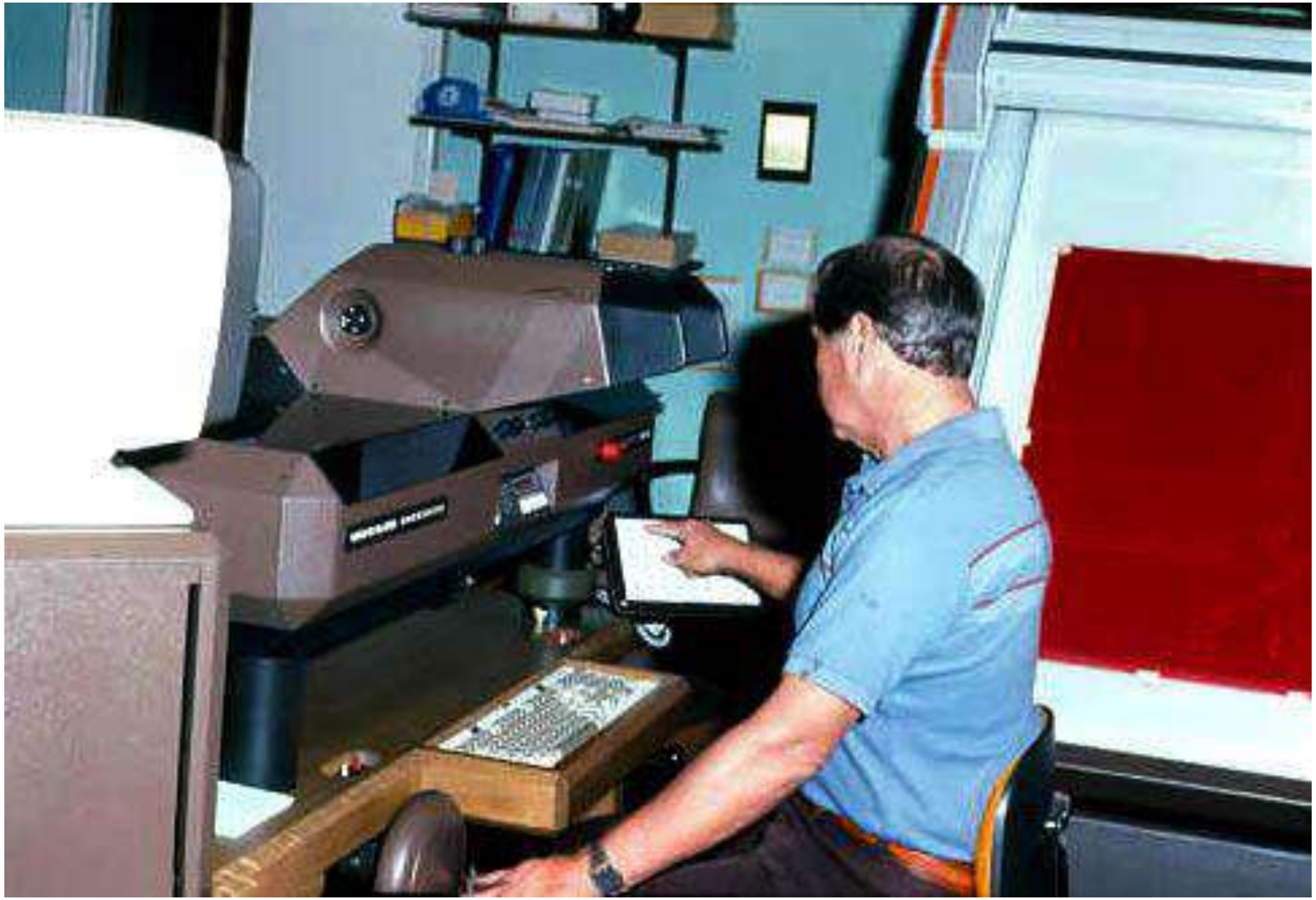
Types of stereoplotter

2.3 Analytical Stereo Plotter

- An analytical plotter is a stereo comparator which uses a mathematical model (based on the collinearity equation) for measurements.
- It is a computer based system where computer solves orientation elements and drives the coordinatograph (an instrument which mechanically plots X and Y coordinates onto a surface) for plotting.
- The movements of the stereoscopic images are introduced by servomotors which are under computer control.
- Analytical plotter execute more precise calculations that ensure additional accurate output instead of approximations. This innovation also allowed a shift to a digital format rather than paper.
- The introduction of the Analytical Stereoplotter was the greatest advancement ever made in photogrammetry.

Types of stereoplotter

2. Analytical Stereo Plotter



Source: https://b-29s-over-korea.com/aerial%20photography/aerial%20photography-pg3.html#:~:text=There%20are%20two%20basic%20types,it%20was%20all%20we%20had.

Fig: Wild BC-2 Analytical Plotter with automatic table

Stereo plotter

Advantage of Analytical stereo plotter over Analog stereo plotter

i. Optical and mechanical errors from light rays and mechanical space rods are not introduced, with greater image measuring accuracy.

ii. They can correct any combination of systematic errors (lens distortion, shrinkage, refraction, earth curvature).

iii. Any form of photography can be accomodated: tilted, oblique, terrestrial, very long focal length, etc.

iv. Mathematical equations of redundant observations and least squares can be used which makes image processing more reliable.

v. Digitalized features are saved as digital file in computer which can reused later.

Digital Photogrammetric workstation (Softcopy plotter)

- It is the combination of hardware (stereo viewing devices and a three dimensional mouse) and software to derive photogrammetric products from digital imagery.
- The fundamental operation of a softcopy plotter is the same as that of an analytical plotter except that instead of employing servomotors and encoders for point measurement, softcopy systems rely on digital imagery.
- The core of a softcopy plotter is a set of computer software modules that perform various photogrammetric tasks.
- Besides the software, another essential component of a softcopy plotter is a computer with a high-resolution graphics display.

Components of DPW

i. Computer System supported by corresponding software

ii. Stereoscopic display device

iii. 3D measurements device

iv. I/O device

Digital Photogrammetric workstation (Softcopy plotter)

Source: https://www.gim-international.com/content/article/digital-photogrammetric-workstations

Advantage of Digital Photogrammetric workstation over Analytical plotter

i. Automation:

- Automated modules in order to automatically generate DTMs, extract tie points for relative orientation and bundle adjustment, and to generate orthophotos and orthophoto mosaics using image matching techniques.

ii. Integration with GIS:

- Since, the photogrammetric products obtained are in digital form so it can be easily integrated with GIS.

iii. Ease of use

iv. It is faster than analytical plotters.

Rectifier and process of Rectification

Background

- Photographs have inherent distortions and displacements in them. The most common distortion in aerial photography is height distortion, followed by tilt displacement due to the aircraft’s movements.
- Rectification is the process of making equivalent vertical photographs from tilted photo negatives.
- The resulting equivalent vertical photos are called rectified photographs. Rectified photos theoretically are truly vertical photos, and as such they are free from displacements of images due to tilt.

Types of rectification

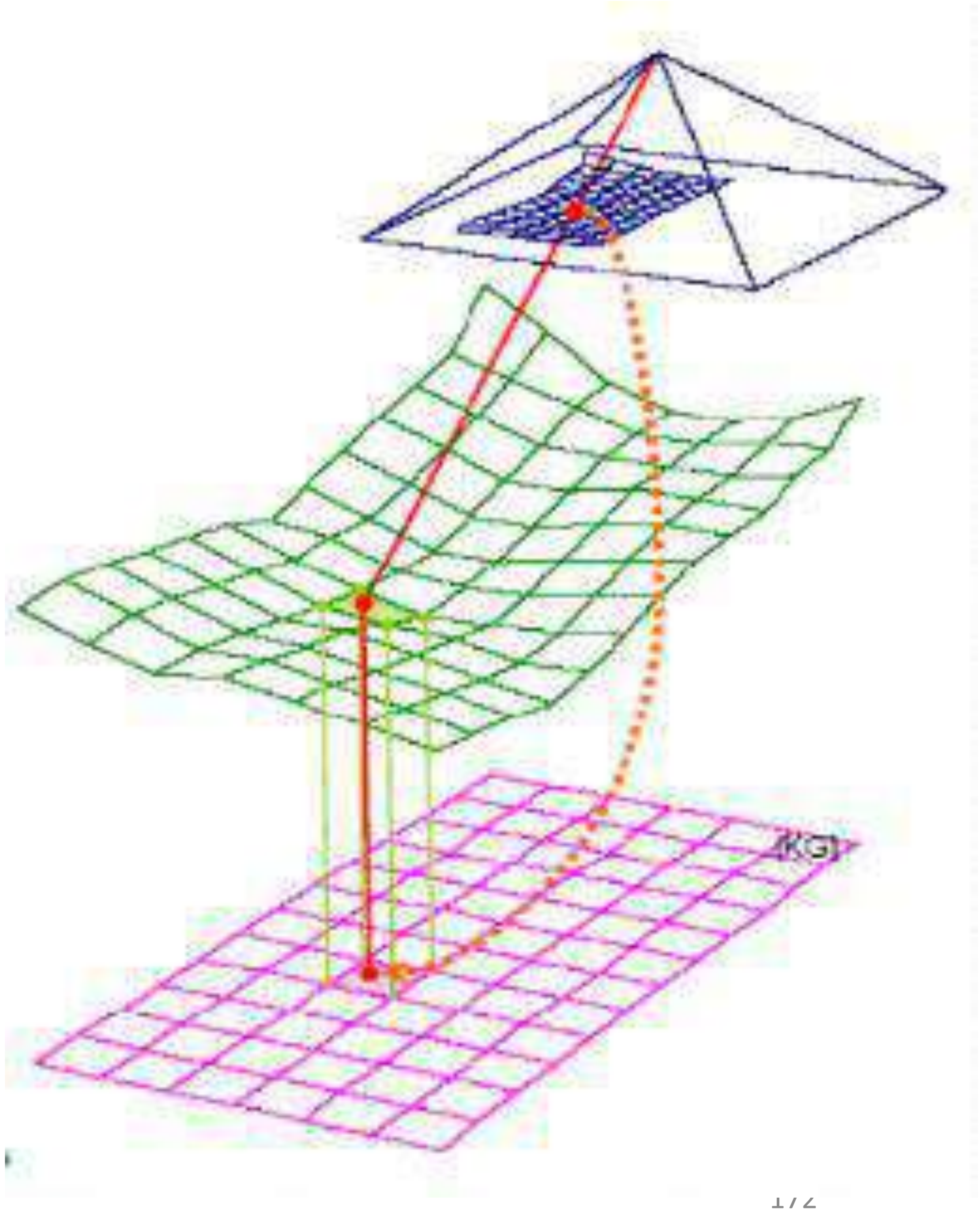
1. Simple Rectification

- Used to remove tilt displacement from an aerial photographs
- Done on the imagery of flat terrain
- It Can be automatic & non-automatic types

Types of rectification

2. Differential Rectification

- Used to remove relief displacement from an aerial photographs
- Done on the area, with moderate variation in height
- Can be automatic & non-automatic types.
- Done by using DTM as reference.



Rectifier and process of Rectification

Rectifier

- The device used in the rectification process is known as rectifier.
- Rectifier is an expensive photogrammetric projector with a table and lens that can be tilted and turned to reproduce and remove the effects of these camera misorientations and bring the print to the desired over-all scale.
- It can compensate for systematic effects like orientation and scale, but can't deal with topographic displacement.
- Differential rectification is done in order to remove the topographic displacement.

Photogrammetric Instrument

Rectifier and process of Rectification

Wild VG1

Enlarger

Wild E4

Rectifier-Enlarger

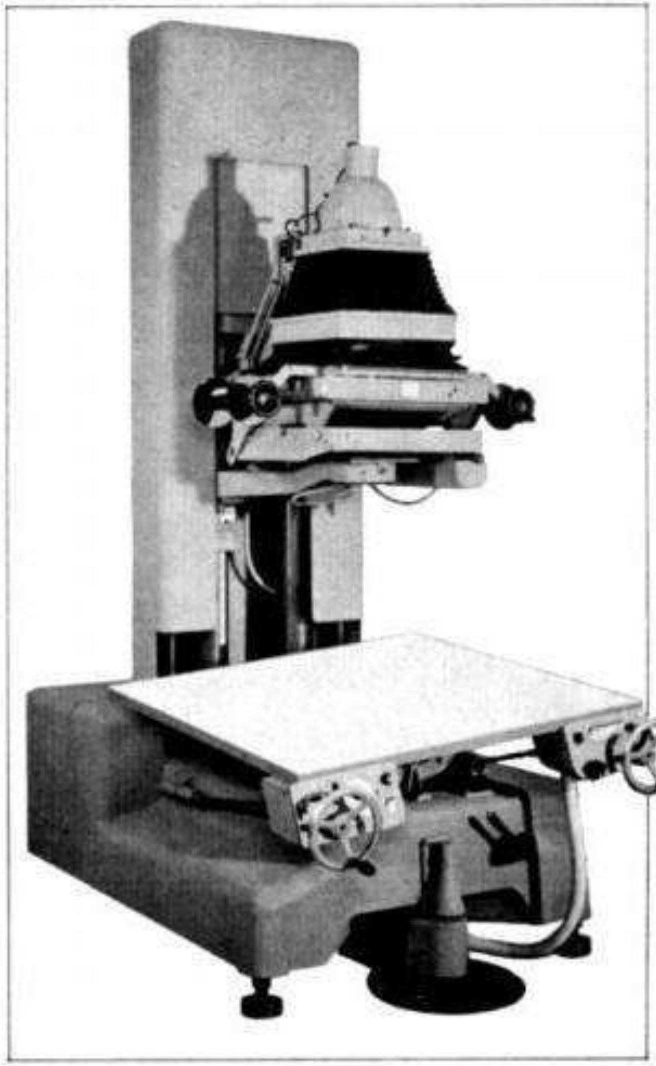


Image matching & its techniques

Image matching techniques

- It is the process of finding matching points i.e conjugate points in the corresponding stereo image pairs.
- The conjugate point in the corresponding image is determined by comparing the similarity measure, e.g. brightness.

Main steps in image matching

- Select a matching point in one image.
- Find its conjugate point in the other image.
- Compute 3D position of the matched point in object space.

