Aerial photo interpretation and photo grammetry

Lecture note prepared for BSc 3rd year students

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Students are strongly recommended to refer Lillesand et al and Avery text books for details of the note. Thanks to Samrajya Thapa/BSc 3rd year student for support.

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Unit: 1

Aerial photography

Aerial photography is defined as the science of obtaining photographs from the air using various platforms, mostly aircraft, for studying the surface of the earth. The sun provides the source of energy (electromagnetic radiation or EMR) and the photosensitive film acts as a sensor to record the images. Variations in the gray tones of the various images in a photograph indicate different amounts of energy reflected from the objects as recorded on the film.

An aerial photograph, in broad terms, is any photograph taken from the air. Normally, air photos are taken vertically from an aircraft using a highly-accurate camera. There are several things you can look for to determine what makes one photograph different from another of the same area, including type of film, scale, and overlap. Other important concepts used in aerial photography are stereoscopic coverage, fiducial marks, focal length, roll and frame numbers, and flight lines and index maps. The following material will help you understand the fundamentals of aerial photography by explaining these basic technical concepts.

The earth's atmosphere, which contain various particles and molecules of gases and water vapor, attenuates the incoming as well the outgoing energy/radiation (scattering) after interaction (reflectance, transmittance and absorption) with the object and thus reduces the contrast between different images formed on the photographic film. Therefore, the quality of aerial photography largely depends upon the atmospheric conditions prevailing at that time. Different filter/lens combinations can, however, be used to eliminate some of the atmospheric effects in black and white photography by making use of a yellow (minus blue) filter to reduce the effects of haze. The problem becomes more complex in the case of colour photography. Other factors that influence aerial photography are:

Scale
Scale is the ratio of distances between two images on an aerial photograph and the actual distance between the same two points/objects on the ground, in other words the ratio $f/H$ (where $f$ is the focal length of the camera lens and $H$ is the flying height above the mean terrain). Due to variations in flying height, the scales of different photographs may vary. Scale may also vary because of the effects of tilt and relief displacements.

Camera/Film/Filter Combinations:
In order to extract the maximum information from aerial photograph, the image should be of the highest quality. To ensure good image quality, modern distortion-free cameras are used. Some of the latest versions have image motion compensation devices to eliminate or reduce the effects of forward motion. Depending upon the requirements, different lens/focal length/film/filter combinations can be used.

Flight direction
As a rule, aerial photography is flown in strips to cover the designated area. For convenience in handling, it is advisable to keep the number of strips to minimum. The flight direction of the strips is therefore kept along the length of the area. This direction may be any suitable direction along a natural or man-made feature and should be clearly specified.
Time or season of photography
The time of aerial photography is very important, as long, deep shadows tend to obscure
details, whereas small shadows tend to delineate some details effectively and are
generally advantageous in improving the interpretational values of a photograph. Based
on experience, aerial photography should be flown when the sun's elevation is 30
degrees above the horizon, or three hours before and after the local noontime. The
choice of the most suitable season depends on factors such as seasonal variations in
light reflectance, seasonal changes in the vegetation cover and seasonal changes in
climatological factors. The purpose for which aerial photography is flown also dictates the
season. For example, for photogrammetric mapping, geological or soil survey purposes,
the ground should be as clearly visible as possible.

Atmospheric condition
As mentioned before, the presence of particles (smoke or dust) and molecules of gases
in the atmosphere tends to reduce contrast because of scattering, especially by the
heavier particles; therefore the best time for photography is when the sky is clear, which
normally in India is from November to February. The presence of dust and smoke during
the pre monsoon summer months and of clouds during the monsoon months forbids
aerial photography during these periods.

Stereoscopic coverage
To examine the earth's surface in three dimensions, aerial photography is normally
flown with a 60 % forward overlap and a 25 % side lap, to provide full coverage of the
area. This is an essential requirement from the photogrammetric mapping point of view
to obtain data both on planimetry and heights using the stereoscopic principle of
observation in 3-D and measurement techniques with stereo plotting instruments.
Stereoscopic viewing also helps in interpretation, as the model is viewed in three
dimensions.

Application of aerial photography

Mapping
The application of aerial photography in photogrammetric mapping is an established
procedure all over the world. It has been found to be fast, accurate, indispensable in
inaccessible areas and cost effective in the long run, as initially the establishment of a
photogrammetric survey/mapping unit involves capital expenditure due to the cost of
photogrammetric instruments and other ancillary equipment.

Interpretation
Photo interpretation has revolutionised the methods of data collection in various
disciplines. It greatly reduces the fieldwork and thereby the cost. The information is
reliable and acceptance for most studies such as in the fields of geology, water
resources, geomorphology, hydrogeology, forestry and ecology, soil surveys, and urban
and regional planning.

Map substitute
In a situation where there are no adequate large-scale maps available, aerial
photographs can serve as map substitutes in the form of photomaps. In the case of
relatively flat terrain, these photomaps can be produced by rectification to remove the
effects of tilt distortion and scale correction. This method has been found to be three to
times faster than conventional mapping by photogrammetric methods. In the case of
hilly terrain, such photomaps (orthophoto maps) can be produced by the orthophoto
technique, which has also proved to be faster than conventional mapping. In some
urgent situations, simple mosaics prepared from aerial photographs can substitute for
maps.
Development of aerial photography

1839 AD: Louis Daguerre announced direct photographic process using exposure made on metal plates (silver iodide coated)
1840AD: Arago demonstrated the use of photography in topo survey
1849AD: Use of photogrammetry in topographic mapping by French army
1859AD: Success of use of photographs in mapping
1894AD: Use of photography for mapping the border between Canada and Alaska
1909AD: Dr carl Pulfrich use stereo scopic pair of photography for anlaysis
1902 AD: Invention of aerial plane for photography away from ground surface
1913 AD: Airplane used first time for obtaining photography for mapping purpose. Use of photography for world war purpose.

Classification/ Types of aerial photo

There are different criteria to classify aerial photographs depending upon the scale, tilt, coverage, film and spectral coverage/response. This classification can be defined as follows:

Scale:
Large scale: between 1:5,000 and 1:20,000
Medium scale: between 1:20,000 and 1:50,000
Small scale: smaller than 1:50,000 (Scale classification may differ from country to Country)

Tilt:
Vertical: when the tilt is within ± 3° (nearly vertical)
Oblique : Low oblique (horizon does not appear but tilt is more than 3° )
High oblique (horizon appears) Horizontal or terrestrial: camera axis is kept horizontal.

Angular coverage:
- Narrow angle : angle of coverage less than50°
- Normal angle : angle of coverage of 60°.
- Wide angle : angle of coverage of 90° .
- Super-wide angle : angle of coverage of 120°

Film:
- Black and white panchromatic.
- Black and white infrared.
- Colour
- Colour infra-red/false colour
Basic Concepts of Aerial Photography

**Film:** most air photo missions are flown using black and white film, however colour, infrared, and false-colour infrared film are sometimes used for special projects.

**Focal length:** the distance from the middle of the camera lens to the focal plane (i.e. the film). As focal length increases, image distortion decreases. The focal length is precisely measured when the camera is calibrated.

**Scale:** the ratio of the distance between two points on a photo to the actual distance between the same two points on the ground (i.e. 1 unit on the photo equals "x" units on the ground). If a 1 km stretch of highway covers 4 cm on an air photo, the scale is calculated as follows:

\[
\text{Scale} = \frac{4 \text{ cm}}{1 \text{ km}} = \frac{4 \text{ cm}}{100,000 \text{ cm}} = \frac{1}{25,000}
\]

Another method used to determine the scale of a photo is to find the ratio between the camera's focal length and the plane's altitude above the ground being photographed.

If a camera's focal length is 152 mm, and the plane's altitude Above Ground Level (AGL) is 7600 m, using the same equation as above, the scale would be:

\[
\text{Scale} = \frac{152 \text{ mm}}{7600 \text{ m}} = \frac{152 \text{ mm}}{7600,000 \text{ mm}} = \frac{1}{50,000}
\]

Scale may be expressed three ways:

- Unit Equivalent
- Representative Fraction
- Ratio

A photographic scale of 1 millimetre on the photograph represents 25 metres on the ground would be expressed as follows:

- Unit Equivalent - 1 mm = 25 m
- Representative Fraction - 1/25 000
- Ratio - 1:25 000

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Two terms that are normally mentioned when discussing scale are:

- **Large Scale** - Larger-scale photos (e.g. 1/25 000) cover small areas in greater detail. A large scale photo simply means that ground features are at a larger, more detailed size. The area of ground coverage that is seen on the photo is less than at smaller scales.

- **Small Scale** - Smaller-scale photos (e.g. 1/50 000) cover large areas in less detail. A small scale photo simply means that ground features are at a smaller, less detailed size. The area of ground coverage that is seen on the photo is greater than at larger scales.

The National Air Photo Library has a variety of photographic scales available, such as 1/3 000 (large scale) of selected areas, and 1/50 000 (small scale).

**Fiducial marks**: small registration marks exposed on the edges of a photograph. The distances between fiducial marks are precisely measured when a camera is calibrated, and this information is used by cartographers when compiling a topographic map.

**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 per cent forward overlap (between photos along the same flight line) and 30 per cent lateral overlap (between photos on adjacent flight lines).