Image matching techniques

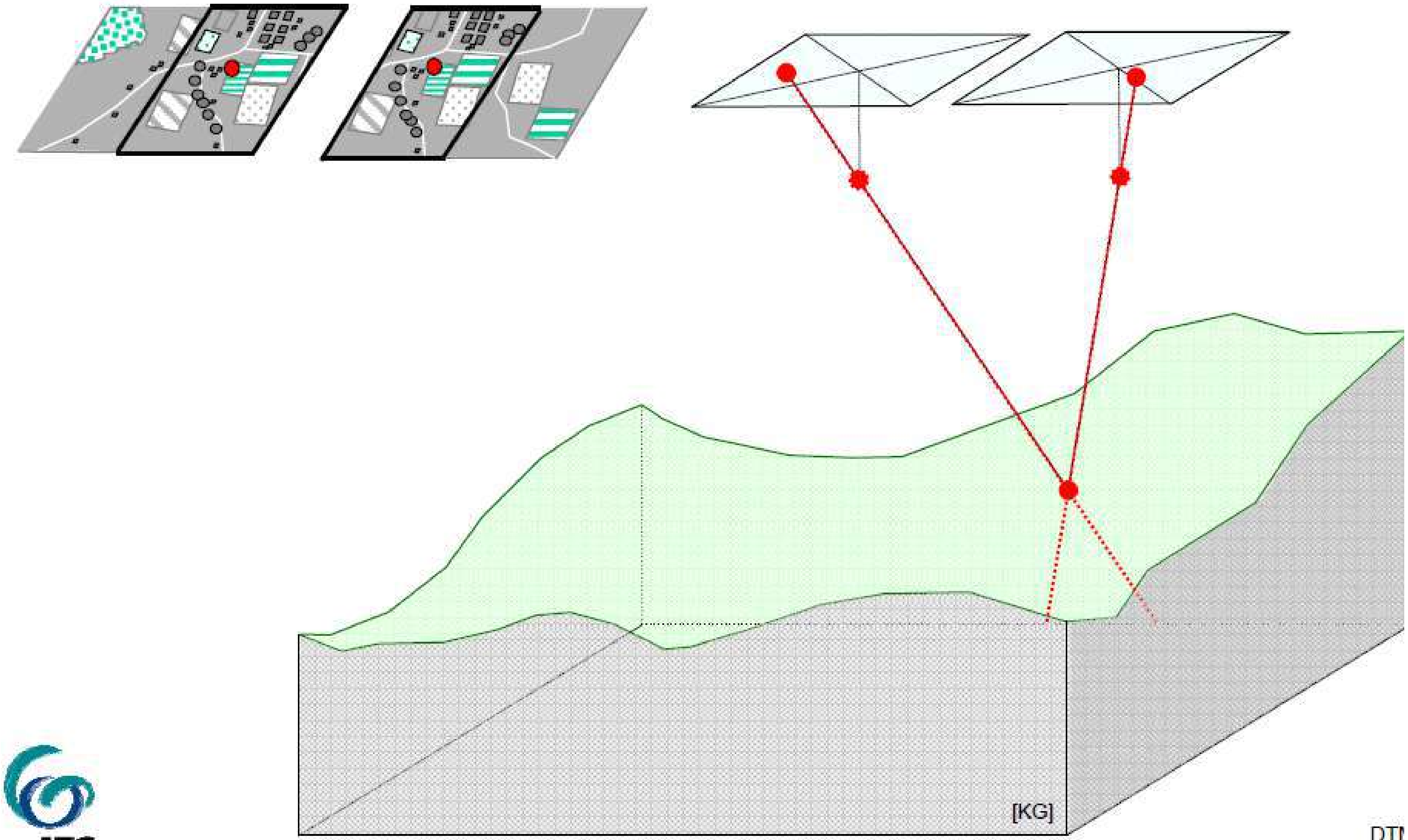


Image matching techniques

Types of Image matching techniques

i. Feature based matching

ii. Area based matching

iii. Relational matching

Area based matching

- Area-based matching is based on the idea that grey values of pixels of conjugate points have similar radiometric characteristics.
- In other words, having a point in one image, its conjugate in the other one is obtained by optimizing a certain similarity measure, defined over the pixel grey values within the image window.
- Two techniques are adopted to calculate the possible similarity measures:

i. a normalized cross correlation method and

ii. a least square matching method.

Image matching techniques

Feature matching

- It is a technique of obtaining automatic tie-points in corresponding multiple images.
- It is used in digital photogrammetry is done with the use of photogrammetric softwares.
- The algorithm attempts to detect well-recognisable features – such as a road marking, a building edge or any other strong change in contrast – in each individual image. Once all the features have been found, the algorithm proceeds to detect corresponding features in multiple images. This results in highly reliable corresponding points that are very suitable as tie points.

Image matching & its techniques

Point transfer technique

- The device which is used to mark and transfer the points along the images for accurate triangulation and co-ordinate transfer is called Point Transfer device.
- In the old days of analogue aerial photogrammetry, such tie points were physically identified by pinning small holes through the image at the tie-point location.
- The accuracy of aerial triangulation results depends to a large extent upon the accuracy with which the points 2 are marked and transferred.
- With the emergence of digital photogrammetry, much of the such manual labour was replaced by automated tie-point search software which can easily detect hundreds of reliable corresponding points in multiple images.

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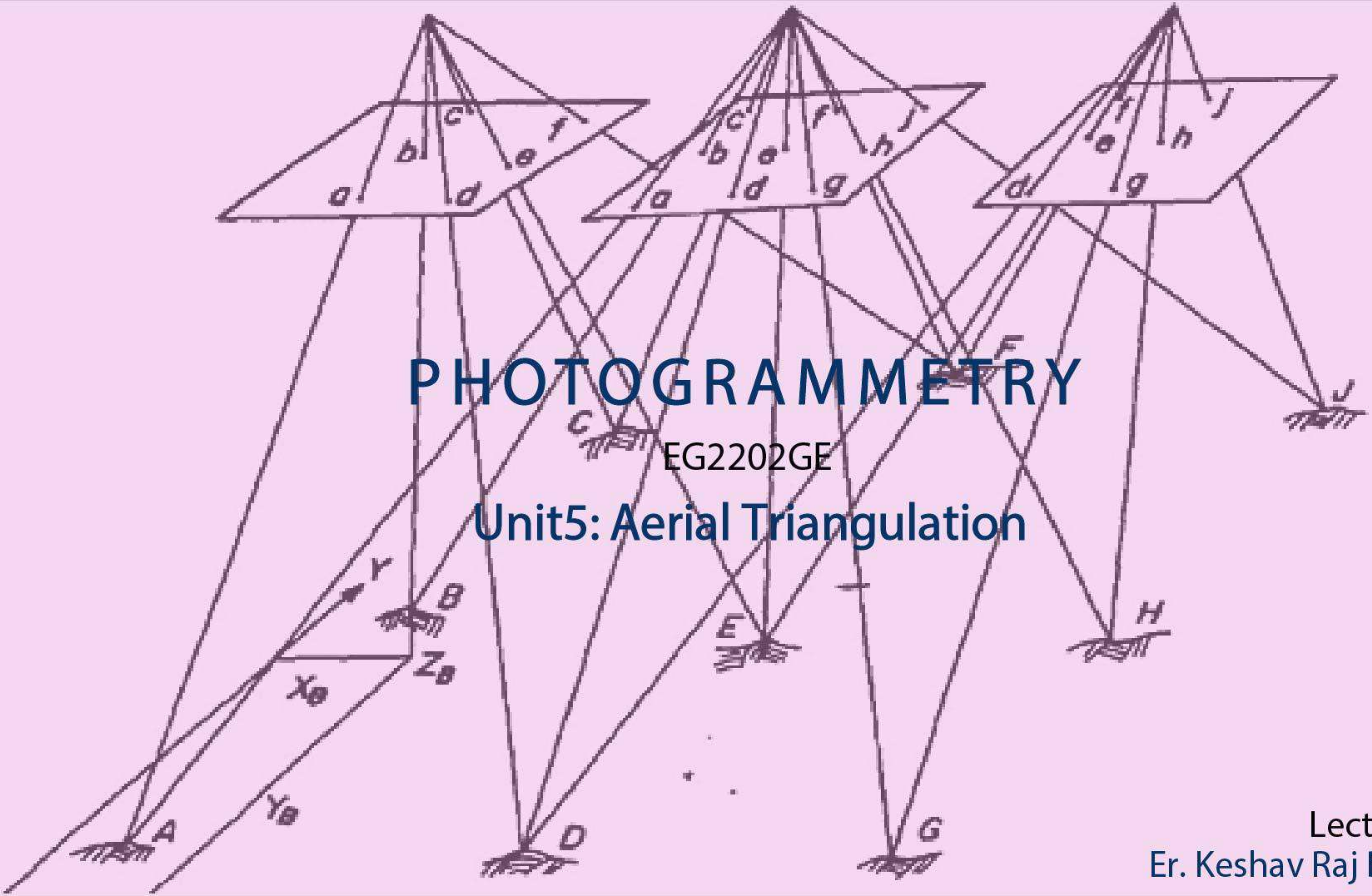

PHOTOGRAMMETRY

EG2202GE

Unit5: Aerial Triangulation

Lecture by
Er. Keshav Raj Bhusal

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5.3. Principle of Aerial Triangulation

5.4. Projective Relation between Photo and Ground Coordinate System

5.5. Spatial Triangulation Methods

- Aero-polygon Triangulation
- Independent Model Triangulation
- Analytical Triangulation

Aerial triangulation

Aerial triangulation

- Aerial triangulation or aero-triangulation is the process of determining the real world(ground) X, Y and Z coordinates of individual points based on photo coordinate measurements.
- Photogrammetric triangulation or photo-triangulation is a more general term as it can be applied to terrestrial photos as well as aerial photos.
- One of the principal application lies in extending or densifying of a sparsely distributed horizontal and vertical control network through:

i. measurements performed on overlapping aerial photographs,

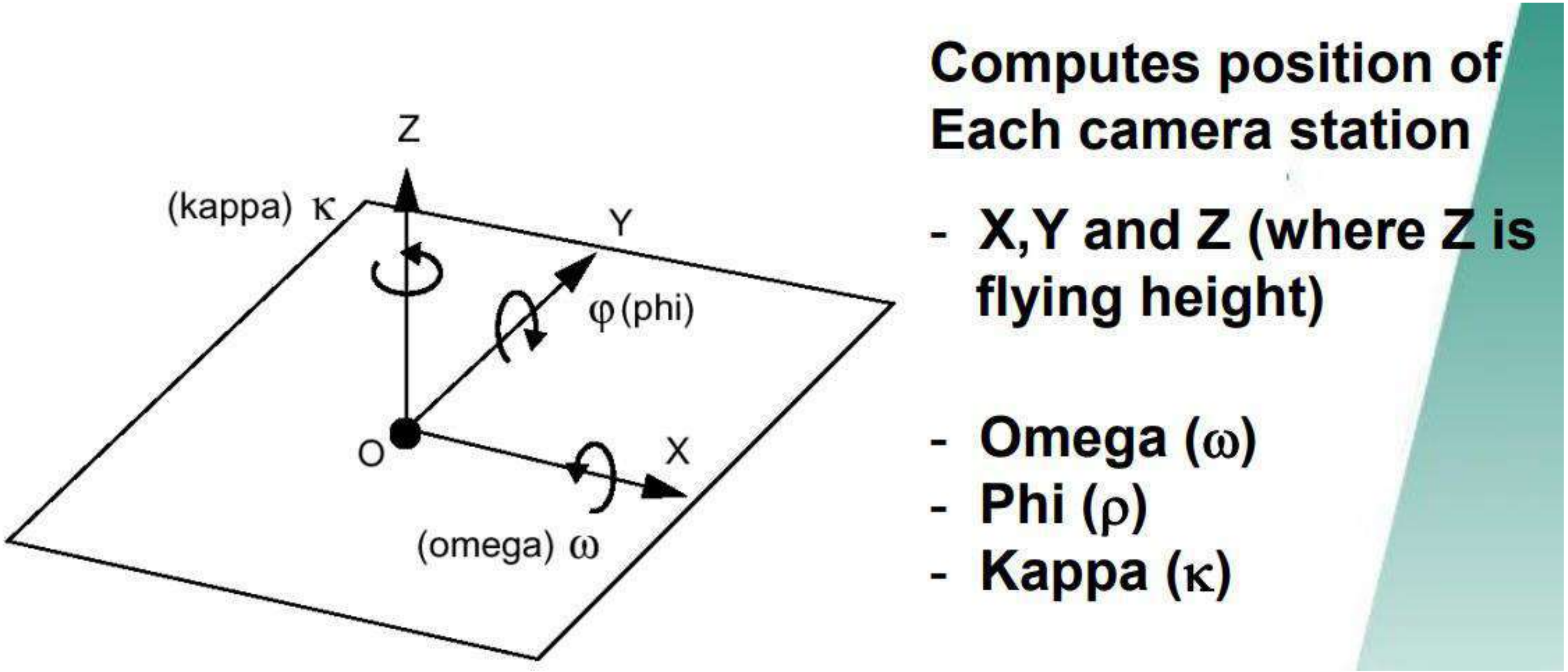
ii. known ground control points coordinates on the ground, and

iii. mathematical modeling and solution

- The process of densification involves establishment of intermediate control points between the field surveyed control that exist in only a limited number of photos in a strip or block.
- Also called bridging in a sense a bridge of intermediate controls are developed.

What it does?

- Computes coordinate values for any point measured on two or more images (tie points).
- Computes positions and orientation for each camera station through exterior orientation.



Source: http://drm.cenn.org/Trainings/Generation%20of%20geodatabases%20using%20ARCGIS%20and%20ERDAS/Lectures/Introduction%20on%20Photogrammetry.pdf

Aerial triangulation

Why we need Aerial triangulation?

Advantages(Besides having cost advantage over field surveying, aero-triangulation has other benefits as well)

i. It minimizes delay and hardship due to adverse weather conditions as aerial triangulation is done in lab.

ii. Access to the property within a project area is not required.

iii. Surveying in difficult areas (like marshes, extreme slopes, and hazardous rock formations) minimized.

iv. Accuracy of field survey (ground control) can be checked with the help of controls generated through aero triangulation.

Principle of Aerial triangulation

- Aero-triangulation is the simultaneous space resection and space intersection of image rays recorded by an aerial mapping camera.
- Conjugate image rays projected from two or more overlapping photographs intersect at the common ground points to define the three-dimensional space (3-D) coordinates of each point. The entire assembly of image rays is fit to known ground control points in an adjustment process.
- Thus, when the adjustment is complete, ground coordinates of unknown ground points are determined by the intersection of adjusted image rays.

Principle of Aerial triangulation

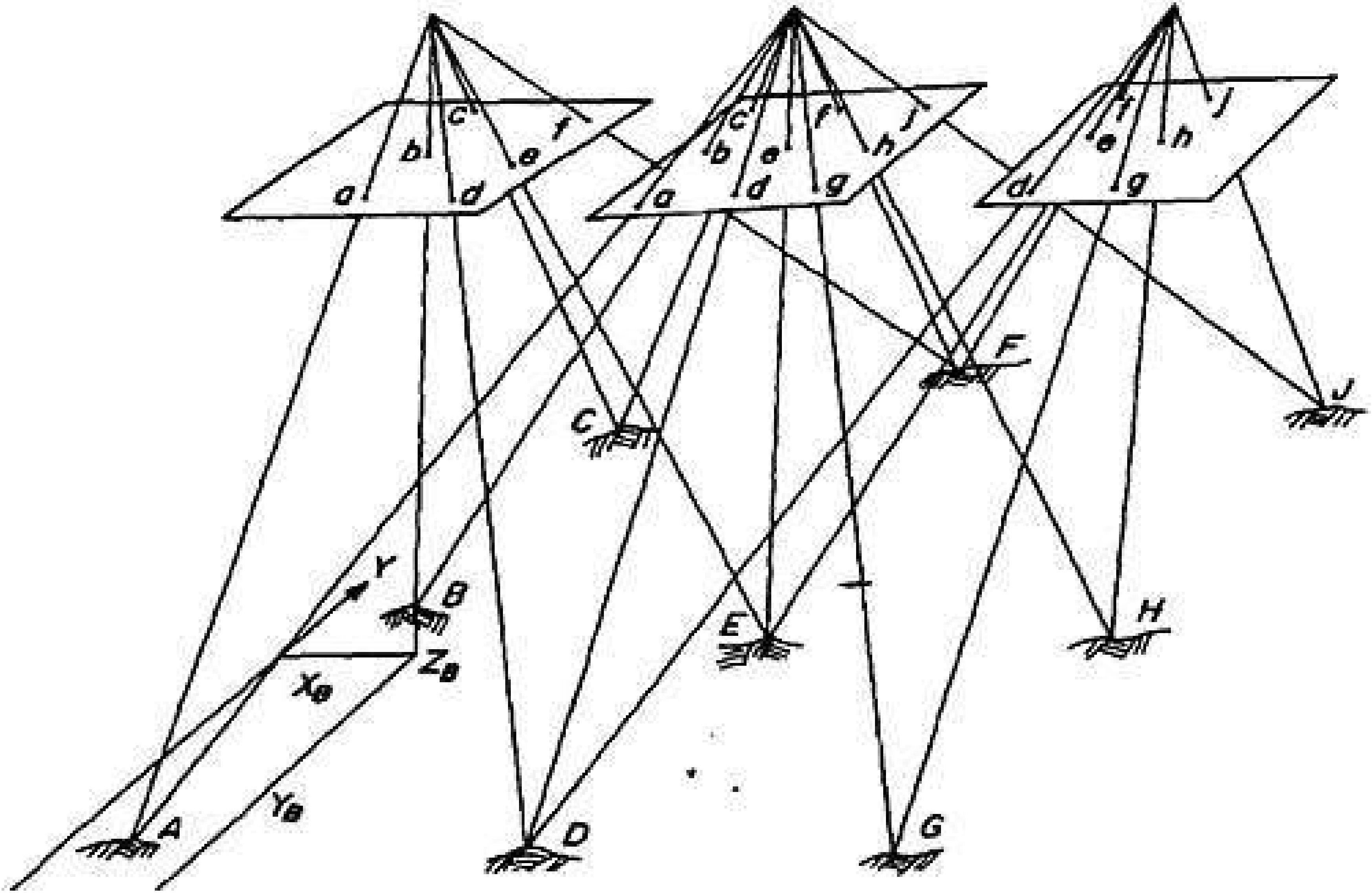


Fig1: showing aero triangulation process.

Why we need Aerial triangulation?

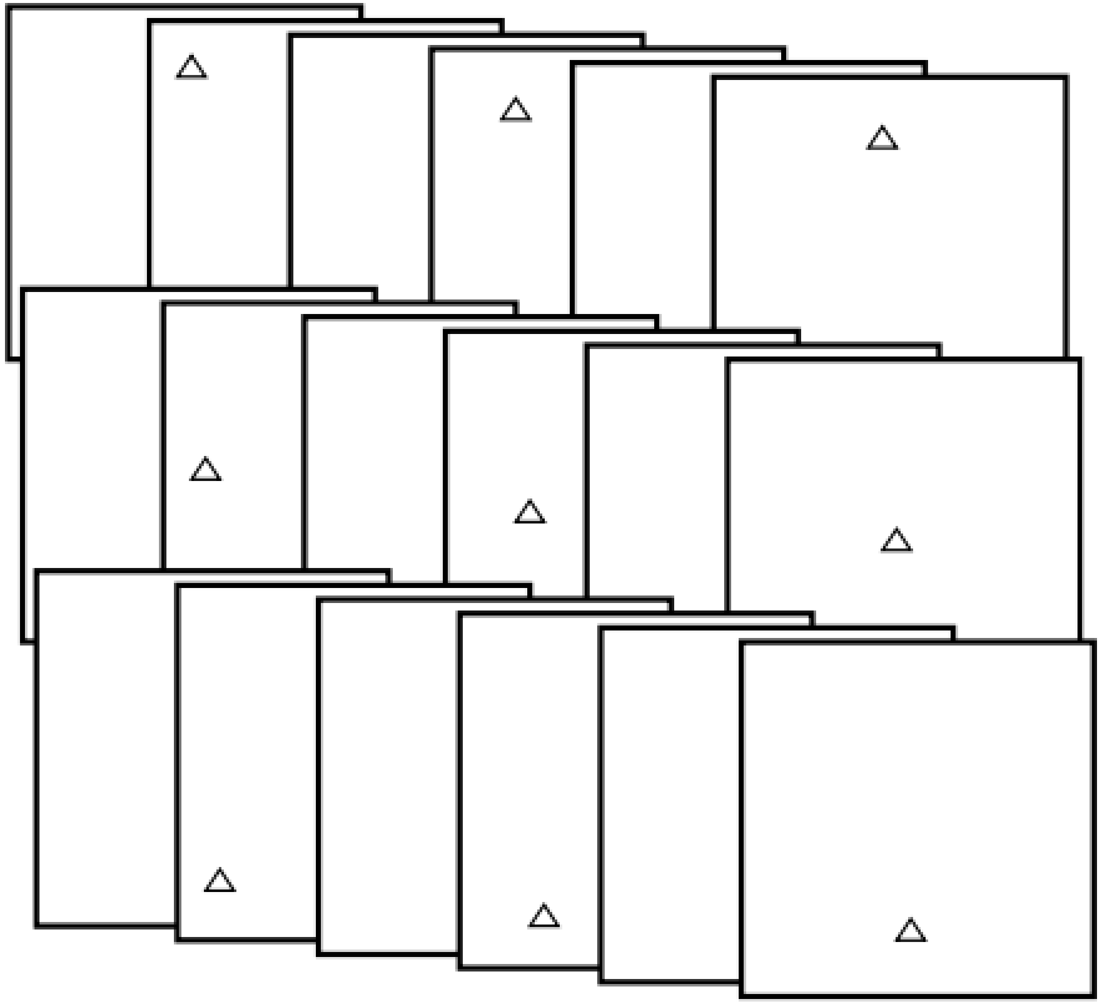


Fig1: showing concept of strips and blocks. Triangles symbolize existing control point which are later densified through aero triangulation process.

Methods of Aerial triangulation (Spatial Triangulation Methods)

Broadly there are three methods of aero-triangulation. They are:

i. Analog Triangulation – Stereo Triangulation

ii. Semi Analytical (Independent Strip Model) Triangulation

iii. Analytical Triangulation

1. Analog Triangulation – Stereo Triangulation

- It involves manual interior, relative, and absolute orientation of the successive stereo models with the help of stereoplotters.
- It involves relative orientation of successive models, scale transfer between consecutive models, connection of adjacent models to form continuous strips and/or blocks and adjustment of the resulting strip to fit the available ground controls.
- These procedures are now obsolete and principally of historical interest.

Methods of Aerial triangulation

Analog Triangulation – Stereo Triangulation

Procedure:

i. The first step in stereo-triangulation is to take first pair of photographs in the strip say photos 1 and 2; and are relatively oriented at some arbitrary scale to form 1st model ½.

ii. After completing the orientation of the first model ½ , the third photo is then oriented to photo 2 to form model 2/3.

- The scale of model 2/3 may in general be different from that of model ½. In such case, scale transfer operation between the two models is performed so that the scale of the new model 2/3 is the same as that of the preceding model ½ .

iii. The process of dependent relative orientation and scale transfer are repeated for all other models down the strip.

- At the end, a continuous strip model at an arbitrary uniform scale is resulted.

iv. The entire strip model is then transformed then adjusted to the available ground control points by graphical methods or by a polynomial strip adjustment.

Methods of Aerial triangulation

2. Semi Analytical (Independent Strip Model) Triangulation

- Model relative orientation is performed instrumentally on a plotter.
- Model connection including scale transfer between successive models is accomplished analytically.

Therefore it is called semi-analytical.

- Also called independent model triangulation, since each model is relatively oriented on the plotter completely independently of other models.
- After relative orientation, each model will have its own coordinate system as shown in the figure 5.2.

Main steps

- It involves relative orientation of each stereomodel of a strip or block of photos.
- After the models have been formed, they are numerically adjusted to the ground system by either a sequential or a simultaneous method.
- In the sequential approach, contiguous models are joined analytically, one by one, to form a continuous strip model, and then absolute orientation is performed numerically to adjust the strip model to ground control.
- In the simultaneous approach, all models in a strip or block are joined and adjusted to ground control in a single step.

Semi Analytical (Independent Strip Model) Triangulation

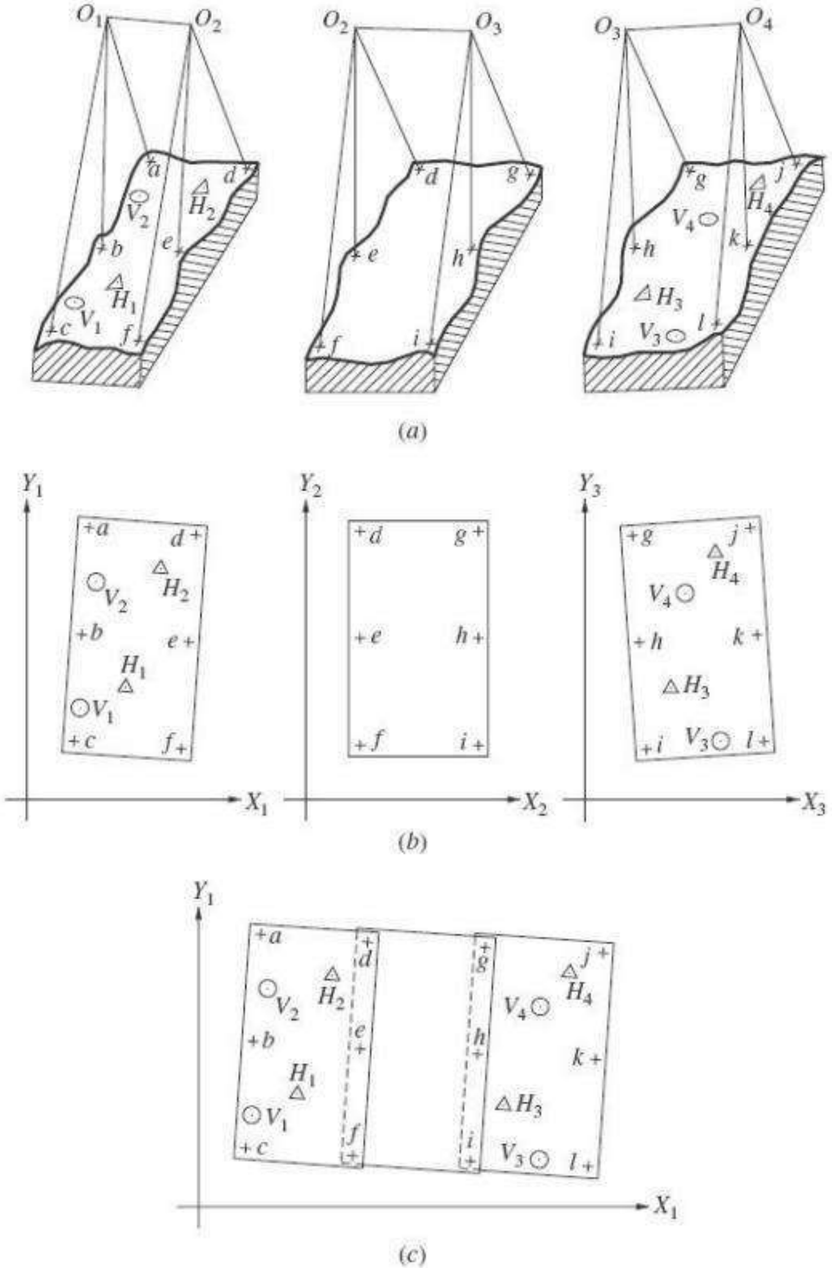
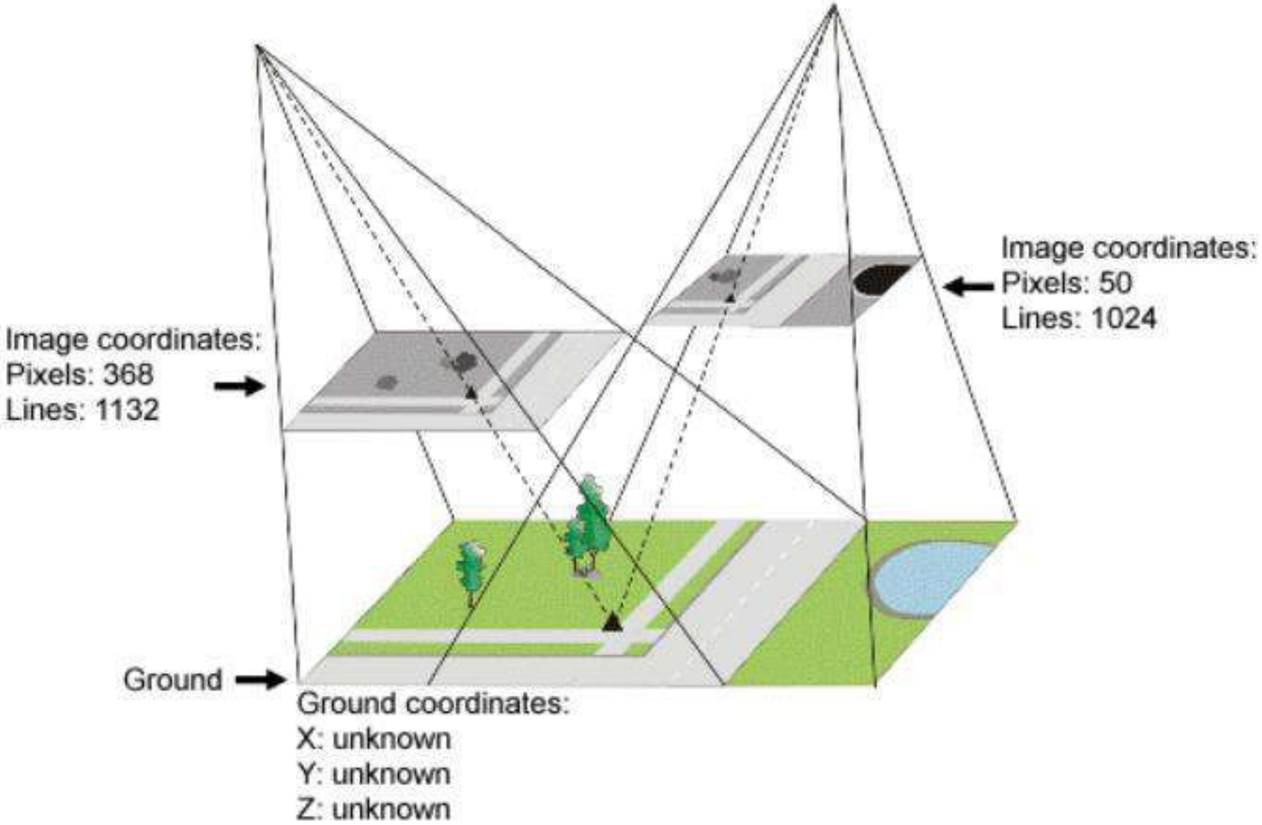