**Stereoscopic Coverage**: the three-dimensional view which results when two overlapping photos (called a stereo pair), are viewed using a stereoscope. Each photograph of the stereo pair provides a slightly different view of the same area, which the brain combines and interprets as a 3-D view.
Unit 2: Principal of photography

2.1 Development of Camera

- Photographic cameras are the **simplest and oldest** of sensors used for remote sensing these days.
- Cameras are **framing systems, which acquire an instantaneous “snapshot” of an area of the surface**.
- **Camera similar to our eyes**, many of the mechanism, including geometry, are analogous.
- **Light sensitive** (Retina=film located at film plane at the back of camera)
- **Amount of light controlled by** (Iris=diaphragm)
- **Control the length of exposure** (eyelids=shutter)

Ancient (early)

- Light tight box with pinhole at one end and the light sensitive material to be exposed positioned against the opposite end.
- Amount of time (exposure) controlled by pinhole (in hrs) because of low sensitivity of photographic materials and limited light gathering capability of the pinhole design.
- Most passive camera

Modern (now)

- Pinhole camera replaced by lens camera
- Pinhole is replaced by lens
- Allowing more light to reach the film in a given amount of time because of large size of lens than pinhole
- In addition to the lens, diaphragm (control lens diameter) and shutter (control duration of exposure)
- Both active and passive

Example: use of sunlight Vs auto flash condition of camera
Modern Cameras
2.2 Types of camera

1. Metric camera:
   - Also called aerial frame camera
   - Widely used for remote sensing purposes
   - Provides highest geometric and radiometric quality

2. Multiple lens camera
   - Also called multi spectral camera
   - Origin for the development of multi spectral remote sensing systems
   - Multi lens system with different film filter combinations to acquire photos simultaneously in a number of different spectral ranges
   - Ability to record reflected energy separately in discrete wavelength ranges
   - Each camera simultaneously records photos of the same geographic area but uses different film
   - Used for monitoring, mapping natural and cultural resources

3. Panoramic camera
   - Uses rotating lens to produce narrow strip of image perpendicular to the flight line
   - Photo does not have rigid geometry
   - Changing photo scale
   - Less application

4. Strip camera
   - Records images by moving film in the focal plane as the camera moves forward
   - Use slit instead of shutter
   - Film rolls pass the slit with the same proportional speed of target, which in the case of speed of the plane
   - Design for the purpose of low altitude, military reconnaissance
   - Continuous image motion in strip offers detailed photography, which could not be obtained by frame camera
   - Smaller field of view

5. Large Format Camera
   - Large camera with long focal length and takes high quality image covering several hundreds of kilometers
   - Film size is much larger than that of others
   - Used by space shuttles, astronauts on board the shuttle

Now the question is:
Q) Which camera is considered to be best for the remote sensing purpose? Justify with reason.
Components of Camera

The major components of an aerial camera are: Lens, lens cone, shutter and diaphragm, camera body, drive mechanism, film magazine, focal plane and film flattening device (Fig below.)

**Lens:** The lens should be distortion-free and of high resolution. The lens surfaces should have anti-reflection coatings.

**Lens cone:** Support the lens and retain it at a predetermined distance and position from the film or plate negative, and serves to include direct light from striking the film or plate. The interior of the lens cone should be black and fitted with baffles so as to reduce the reflection of flare light. This holds the lens and the filter

**Focal plane:** Perpendicular plate aligned with the axis of the lens

**Diaphragm:** It is a ring or plate with a hole in the center that controls the amount of light entering the camera

**Shutter:** It is a movable cover for an opening. It opens and closes to control how long the focal plane is exposed to light

The camera body houses the camera drive mechanism, driving motor, operating handles and levers, electrical connections and switches and other accessories which may be necessitated by specified requirements.

The camera derive mechanism is the power unit and power distributor for the entire camera. The electric motor causes the many cams gear and shafts of the camera to move. By means of rods and couplings, the power is routed to the shutter and the film magazines. When a cycle is completed, the camera drive receives and electrical or mechanical impulse, operates the shutter, and thus exposes the sensitized material.

The film magazine is first of all a container of film. Besides this it contains a driving mechanism, which receives power from the camera drive mechanism and thereby shifts the film after each exposure has been made. In addition, the magazine contains a means of holding the film flat in the focal plane while the exposure is being made.

The focal plane of an aerial camera is the plane in which all light rays through the lens cone come to a focus. A frame bound the focal plane, which determines the size of the negative. In order to provide a means for placing the emulsion of the film in the exact focal plane, a metal plate known as locating back is used in modern aerial cameras.

The film flattening is usually accomplished in modern aerial cameras by a vacuum system. The locating back has grooves in which there are small holes which leads to a central vacuum connections and hold the film firmly against the focal plane frame.

**Parts of an aerial camera**
- a= film
- b= pressure plate
- c= focal plane frame
- d= lens
- e= filter

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Calibration of camera

- It is performed to obtain a standard and desired object in the output image for a given material.
- Particular example is: shutter, pixel size

2.3 Relation: Aperture Vs shutter speed

SHUTTER SPEED

- **Shutter Speed** – the length of time a camera shutter is open to expose light into the camera sensor. Shutter speeds are typically measured in fractions of a second, when they are under a second.
- Slow shutter speeds allow more light into the camera sensor and are used for low-light and night photography, while fast shutter speeds help to freeze motion.
- Examples of shutter speeds: 1/15 (1/15th of a second), 1/30, 1/60, 1/125.