Fig 5.2: showing Independent model or semianalytical aerotriangulation. (a) Three adjacent relatively oriented stereomodels. (b) Individual arbitrary coordinate systems of three adjacent stereomodels. (c) Continuous strip of stereomodels formed by numerically joining the individual arbitrary coordinate systems into one system.

Tie Points

- A point in a aerial photograph whose ground coordinates are not known and represents the same location in an adjacent image or aerial photograph.
- It is usually expressed as a pair, tie points can be used to link images and create mosaics.
- Tie points can be measured both manually and automatically.
- These are supplementary control points selected to connect strips of photographs together to form a block.



Source: https://catalyst.earth/catalyst-system-files/help/COMMON/concepts/TiePoint_explain.html

Tie Points

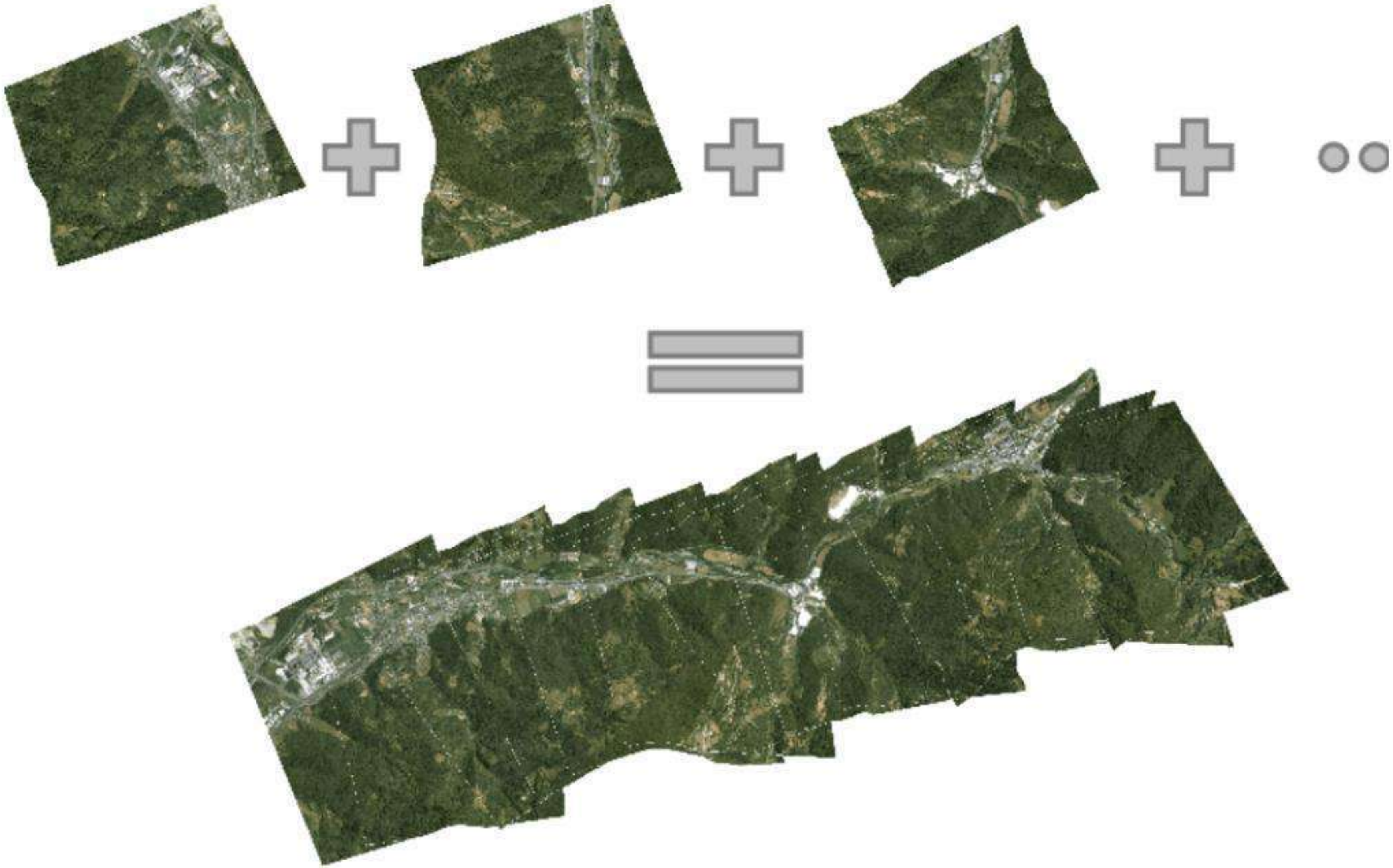


Fig 5.4: showing join of several images through tie points

Methods of Aerial triangulation

3. Analytical Triangulation

- Analytical methods consist of photo coordinate measurement followed by numerical interior, relative, and absolute orientation from which ground coordinates are computed.
- Comparator(in stereo mode or mono mode plus point transfer device) and analytical plotter (in comparator mode) are used to do measurements.
- Analytical aerotriangulation tends to be more accurate than analog or semianalytical methods, largely because analytical techniques can more effectively eliminate systematic errors such as film shrinkage, atmospheric refraction distortions, and camera lens distortions.
- Another advantage of analytical methods is the freedom from the mechanical or optical limitations imposed by stereoplotters.

Types of Aerial triangulation

Essentially, there are two types of aerial triangulation:

1. Radial aerial triangulation
2. Spatial aerial triangulations

Radial aerial triangulation

- Radial aerial triangulation in which measurements are made on the plane of the photograph itself without considering the third dimension, thus giving rise only to planimetric controls.

Spatial aerial triangulations

- Spatial aerial triangulations in which the three-dimensional stereomodel is reconstructed, usually in an analogue instrument or by computation using an analytical approach, thus capable of giving to both height and planimetric controls (i.e. X-, Y- and Z-coordinates of a point).

Types of Analytical Triangulation

3.1 Independent model method

- Models are joined together and transformed to the ground control system in a simultaneous adjustment.
- The mathematical model is based on 7-parameter transformations (3-D similarity transformation).
- Model coordinates are either measured on stereoplotters, or computed from photo-coordinates (e.g. by a relative orientation).

3.2 Bundle method (bundle block adjustment)

- Bundle block adjustment uses the collinearity condition as the basis for formulating the relationship between image space and ground space.
- The photo-coordinates of all images of a block participate in an adjustment where the exterior, interior orientation of all photographs are determined, together with the ground points.

3.3 Polynomial strip adjustment

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https://wp.kntu.ac.ir/ebadi/AAT.pdf

PHOTOGRAMMETRY

EG2202GE

Unit6: Photo Interpretation

Lecture by
Er. Keshav Raj Bhusal

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6.1. Introduction

6.2. Elements of Photo interpretation

6.3. Recognition of topographical features on the photographs

Introduction

Photo/Image interpretation

- It is a process of examining and extracting useful information from aerial photographs.
- It involves studying and gathering the information required for identifying the various cultural and natural features and consists of points, lines, or polygons.
- Photo interpretation is easy in oblique photographs than the vertical photographs.
- The reliability of information collected from aerial photographs depends on the quality of aerial photographs, instruments used for interpretation, working conditions and personal experience with photo interpretation techniques.
- Preliminary knowledge of the area of interest which comprises of its geographic location, past and present climate conditions, vegetation and published literature are always useful for accurate identification of features.

Introduction

Factors affecting Photo/Image interpretation

- Training ,skills and experience of the interpreter possessed.
- Characteristics of the objects or features on the photographs to be studied.
- Quality of photographs being used.
- Proper selection of emulsion , scale of photographs, season of flight and time of day.

Elements of Photo interpretation

1. Shape:

- Shape refers to general form, structure, or outline of individual objects.
- Regular geometric shapes are usually indicators of human presence and use.

Agricultural areas tend to have geometric shapes like rectangles and squares.

Streams are linear (line) features that can have many bends and curves.

Roads frequently have fewer curves than streams.

- Some objects like buildings, playground, river etc. can be identified almost solely on the basis of their shapes.

2. Texture

- It refers to the "smoothness" or "roughness" of image features.
- It is caused by the amount of change of tone in photographs. Grass, cement, and water generally appear "smooth", while a forest canopy may appear "rough".

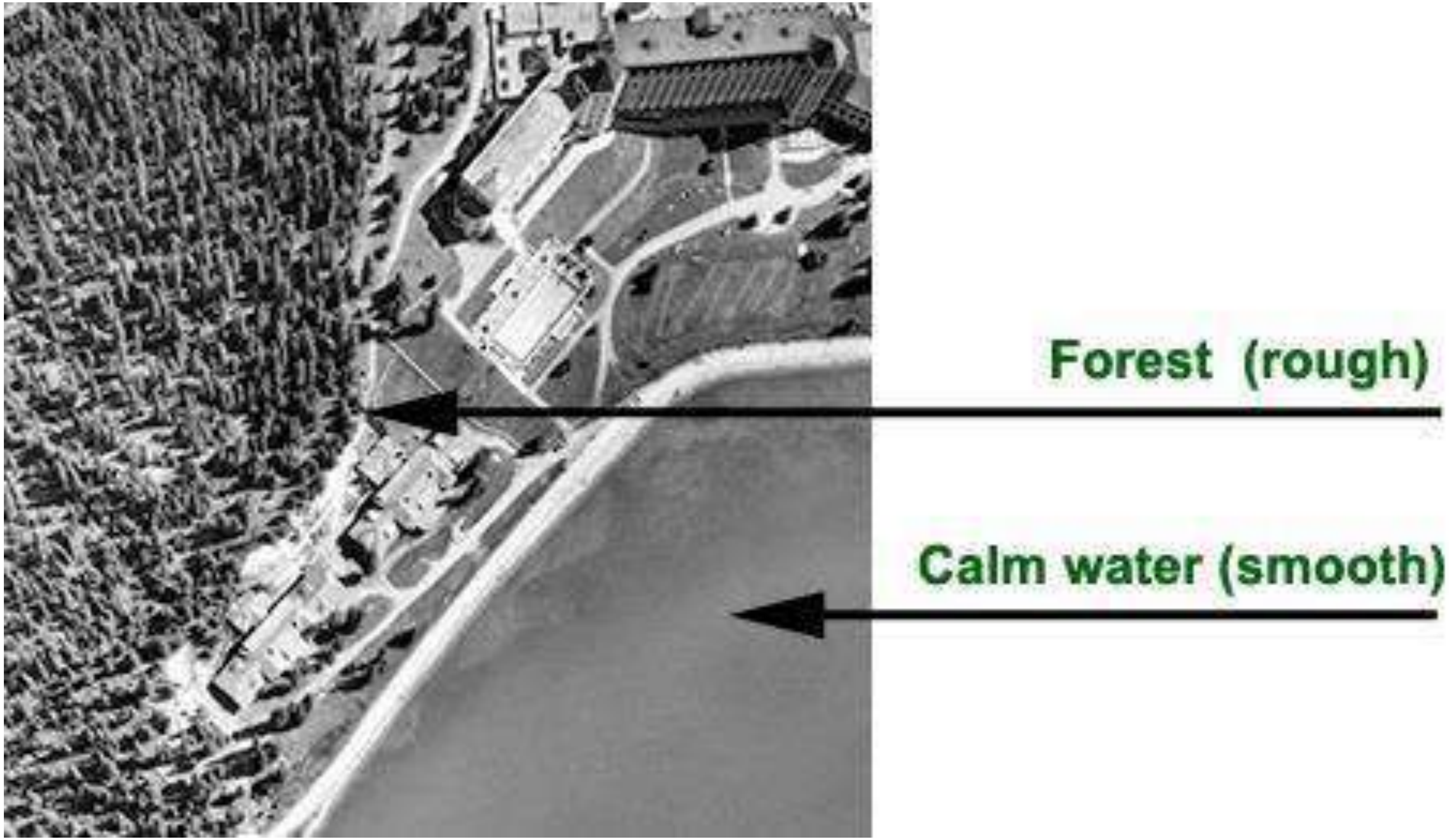
Elements of Photo interpretation

1. Shape:

Source:https://jimcoll.github.io/classes/geog111/labs/lab10/

Elements of Photo interpretation

2. Texture



Source:https://www.nrcan.gc.ca/maps-tools-publications/satellite-imagery-air-photos/air-photos/national-air-photo-library/about-aerial-photography/introduction-air-photo-interpretation/9689

Elements of Photo interpretation

3. Size:

- The size of objects must be considered in the context of the scale of a photograph.
- The scale will help you determine if an object is a small pond or a large lake. Major highways can be

distinguished from smaller roads. Long rivers can be distinguished from smaller tributaries.