  **Point to remember: Relation between Shutter speed……..amount of light**

APERTURE

- **Aperture** – a hole within a lens, through which light travels into the camera body. The larger the hole, the more light passes to the camera sensor.
- Aperture also controls the **depth of field**, which is the portion of a scene that appears to be sharp.
- If the aperture is very small, the depth of field is large, while if the aperture is large, the depth of field is small.

  **Why this???? Imagine once......Think once**

In photography, aperture is typically expressed in “f” numbers (also known as “focal ratio”, since the f-number is the ratio of the diameter of the lens aperture to the length of the lens). Examples of f-numbers are: f/1.4, f/2.0, f/2.8, f/4.0, f/5.6, f/8.0.
What is film exposure? Write relation between shutter speed and aperture.

Exposure in film photography is defined as the quantity of light that is allowed through the camera lens and onto the photo film controlled by the intensity of light (through the aperture) and length of time (determined by the shutter speed). For correct exposure in a film camera, whether 35mm, medium format, or large format, it is essential that you correctly set both the shutter speed and aperture. Film speed will also play a role in determining the correct exposure.

The shutter is a sheet that moves to uncover or obscure the film or CCD and normally obstructs the passage of light. The aperture is a hole in an optical diaphragm which can be varied in size to alter the amount of light entering the lens (a lot like the pupil and iris of a human eye). In general to maintain a good exposure, if you lengthen the shutter speed (allowing more time for light to reach the film or sensor) you must decrease the aperture size (to allow less light into the lens in the first place) and vice versa.

Mathematical Relationship:
In photography and other branches of optics, the aperture size of a given lens is often described as an F-ratio or F-stop number. This is the ratio of the aperture diameter to the focal length of the specific lens.

This is expressed as $NF = \frac{F}{DA}$

Where:
$NF =$ F-Number
$F =$ Focal length of lens
$DA =$ Aperture Diameter
As such the mathematical relationship between shutter speed and aperture diameter is directly proportional (when the shutter speed gets higher, the aperture must get larger to maintain correct exposure) and the mathematical relationship between the shutter speed and F-stop number is inversely proportional (as the shutter speed decreases, the F-Stop number must increase - meaning that the aperture diameter is decreasing to avoid over exposing the image). This is known as a reciprocal relationship. However, when the shutter is slowed down beyond a certain point or the effective shutter speed is made extremely fast (via the use of strobe lighting), the purely mathematical relationship fails. This is known as reciprocity failure. Rather than explain it here, search for the question "What is reciprocity failure" (hopefully, no one changes the wording of the question).

Their use in photography:

Fast shutter speeds will "freeze" the object in the frame whereas slow shutter speeds will cause moving objects to blur (which can be a very effective technique when photographing flowing water / waterfalls). A very low shutter speed will actually cause moving objects to disappear from a photograph totally and is a common technique used by architectural photographers to ensure that moving people or vehicles do not appear in photographs of buildings.

A small aperture (higher F number) will create greater depth of field, which is the distance in front and behind the point of interest which is being focused on. This is useful in landscape photography where you wish to include detail in the whole of the image. A large aperture (lower F number) will greatly reduce the depth of field, meaning that less distance in front and behind the point of focus will be sharp. This is very commonly used in portrait and wildlife photography where you wish to isolate the subject of interest from the potentially distracting background.

**Lens quality assessment**

- Sharpness
- Distance from the center of the image
- Aperture
- Focal length

The center of picture will always be the sharpest area and the edges will be more or less blurry depending on the lens and aperture.

**Explain why camera calibration is important before aerial photography?**

Camera calibration is the process of finding the true parameters of the camera that took your photographs. Some of these parameters are focal length, format size, principal point, and lens distortion. If the software does not know the true camera parameters you will get poor results or no results at all. Sometimes good guesses or approximate values for the parameters are good enough
(they do have to be close to the correct values). If you need high accuracy though, completing a camera calibration is very important.

**Lateral magnification/Optical magnification**

- **Magnification** is the process of enlarging something only in appearance, not in physical size.
- The ratio of the size of the image of an object to that of the object.

\[ M = \frac{f}{f - d_0} \]

where \( f \) is the focal length and \( d_0 \) is the distance from the lens to the object.
**Three Kings of Photography**

ISO is level of sensitivity of your camera to available light. And is represent by number. Low number means low sensitivity and vice versa.

**Depth of Field**

- **Depth of field (DOF)** is the distance between the nearest and farthest objects in a scene that appear acceptably sharp in an image.
- depending on camera type, aperture and focusing distance, although print size and viewing distance can also influence our perception of depth of field.

![Fig showing – Depth of Field](image)

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Shutter speed influence

In addition to its effect on exposure, the shutter speed changes the way movement appears in the picture. Very short shutter speeds can be used to freeze fast-moving subjects, for example at sporting events. Very long shutter speeds are used to intentionally blur a moving subject for artistic effect.

Aperture

The biggest difference between a large and optimal aperture (e.g. f/1.8 vs f/8) will be visible in the corners of the image.
Most zoom lenses perform best in the middle range and worse at the extremities (e.g. an 18-135mm zoom will perform better at 50mm than 18 or 135mm).........**Need consistent sharpness across image**

### 2.4 Photographic films and filters

**Photographic films**

- **Photographic film** is a sheet of plastic coated with an emulsion containing light-sensitive silver halide salts with variable crystal sizes that determine the sensitivity, contrast and resolution of the film
- When the emulsion is sufficiently exposed to light (or other forms of electromagnetic radiation such as X-rays), it forms a latent (invisible) image
- Chemical processes can then be applied to the film to create a visible image, called a photograph
- In black-and-white photographic film there is usually one layer of silver salts
- But in color film uses at least three layers
- Typically the blue-sensitive layer is on top, followed by the green and red layers
- Silver salt converted to metallic silver while processing in B/W film
- By products of above reaction, combine with chemical know as color couplers to form color image

**Filters**

- A filter is a glass or plastic disk with a metal or plastic ring frame which can be screwed in front of or clipped onto the lens.
- Filters modify the images recorded
- As the filter is in the optical path, filters absorb part of the light available, necessitating longer exposure.
- Use: color correction, color conversion, color separation, color enhancement etc
Unit 3

Photographic Measurements

3.1. Geometry of aerial photographs

- Aerial photograph classifies into vertical and oblique
- But there is unavoidable tilts cause slight (1-3)degree unintentional inclination of the camera axis, which resulting tilted photography
- Virtually all photography are tilted, when tilts unintentionally and slightly, tilted photography are usually referred as “vertical”

Some major geometrical elements of photography

- **Fiducial marks**: Fiducial marks are optically projected fine crosses, dots, or half arrows, located either in the corners or on the sides of the photo.
- Usually 4 or up to 8, depending upon the type of camera used.
- These are reference marks which defines the co-ordinates axis and the geometric center of single photography
- **Axis**: Line on the photography between opposite fiducial marks. X axis is parallel to the line of flight and y axis is perpendicular to line of flight
- **Principal Point (PP)**: Intersection point of x and y axis line on the photo. It is center of the photo
- **Nadir**: Is point where plumb (line dropped from the camera lens to the ground intersects the photo image.
- **Iso center**: Point (exactly) halfway between PP and Nadir. Generally, in true vertical photo PP, Isocenter and Nadir all coincide at the photographic center. It is the point from where tip and tilt displacement radiates

Photo coordinates measurement

- Measurement devices, which vary in their accuracy, cost and availability
- It can be measured using *co-ordinate digitizer*
- *Such devices continuously display the XY positions of a spatial reference mark as it is positioned anywhere on the photography*
- A monocomparator can be used to measure very accurate co-ordinates
- A stereocomparator can be used for making measurements on stereopairs
- In softcopy/digital format row and column co-ordinates in the digital raster representation will be used to identify individual points

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Sources of errors for co-ordinates

- Camera lens distortion
- Atmospheric refraction
- Earth curvature
- Failure of the fiducial marks intersection at the PP
- Shrinkage or expansion of the photographic material

Distortion and displacement

**Distortion**: The shift in position of a landscape feature on a photograph that alters the perspective characteristics of the image.

- Film and print shrinkage
- Atmospheric refraction of light rays
- Motion of the landscape feature
- Lens distortion

**Displacement**: Any shift in the position of a landscape feature on a photograph that does not alter the perspective characteristics of the image.

- Curvature of the earth
- Tilt
- Topographic relief

Shrinkage and expansion of photographic films and papers

- Photo co-ordinates measured may contain errors due to shrinkage and expansion of the photographic materials
- Correction before use is imperative
- Amount of shrinkage and expansion of the photographic materials is
  \[ =f(\text{temperature, humidity, material types, processing techniques}) \]
- Can be corrected by comparing the measured photographic distances between fiducial marks on the print with their corresponding values given in the camera calibration report.
- Ratios of these measured values \((Xc/Xm, Yc/Ym)\) are used as correction factor to be applied to each \(X\) and \(Y\) photo co-ordinates

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- Measured co ordinates must be corrected by multiplying each with correction factors

**Radial Lens Distortion**

- This distortion radiates from the PP and causes an image to appear either closer or farther from the PP than it actually is.
- Distortion more serious near the edge of photo
- **Correction:** Reading a distortion curve which shows us how the distortion varies with radial distance
- Than Interpolating corrections from table

**Earth Curvature**

- Map co-ordinates are used to determine the object position in the real ground surface
- But, image distortion caused by curvature of the earth surface is necessary to understand
- Always, distortion is radiant from PP
- Therefore, distortion radiant given by earth curvature is
  \[ dr = \frac{H'r^3}{2RF^2} \]
  