4. Tone

- Tone refers to the colour or relative brightness of an object in colour image and the relative and quantitative shades of gray in black and white image.
- The tonal variation is due to the reflection, transmission or absorption characteristic of an object.
- Tone is one of the most basic elements because it is difficult to recognize other elements without tonal differences.

Elements of Photo interpretation

4. Tone

Source: http://keshavrajbhusal.com.np/

Elements of Photo interpretation

5. Shadow:

- Shadow is an especially important clue in the interpretation of objects. the outline or shape of a shadow provides a profile view of objects, relative height of a target which aids in image interpretation.
- The disadvantage of shadow is objects within shadow reflect little light and are difficult to recognize on image, which hinders interpretation.

Elements of Photo interpretation

6. Association:

- It refers to the occurrence of certain features in relation to others.
- Sometimes objects that are difficult to identify on their own can be understood from their association with objects that are more easily identified.
- It takes into account the relationship between other recognizable objects or features in proximity to the target of interest.
- For example a lake is associated with boats and adjacent recreational land, airport with planes, runway etc.

7. *Site*:

- It refers to location of object in relation to its geographic or topographic setting.
- For example, certain vegetations or tree species are expected to occur on well drained uplands or in certain countries), man made features may also be found on rivers (e.g. power plant) or on a hill top (observatory or radar facility) etc.

Elements of Photo interpretation

6. Association:

Source: https://speaklounge.files.wordpress.com/2013/09/f930f-flight-line-2010-04-24.jpg

Elements of Photo interpretation

8. *Pattern*:

- Pattern is the spatial arrangement of objects.
- Typically orderly repetition of similar tones and textures will produce a distinctive and ultimately recognizable pattern.
- Pattern can be either man-made or natural.
- Orchards with evenly spaced trees and urban streets with regularly spaced houses are good examples of pattern.

Elements of Photo interpretation

8. *Pattern*:

Feature extraction

Recognition of topographical features on the photographs(Feature extraction)

1. Roads

- Well built main roads may appear light or dark according to type of surface. They have well-defined edges and are of even width.
- Look for bridges and culverts where waterbodies cross the road.

2. Tracks and Footpaths

- The characteristics of tracks and footpaths are: usually light tone, tend to wander about often not bridges at water.
- Leads somewhere such as buildings, forest or cultivation.

3. Bridges

- Occurs at crossing of the roads, tracks, railways and watercourse.
- They are invariably straight, are generally uniform in width, and probably cast a shadow.

Recognition of topographical features on the photographs(Feature extraction)

4. Railways

- Similar to good roads but because of poor reflectivity usually darker may have long stretches, very smooth curve, never turn at sharp angles, never go up a steep slope, junction come in at very flat angles often parallel and close to road.
- Some associations details are stations, bridges etc

5. Water

- Ponds and lakes are very even in tone depending upon the clarity of water and smoothness of the surface.
- Tones of the water and rivers , streams can be anything from black, white or light green.

6. Stone and sand

- Rocks vary from white to dry grey; according to surface, the type of rock, and direction of the sun.
- Those facing the sunlight appear white. Sand generally appear light and has smooth surface.

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PHOTOGRAMMETRY

EG2202GE

Unit 7: Photogrammetric Procedure

Lecture by
Er. Keshav Raj Bhusal

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7.1 Elements of Photogrammetric mapping

7.2 Introduction to Digital Elevation Model (DEM)

7.3 Process of DEM generation

7.4 Ortho Rectification and the process of orthophoto production

7.5 Mosaic

7.6 Photo index

7.7 Difference between aerial photo and orthophoto

7.8 Feature extraction

General Workflow in Photogrammetry

Elements of Photogrammetric mapping

1. Project Planning (recce, instruments etc.)
2. GCP establishment
3. Flight planning and image acquisition
4. Image processing (Orientation & Aerial Triangulation)
5. Production of Photogrammetric products (After Point cloud densification

DSM, Orthophoto, DTM and contour generation)

Elements of Photogrammetric mapping

1. Project Planning

- This is the first stage where all the necessary decisions are taken and relevant documents are collected.
- Necessary decisions include the methodology, instruments, human resources, budget, mapping areas, product accuracy etc. Relevant documents include existing maps, mapping specification (Scale of map, Contour Interval, etc), flight permission etc.

2. GCP establishment

- Ground control points(GCP) increases the accuracy of photogrammetric products. At present GCPs are establish using DGPS, RTK and other survey grade receivers.
- It depends on client accuracy and budget.
- Cost of establishing ground control ranges between 20 to 50 % of total mapping cost.
- In GCPs position, generally some large flags and symbols are kept in grounds so that they can be recognized clearly in aerial photographs and georeferencing can be done easily.

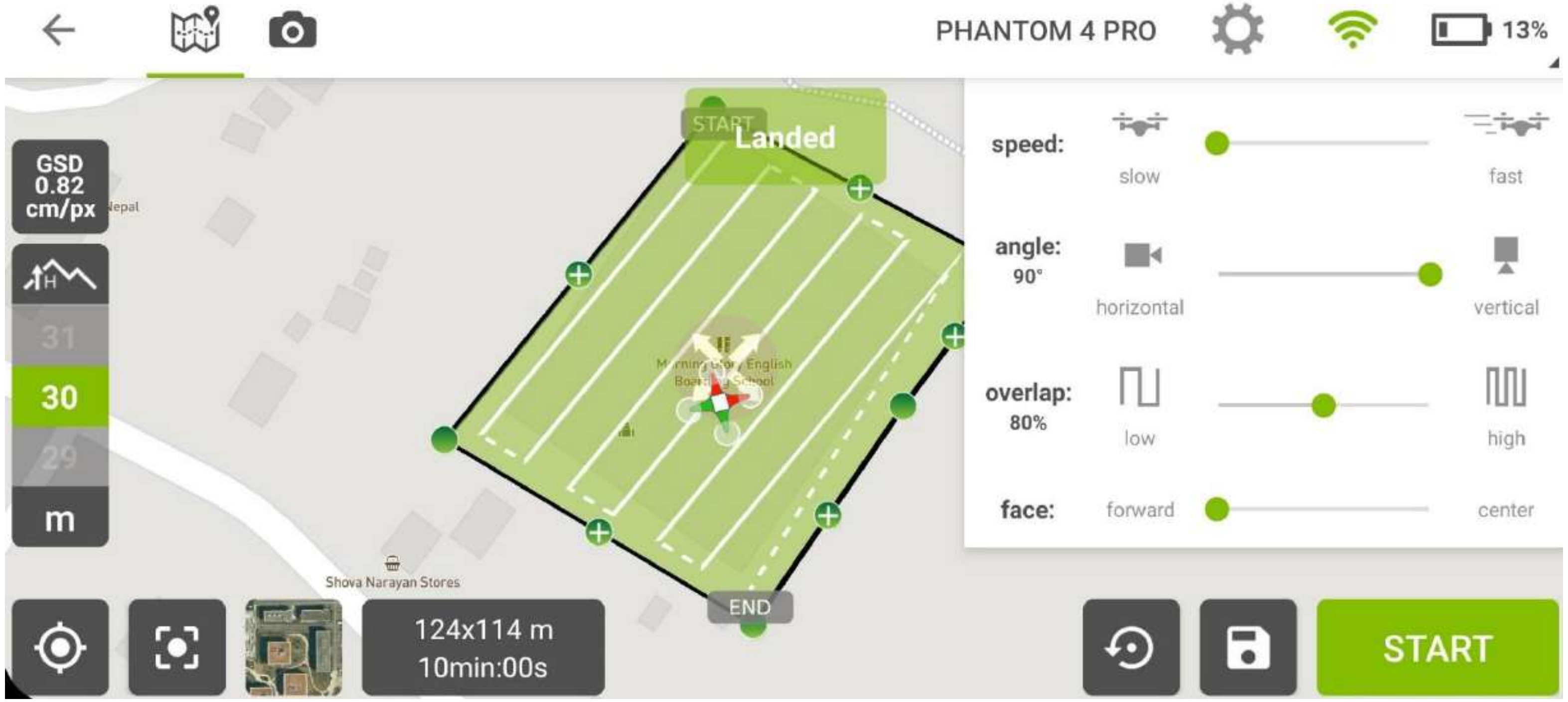
2. GCP establishment

Source: https://www.pix4d.com/blog/why-ground-control-points-important

Elements of Photogrammetric mapping

3. Flight planning and image acquisition

- In this stage, flight path for aircraft is planned and images along that respective path is taken .
- These days, flight planning is done using mobiles apps like Pix4d capture, DroneDeploy etc. We can adjust the settings like required overlap, speed of UAV, flying height and other various settings.
- Flight planning has become very easy with the technological development.



Source:
http://keshavrajbhusal.com.np/

Fig7.2 : showing flight planning and settings adjustment in Pix4d capture.

Elements of Photogrammetric mapping

4. Image processing

- Once the image is captured they are to be processed. In modern photogrammetry, processing of such digital aerial images is done using softwares like Pix4d Mapper, Webodm etc.
- It involves orientation (interior and exterior orientation) and aerial triangulation (when orientation process is done in blocks). Aerial triangulation also enables densification of control points required to make mosaics.
- It also includes image matching(the determination of conjugate points in a stereo image pair), feature matching processes.

5. Production of Photogrammetric products

- Image processing results generation of point cloud. After point cloud densification DSM, Orthophoto, DTM and contour are generated.

DEM

Introduction to Digital Elevation Model (DEM)

- A DEM refers to bare-earth elevations, disregarding(exclusion) of the built (e.g., buildings) or natural (e.g., vegetation cover) features.
- It is the most versatile and useful representation of terrain in GIS. This is a raster representation, in which each grid cell records the elevation of the Earth's surface, and reflects a view of terrain as a field of elevation values.
- DEM are used often in GIS and are most common basis for producing relief maps.
- The data sources for DEMs are:

1. Digitalization of topographic maps
2. Satellite images (from both passive and active systems)
3. Light detection and ranging (LiDAR) data
4. Unmanned aerial systems-based photogrammetry and terrestrial laser scanning.
5. Field survey methods using GPS, Total station etc.

DEM

Applications

1. Civil engineering

- Cut- fill estimation of road design, earthwork etc.

2. Cartography

- It is used to create of relief map.
- 3D visualizations by overlay of dem with satellite imagery.

3 Earth sciences

i. Hydrological modelling:

- Hydrologists use DEMs to delineate watersheds, and calculate flow accumulation and flow direction in HEC-

RAS and other GIS softwares.