  Where, \( H' \) = flight height, radian distance from PP, \( f \) = camera focal length, \( R \) = earth radius (6,372,200m)

  Now, corrected radial distance \((r')=dr+r\)
  
  Now, Correct co ordinates for
  
  X axis= \((r'/r)x\) and Y axis= \((r'/r)y\)

**Tilt displacement**

- Radiates from the isocenter of a photograph.
- Caused by the aircraft not being perfectly horizontal at the time of exposure of the film.
- If the amount of tilt is known, photographs can be rectified (expensive).
- If we can determine the direction of the tilt, in terms of “upper side” of the tilt and the “lower side” of the tilt, we can determine how landscape features are being displaced.
- Flowing figure shows the formation of tilt displacement
Some landscape feature (a’) is being displayed on a photograph (point a) that is displaced radially inward from the appropriate place on the photograph (c) by the amount d.

**Topographic displacement**

- Radiates from the nadir of a photograph.
- Varies directly with the height of the landscape feature.
- Varies directly with the radial distance from nadir to the top of a landscape feature.
- There is no displacement at nadir.
- Varies inversely with the flying height above the base of the landscape features.
- We can view in 3-dimensional images because of it.
- We can use the “similar triangles” theory to arrive at an equation to allow us to calculate topographic displacement.

In the example that follows, we will assume that the nadir and the Principal Point are the same (since topographic displacement is radial from the nadir, yet the nadir is often difficult to determine, and the Principal Point is not).

\[ r = \text{distance on the photo from the nadir to the displaced landscape feature.} \]
\[ r’ = \text{actual place on the photo where the landscape feature should be located.} \]
\[ d = \text{relief (topographic) displacement.} \]
\[ f = \text{focal length.} \]
h = height of the landscape feature.
A = altitude of the aircraft above sea level.
E = elevation of the landscape feature.
H = Flying height above the base of the landscape feature at nadir
R = distance from the nadir to the landscape feature.

From given shaded similar triangles:

\[
\left( \frac{f}{H - h} \right) = \left( \frac{r}{R} \right)
\]

Thus

\[
r = \left( \frac{f \cdot R}{H - h} \right)
\]

Again,

From similar trainings:

\[
\left( \frac{f}{H} \right) = \left( \frac{r'}{R} \right)
\]

Therefore,

\[
r' = \left( \frac{f \cdot R}{H} \right)
\]

We are usually interested in two things: d (object topographic displacement on a photograph) h (object height). Now calculate

\[
d = r - r'
\]
Substituting following value of the in above equation

Then, formula for calculating \( d \) and \( h \) will be following:

**Example:**
Tree Height
Suppose we have the measured displacement of a tree, on flat ground, or \( d = 2.1 \) mm. The distance from the top of the tree to the nadir of the photograph is \( 79.4 \) mm, or \( r = 79.4 \) mm. The flying height of the aircraft, \( A \), above sea level is 10,000 feet. The elevation of the area, \( E \), from a topographic map is 2,000 feet.

What is the height of the tree? (answer: 211.6 feet)

### 3.3. Other measurements

- **Scale determination:** One unit of distance on a photograph represents specific number of units of actual ground distance
- It may be expressed as: unit equivalent, representative fractions (RF) or ratios
- \( 1 \) mm = \( 25 \) m (unit equivalent), or \( 1/25000 \) (RF) or \( 1:25000 \) (ratio)

Small Vs larger scale

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Fill in the blank:
  o  ..........scale covered more area of the Kathmandu city than scale.........., which covers more details representation of the ground.

1:10,000 Vs 1:50,000

3 Methods for determining scale

1. Photo scale = photo distance / ground distance or d/D
2. Using focal length, Scale: camera focal length (f)/flying height above terrain (H') where, H' = Aircraft flying height (H) - Terrain elevation (h)
3. Scale of photo with the help of map scale
   RF of photo = P/m* RF of map

Where P is photo distance and m is map distance

Example:
Assume a vertical photography was taken at a flying height of 5000m above sea level using a camera with a 152 mm focal length lens (a) Determine the photo scale at points A and B, which lie at elevations of 1200 and 1960m. (b) what ground distance corresponds to a 20.1 mm photo distance measured at each of these elevations?

Answer
Scales A= 1:25000 B=1:20000

Ground distance : 502.5m and 402 respectively

Horizontal distance
If scale of vertical photo is 1:10,000. Horizontal distance between two objects is 0.5 cm on photo. Then calculate the horizontal distance in ground.

Horizontal distance

Methods
If photo scale is given, It can be used to identify horizontal distance/length of any objects on the ground

For e.g. if Rf is 1:10000 and an object measure is 0.5 cm on photo. Then, actual seize (or length) is:
Photo scale reciprocal* 0.5cm=5m

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Proportional method of calculation

For e.g. In a photo fallen tree is 10m long and measured 1 cm on the photography, similarly post lying on the ground which is 0.2 cm in a photo than calculate its ground distance.