ii. Geological Mapping

iii. Geo-morphological simulation and classification

Applications

1. Civil engineering

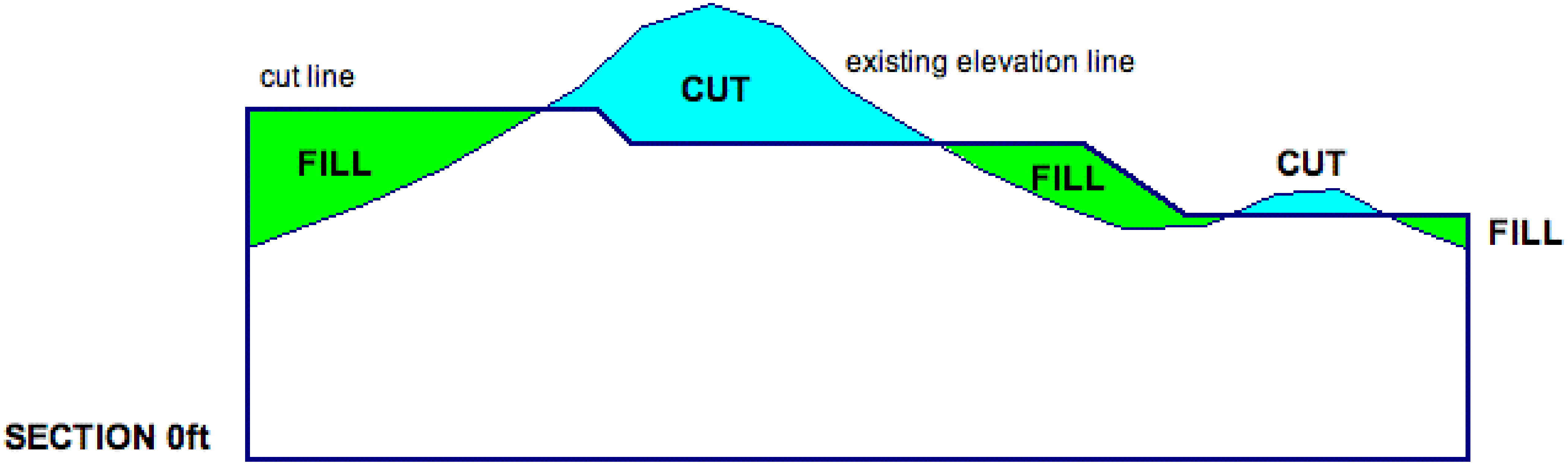


Fig7.1 : showing cut-fill estimation concept

Applications

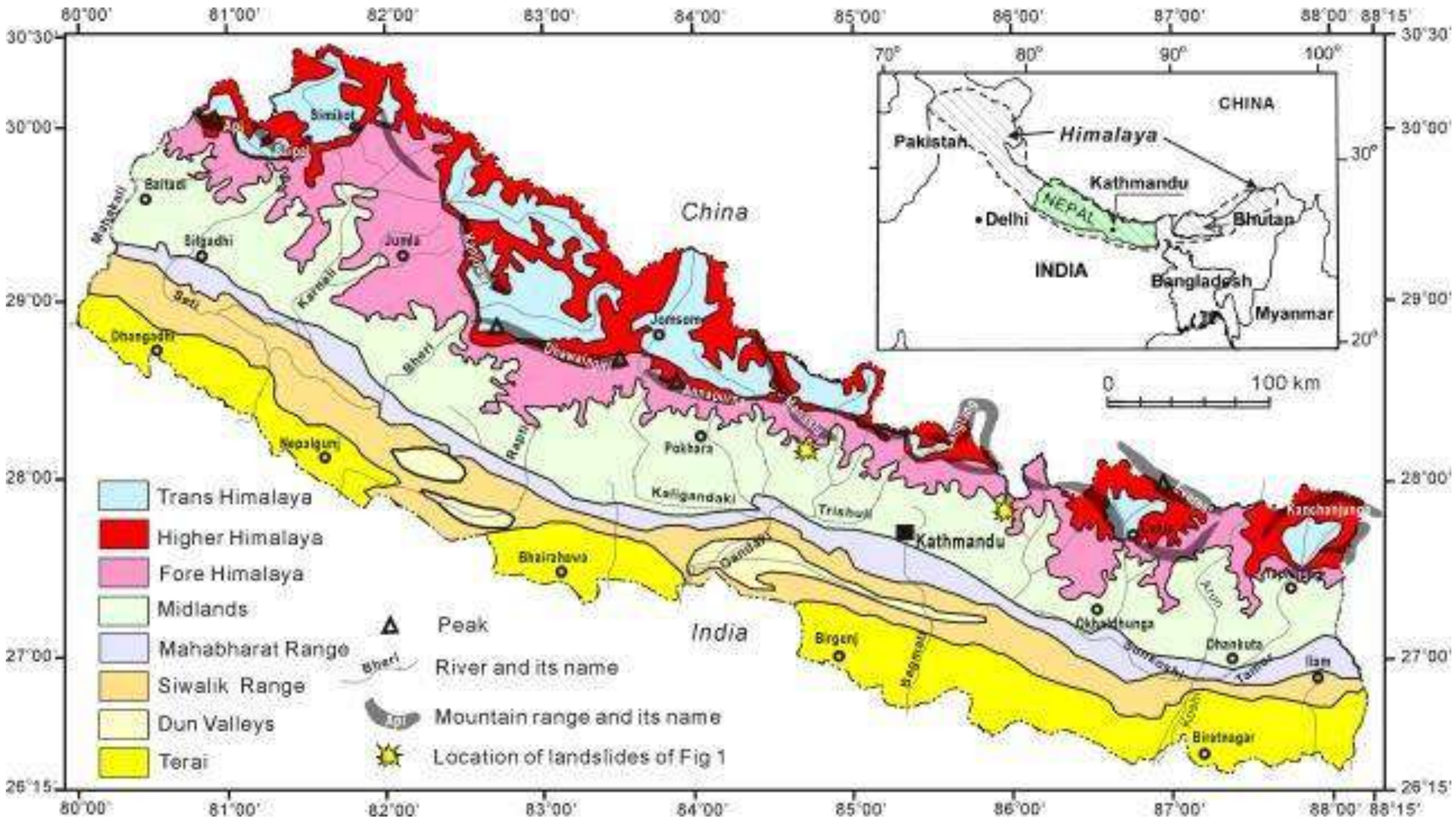


Fig7.1 : showing geomorphological map of Nepal

DEM

Applications

4 Military Application

- In the military the DEMs are used for the battlefield management and strategic planning through the use of topographic maps having elevation data (contour).

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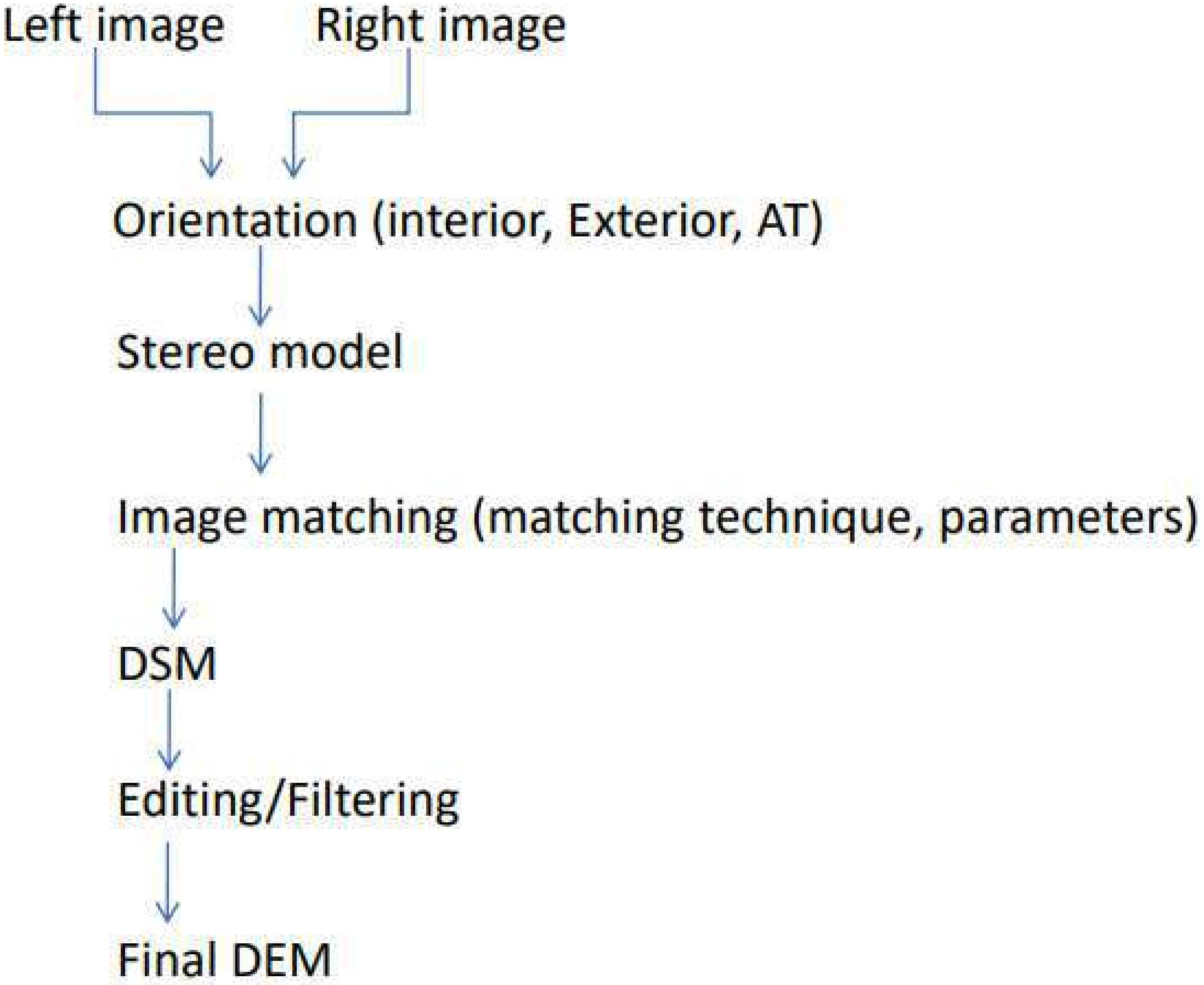
Steps in DEM generation/Process of DEM generation

Major Steps in DEM generation

1. Orientation
2. Image matching
3. Editing/Filtering



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Steps in DEM generation

Process of DEM generation in digital photogrammetry

Image matching:

It includes:

i. Select a matching point in one image.

ii. Find its conjugate point in the other image.

iii. Compute 3D position of the matched point in object space.

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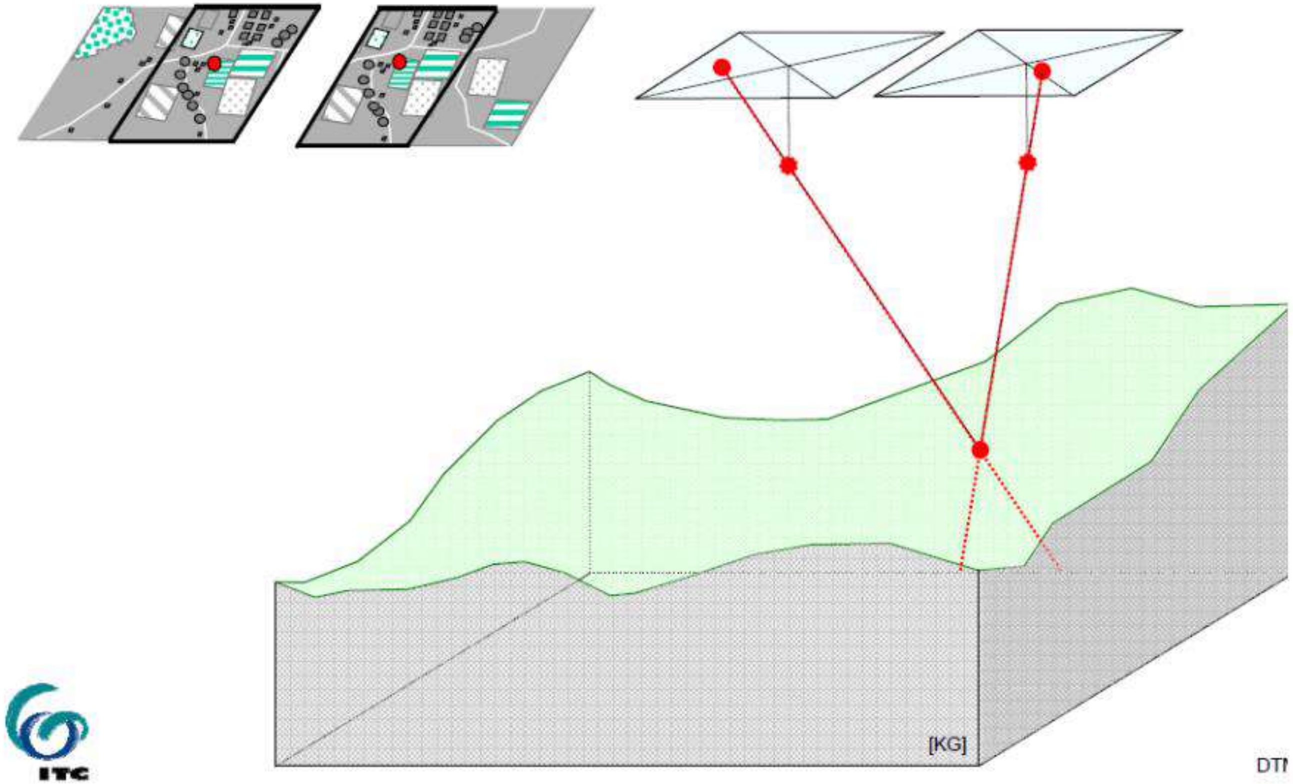


Steps in DEM generation

Process of DEM generation in digital photogrammetry

Editing/Filtering

- Filtering process are applied for reducing the height point to the ground.

Different types of filtering is carried out while creating DEM from DSM which are as follows:

i. Morphological filters (eg: slope-based filtering)

ii. Surface based filters (eg: robust interpolation in addition with hierarchic extension)

iii. Progressive densification (eg: TIN densification)

iv. Segmentation based filters

.

Ortho Rectification

- Orthorectification is the process of removing sensor, satellite/aircraft motion and terrain-related geometric distortions from raw imagery and creating a planimetrically correct image.
- It is the process to make orthophoto. This procedure is totally based on the computer technology in which orthophoto production is done using softwares.
- The resultant orthorectified image has a constant scale where in features are represented in their 'true' positions like in map. This allows for the accurate direct measurement of distances, angles, and areas.
- Required input for orthorectification:

i. Photographs

ii. camera calibration data

iii. ground control points

iv. DTM

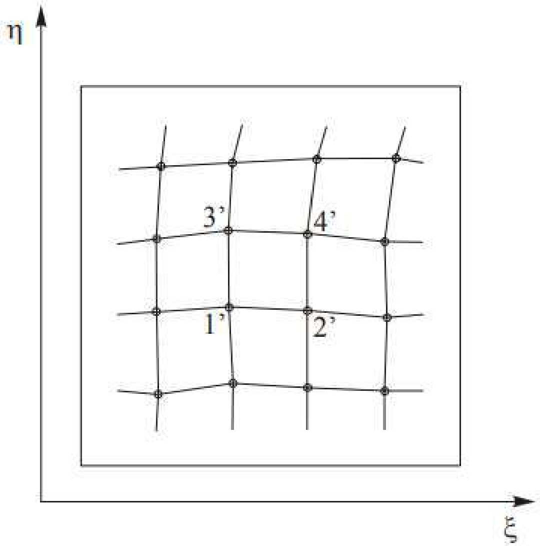
- The various ortho rectification techniques are:

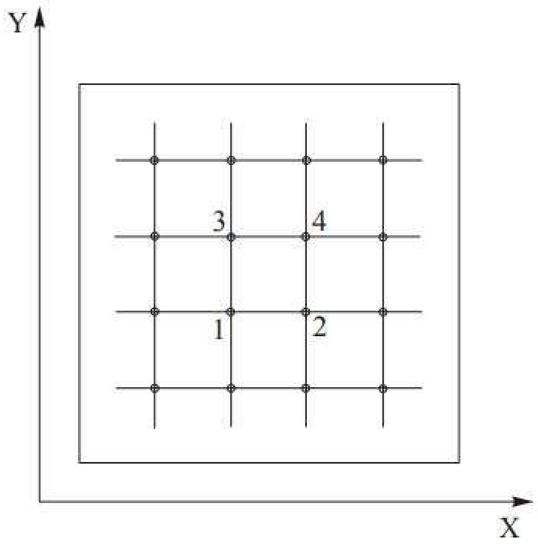
i. Polynomial rectification

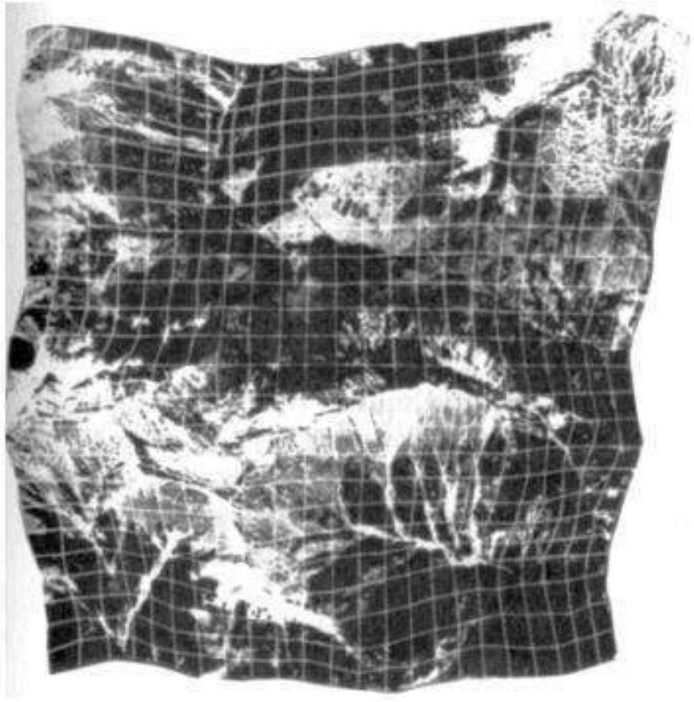
ii. Projective rectification

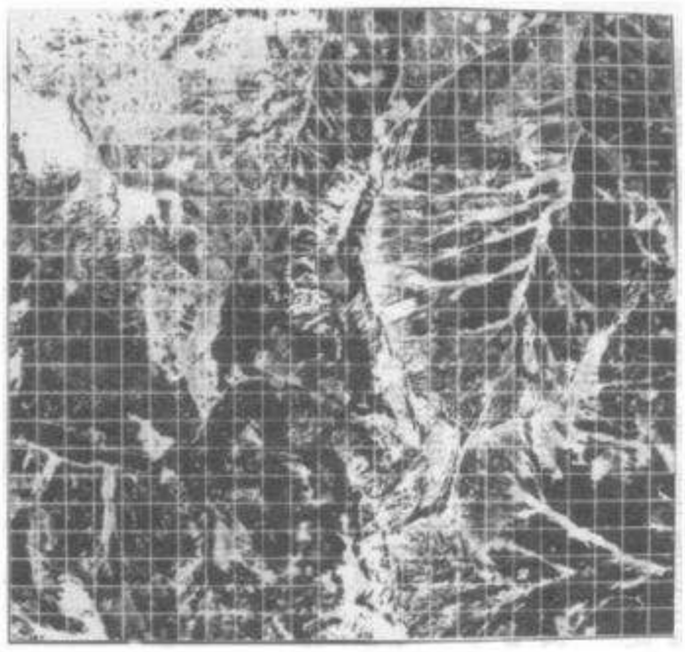
iii. Differential rectification

Ortho Rectification









Process of orthophoto production

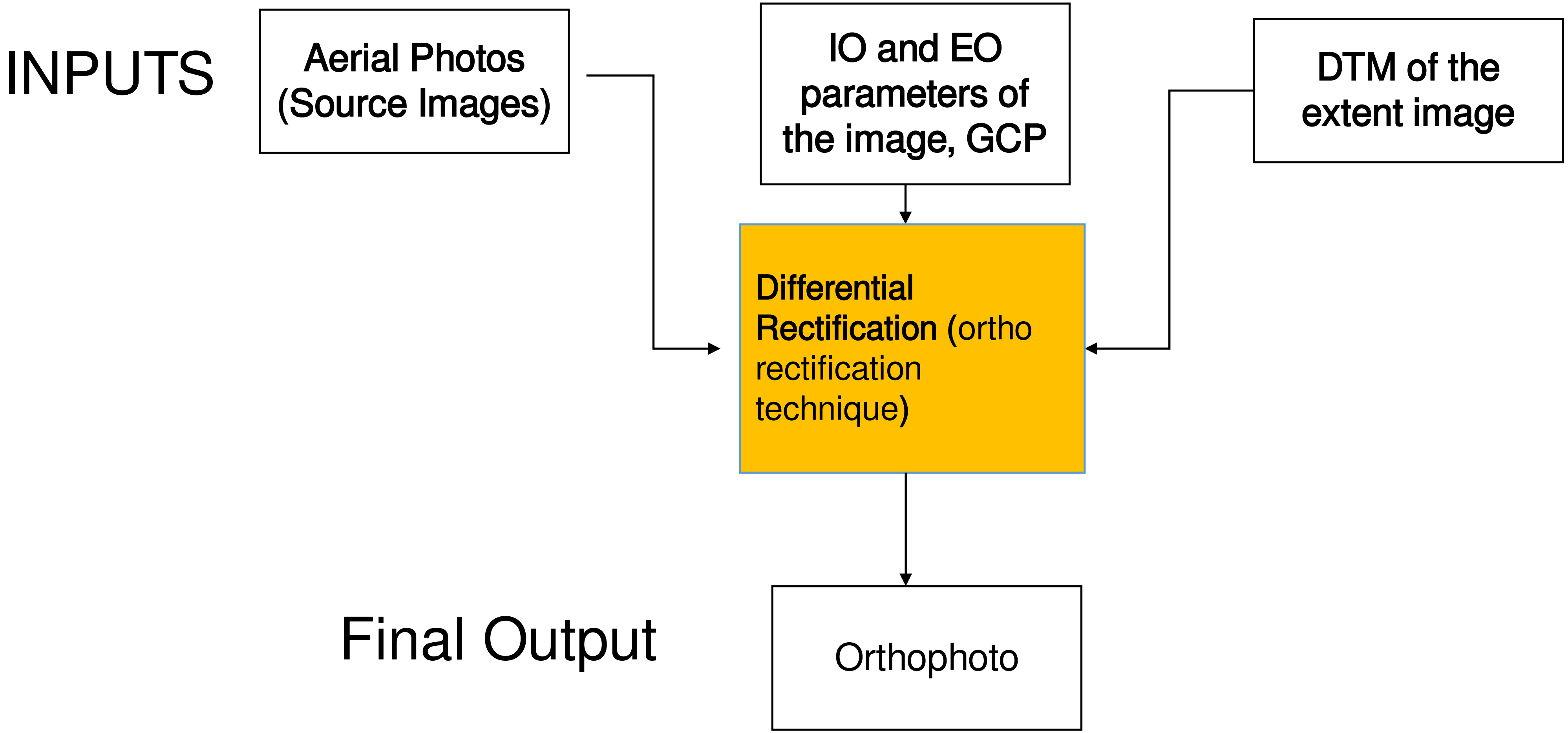


Diagram: Process of orthophoto Production

Process of orthophoto production

1. Aerial Images (Source Images)
- The images from which orthophoto are produced refers to the source image.
- These aerial images are distorted due to tilt, relief and other geometric errors.

2. IO and EO parameters of the image, GCP:

3. DTM:
- This is one of the main input during the production of the ortho photo
- The 3D information (X,Y,Z) are generated from the DTM.

Process of orthophoto production

4. Differential Rectification:

- It is an assignment of color intensity value(gray value) from the perspective image to each pixel of the DSM or DEM.
- To determine gray values, we follow this procedure:

i. Collinearity equations are applied to determine the intensity values as follows:

$$x - x_0 - \Delta x = -c \frac{r_{11}(X - Xc) + r_{12}(Y - Yc) + r_{13}(Z - Zc)}{r_{31}(X - Xc) + r_{32}(Y - Yc) + r_{33}(Z - Zc)} = f_x(X', y') \qquad (1)$$

$$y - y_0 - \Delta y = -c \frac{r_{21}(X - Xc) + r_{22}(Y - Yc) + r_{23}(Z - Zc)}{r_{31}(X - Xc) + r_{32}(Y - Yc) + r_{33}(Z - Zc)} = f_y(X', y') \qquad (2)$$

❖ The DSM coordinates (X, Y, Z) defined by the DSM pixel are transformed into the perspective image by (1) and (2).

ii. Then the color intensity value is interpolated by one of the resampling methods at the image position (x, y), and it is stored at the the x', y' position of the orthophoto, which is equal to the position of the DSM point.

4. Differential Rectification:

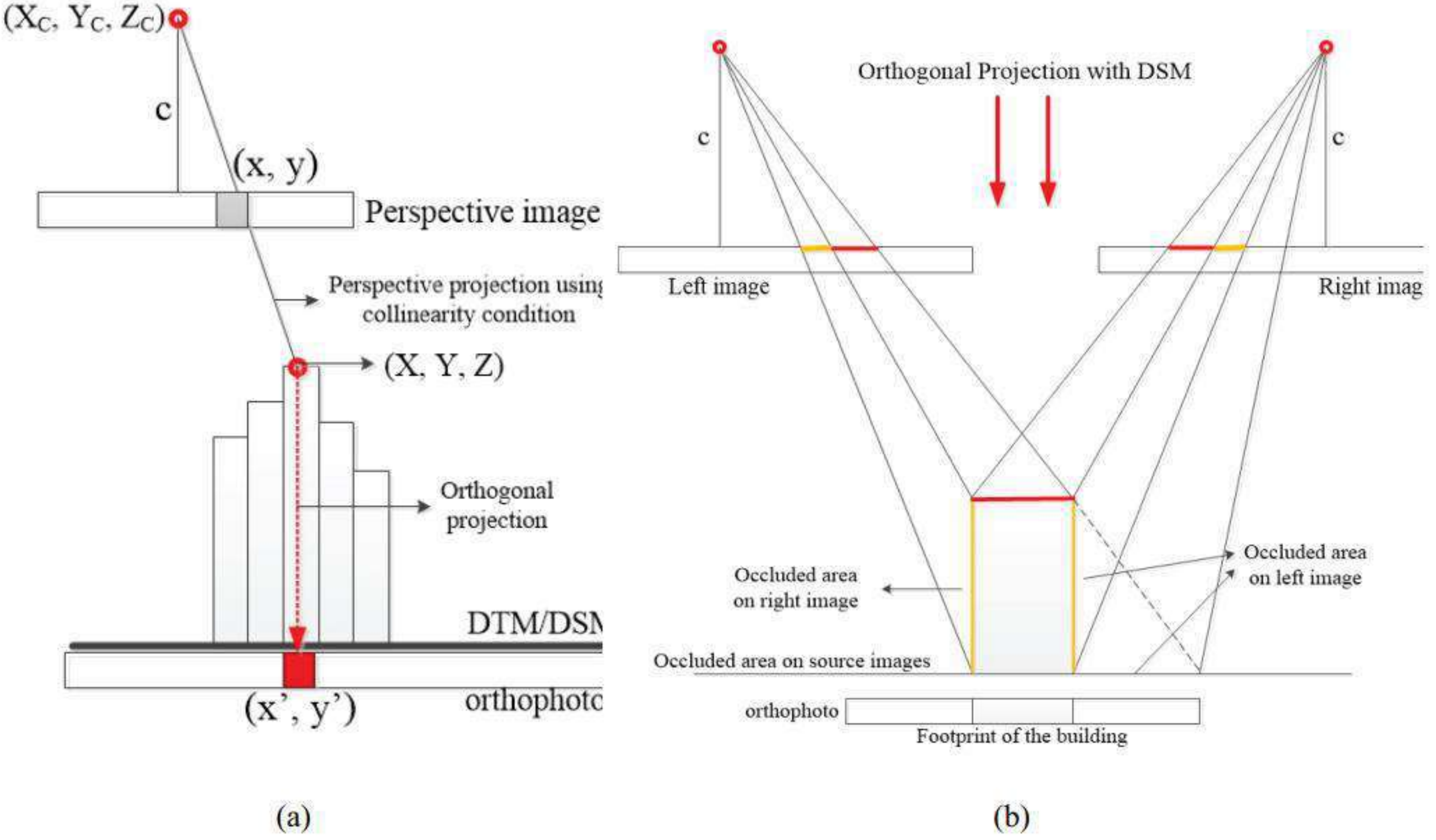
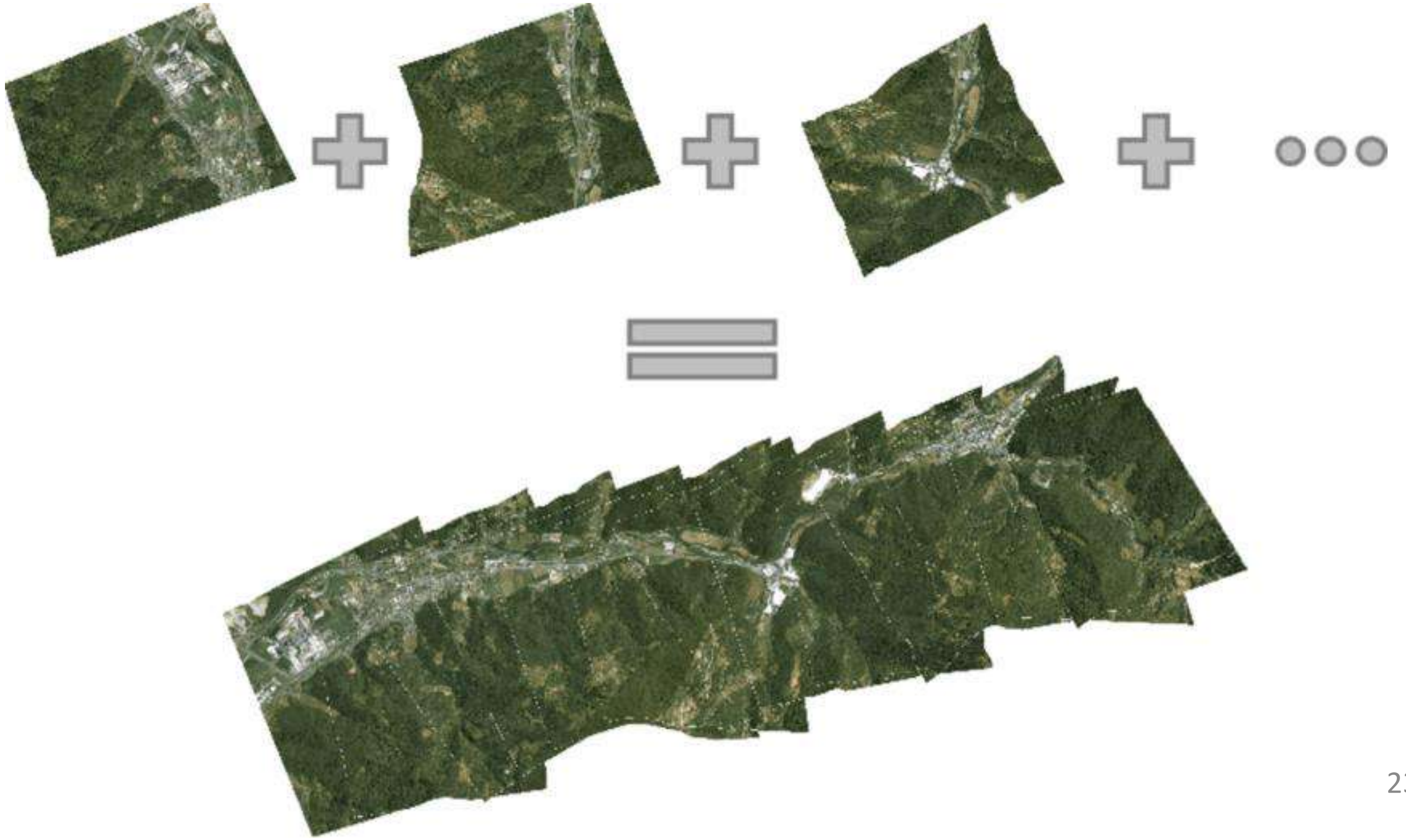


Fig7.2 showing Orthorectification process: (a), each 3D surface point defined as pixel of the DSM is transformed into the image the color intensity value from the source image. This value is assigned to the orthophoto raster at the same pixel location as the DSM point.