Assuming both object at same elevation,

\[
\frac{1\text{cm}}{10\text{m}} = \frac{0.2\text{cm}}{X}
\]

Find RF scale from above condition

3.3.3. **Height and slope**

**Height calculation methods**

1. **Relief displacement:**

\[ d = \frac{rh}{H} \]

where,

- \(d\) = relief displacement,
- \(r\) = radial distance on the photograph from the PP to the displaced image point,
- \(h\) = height above datum of the object point,
- \(H\) = flight height above the same datum

2. **Shadow method:** If the sun angle and shadow length (must clearly visible) is known, trigonometric principle can be used.

\[ \tan \theta = \frac{\text{Height of object}}{\text{Shadow length}} \]

3. **Parallax method:** The term parallax refers to the apparent change in relative positions of stationary objects caused by a change in viewing position.

Parallax displacement creates opportunity for 3D viewing of overlapping photography

Such form is used to measure the elevations of points in terrain

**Formula for Height estimation using parallax method**

First,

Parallax of any points is calculated by

\[ P_a = X_a - X'_a \]

where,

- \(P_a\) = Parallax of point A,
- \(X_a\) = measured x co-ordinate of image a on the left photography of the stereopair
- \(X'_a\) = x co-ordinate of image a’ on the right photography

Elevation of discrete points
Where, \( H = \text{flight height}, B = \text{air base}, f = \text{camera focal length}, P_a = \text{parallax of point A} \)

**Or**

\[ h = (dp/p + dp) \times H \]

Where, \( h = \text{object height} \)
\( dp = \text{differential parallax} \)
\( P = \text{photo base length/air base} \)
\( H = \text{flying height} \)

**Slope**

\[ \tan \theta = \frac{h}{d} \]

**Or**

\[ \theta = \tan^{-1} \left( \frac{h}{d} \right) \]

where, \( h \) can be calculated by parallax method and \( d \) by horizontal distance calculation method.

### 3.3.4 Area

**Area calculation method**

- Use of dot grid
- Grid is uniformly spaced dots, which is superimposed over the photo
- Dot grid is placed over the desired ground area
- Counting dot grid units that fall within the unit to be measured gives the area
- Understanding of dot density is important

**Some examples**

- A rectangular agriculture field measures 8.65 cm long and 5.13 cm wide on a vertical photography having a scale of 1:20,000. Find the area of the field at ground level.
- The area of a lake is 52.2 cm\(^2\) on a 1:7500 vertical photo. Find the ground area of the lake. (Formula: Ground area = photo area \(* 1/S^2\))
- A flooded area is covered by 129 dots on a 25 dots/cm\(^2\) grid on a 1:20,000 vertical aerial photo. Find the ground area flooded.

\[
\text{Ground area (dot density)} = \\
(1\text{cm}^2/25\text{dots}) \times 20,000^2 \\
16000000 \text{ cm}^2/\text{dot} = 0.16 \text{ ha/dot} \\
\text{Total area covered} = 129 \text{ dots} \times 0.16 \text{ ha} = 20.6 \text{ ha}
\]

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Unit 4:

For deriving maximum benefit from photographs they are normally studies stereoscopically. A pair of photographs taken from two camera stations but covering some common area constitutes a stereoscopic pair which when viewed in a certain manner gives an impression as if a three dimensional model of the common area is being seen. The basis of this subjective impression is dealt in the end of this lesson.

4.1. Stereoscopes and their use

The function of stereoscope is to deflect normally converging lines of sight so that each eye views a different photographic image. There are two types of it, one is lens stereoscope and other is mirror prism stereoscope.

**Lens:** By far the most popular is the lens stereoscope commonly known as pocket stereoscope. The pocket stereoscope usually has plane-convex lens, upper side flat with a focal length of 100 mm. The rays entering the eyes are now parallel and converge at infinity and have been accommodated (focussed) at 100 mm distance (Fig. 18). Since the normal viewing distance is 250 mm, a closer view, i.e. at 100 mm result in a magnification. The magnification is then 250/100 = 2.5. More expensive types have a changeable eye base. Such a refinement is not necessary for operators with an average eye-base range of 60 to 68 mm. The pocket stereoscope is cheap, transportable, and has a large field of view. It has two big disadvantages:

Limited magnification. Pocket stereoscopes with more than three times magnification cannot be equipped with simple plane-convex lenses, due to the too large an increase in lens aberrations. In addition the distance between the head and the photos becomes to small for adequate illumination without undue complications.

The distance between corresponding points on the photos must be equal to or smaller than the eye base. With normal size photographs this becomes difficult or impossible without bending or folding the photos.