Mosaic

- A mosaic is an assesmbly of series of aerial photographs put together in such a way that the detail of one photograph matches the detail of all adjacent photographs.
- While assembling, the edge have been cut and matched and fitted together systematically to form a continuous photographic representation of a portion of the Earth's surface.
- It consist of three main types:

i. uncontrolled mosaics
ii. semi-controlled mosaics
iii. controlled mosaics.



Mosaic

Uncontrolled mosaics

- If this assemblage(collection of series of aerial photographs) is made without any control, then it is called uncontrolled mosaic.

Semi-controlled mosaic

- A semi controlled mosaic may be prepared from unrectified photograph assembled to have ground control.
- Alternatively rectified photographs may be used with no ground control.

Controlled mosaics

- If aerial photographs have been properly rectified, i.e., enlarged or reduced and fitted on adequate ground control the mosaic is said to be a controlled mosaic.

Concepts of Orthophoto, Orthomosaic

Orthophoto, Orthophotograph or Ortho image :

- It is an aerial photograph which is geometrically corrected (“orthorectified”) with all the distortions removed such that the scale is uniform.

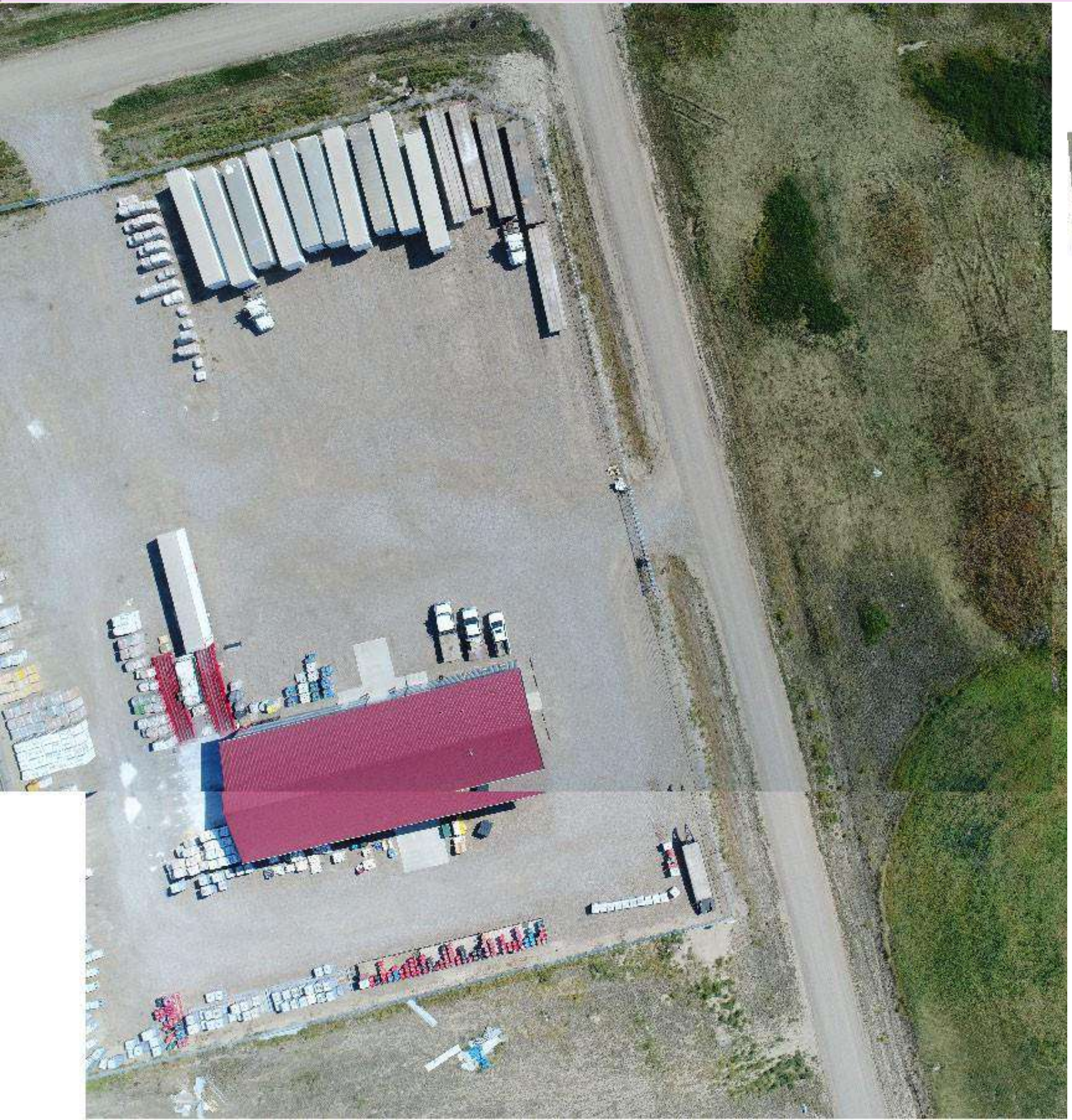
Orthomosaic

- Ortho — meaning straightened or aligned
  Mosaic — piecing things together
- Orthomosaic is the final product after stitching together all the individual orthophotos.

Aerial photo vs Orthophoto

Aerial photo	Orthophoto
1. Aerial photo contains errors due to terrain relief, sensor, satellite/aircraft motion, ens distortion etc.	Orthophoto is free from such errors as it passess through orthorectification process.
2. Ground features are not in planimetrically true position.	Ground features are in planimetrically true position.
3. It has non-uniform scale. 4. It has perspective projection. 5. It is obtained from aerial cameras fixed in aircraft, UAV and other vehicle.	It has uniform scale. It has orthogonal projection. It is obtained by processing (orthorectification) aerial photos.

Aerial photo(left) vs Orthophoto(right)



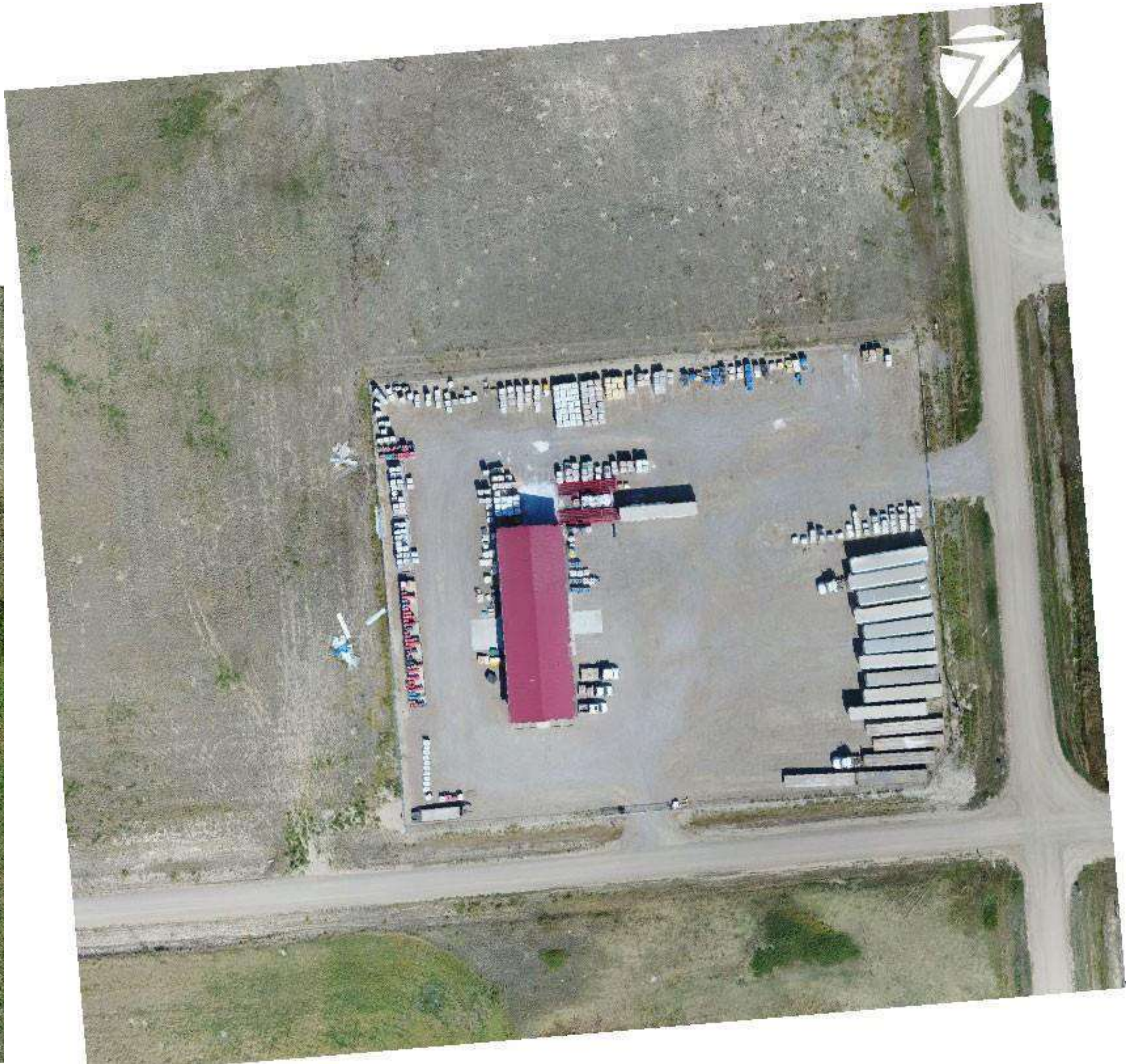


Photo index

- The photographs are laid in such a sequence as to allow photo number and flight number of each photograph to appear on the finished assembly. This assembly is called an index mosaic or photo index mosaic.
- They are prepared for the purpose of providing an index to the individual photographs.
- The margin of each photograph is clearly labeled so that the observer can quickly determine which piece covers a particular area.

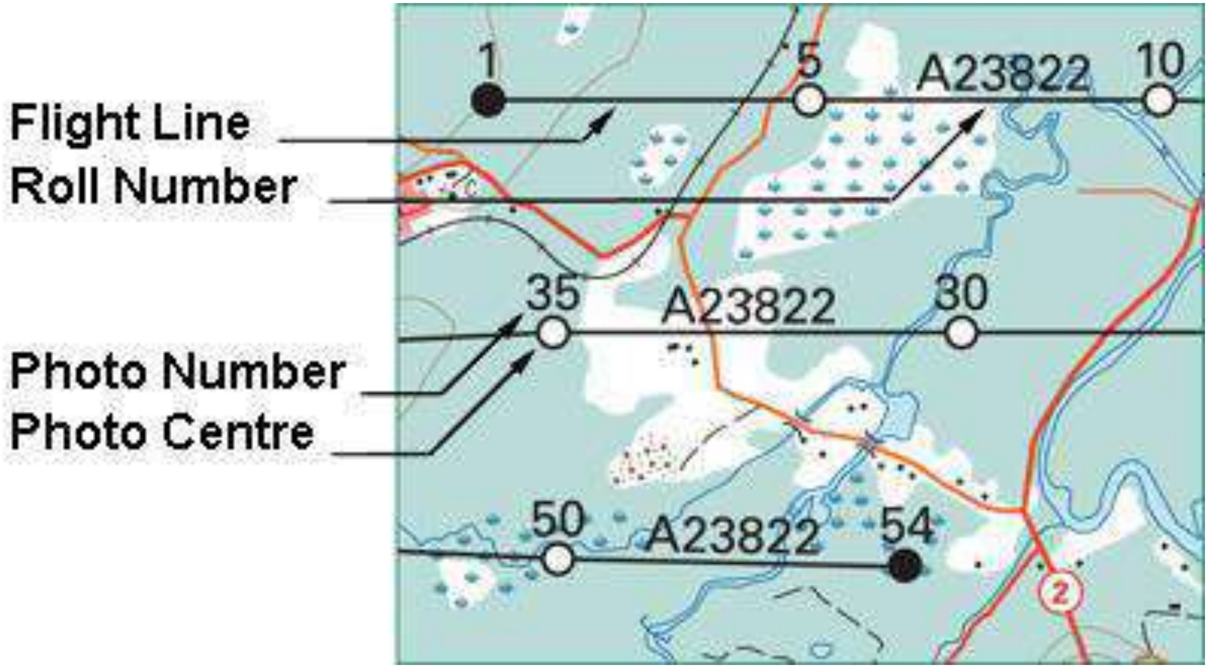


Fig: Photo index map

Feature extraction

- Feature extraction is the process of extracting the required topographic or planimetric features from photograph.

Main Steps in Feature Extraction:

i. Image Interpretation
ii. Detail Classification
iii. Digitization (2D or 3D)

Image Interpretation:

i. Spontaneous recognition: It is the detail type which is familiar and can be identified easily e.g. building, river
ii. Logical inference: It is the detail which are not easily identified are interpreted by applying logical inference e.g. colour, shape, size, pattern, texture, orientation/location, association etc.

Feature extraction

Detail Classification

There may be different types of details on the photographs and can be classified according to their common characteristics:

e.g. Different types of buildings like residential, commercial, industrial, school, hospitals can be put together in a class ”Building”

Similarly, highway, motorable, cycle track, foot trails can be categorised as ” Road”

- As these extracted information can be used as GIS layers, so this type of classification plays important role for further data management.

Digitization

- After classifying features digitizing rules should be followed for point, line and area features.
- The features should be digitized under the same feature classes.

QUESTIONS to think ?

1. Is the image that we see on google earth orthorectified ?

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