**Mirror prism:** The two above mentioned drawbacks have led to the development of the mirror stereoscope. The normal size photos (23 cm x 23 cm) can be separated and seen under the stereoscope without folding them. The path of the bundle of rays has been diverted and brought to the eyes at 65 mm separation. This is achieved by reflecting mirrors. Normally the distance between corresponding points is kept at 240 mm so that photographs are placed separately, i.e., it effectively increases the eye base from 65 mm to 240 mm. As in pocket stereoscope the picture must be at the focal plane of the lenses in order to have convergence at infinity. The mirrors M1 are placed in such a way that the picture distance via the small mirrors M2 (generally prisms) become equal to the focal length of the lens, usually 300 mm (Fig. 19(a). This gives approximately 250/300 = 0.8 x magnification, or rather reduction the picture observed, to magnify the image additionaloculars of magnification 3x to 8x can be used over the prisms or a lens placed before each prism (See The two above mentioned drawbacks have led to the development of the mirror stereoscope. The normal size photos (23 cm x 23 cm) can be separated and seen under the stereoscope without
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In summary:

- Using both eyes to see the objects is binocular vision. The perception of depth through binocular vision is referred to as stereoscopic viewing, which means viewing an object from two different location.
- Optical device for stereoscopic view is stereoscopes, which normally converging lines of sight, so that each eyes views a different photographic views.
- Mono scopic view is with only one eye.
- Use of it: depth information can be perceived with great detail and accuracy. As result, geographic information can be collected to a greater accuracy, compared to traditional mono scopic techniques. Aerial photo interpretation, primarily based on stereo scopic view.

4.2. Depth of perception

Human beings can distinguish depth instinctively. However, there are many aids to depth perception, for instance, closer objects partly cover distant objects or distant objects appear smaller than similar objects nearby. These aids apply to monocular vision. For short distances binocular vision is more important and is of interest to Photogrammetrists, for it is binocular vision which enables us to obtain a spatial impression of a MODEL formed by two photographs of an object (or objects) taken from different view points. Normally, our eyes give us two slightly different views, which are fused physiologically by the brain, and result in a sensation of seeing a model having three dimensions. This three-dimensional effect, due to binocular vision, is very limited however, decreasing rapidly beyond a viewing distance of one metre. Thus it may be concluded that binocular vision is primarily an aid in controlling and directing the movements of one's limbs.

A small percentage of the people do not have the facility of binocular vision and no amount of training will give it to them. Unfortunately, there is no known physical aid to provide stereoscopic sight to such person who does not possess it naturally, but training can help those having weak fusion.

- Ability to distinguish features/object
- Depends on types of view: mono scopic and stereo scopic
- Types of view determine the distance estimation
- Relatively, depth of perception based on the relative size of objects
4.2. Conditions for viewing photos stereoscopically

Before viewing photo stereoscopically, two photos must have following conditions:

- The camera (spatial) axes should be approximately in one plane, though the eyes can accommodate the difference to a limited degree.

- The ratio $B/H$, in which $B$ is the distance between the exposure stations and $H$ is the distance between an object point and the line joining the two stations, must have an appropriate value. In aerial photogrammetry this ratio is called the base-height ratio.

  If this ratio is too small say smaller than 0.02, we can obtain a fusion of the two pictures, but the depth impression will not be stronger than if only one photograph was used. The ideal value of $B/H$ is not known, but is probably not far from 0.25. In photogrammetry, values upto 2 are used, although depending on the object, sometimes much greater values may be appropriated.

- The scale of the two photographs should be approximately the same. Difference upto 15% may, however, be successfully accommodated. For continuous observation and measurements, differences greater than 5% may be disadvantageous.

- Each photograph of the pair should be viewed by one eye only, i.e., each eye should have a different view of the common overlay area.

- The brightness of both the photographs should be similar.

Steps for stereoscope viewing:

1. **Arrangement of photo**: Photo should be arranged in the line of flight, where overlap around 60% of their width and 20-30% between flight strips.

2. **Identification of PP**: Using opposite fiducial marks, PP will be created at the intersection of $X$ and $Y$ (mid point) axis fiducial marks.

3. **Location of conjugate principal points (CPP) on each photography**: CPP is the points that correspond to PPs of adjacent photos.

   - Photographs from a given flight line are arranged so that gross features overlap.
   - Images shadows should be towards the observer.
   - One photo is clipped down and the adjacent photo is moved in the direction of flight until images are about 5.5 cm apart.
   - The lens stereoscope is place, so that left hand lens is placed over the left photo and so on.
   - The area directly under each lens should then appear as a three dimensional picture.
   - Then, picked hole for the PP, which locates CPP, although a monocular check should be made. This process repeated for all images to identify CPP.
4. **Alignment of flight line using PPs and CPPs:** Connect the lines between PP and CPP to align flight lines.

5. **Photo base length for each stereo overlap:** The photo base length for each stereo overlap is the average of the distance between PP and CPP on one photograph and the corresponding distance on an overlapping print.

There are three ways of observation of stereoscope photographs:

1. **Observation with crossed eye axes:**
   This involves looking with the right eye at the left photograph and with the left eye at the right photograph (Fig. 16(a). The convergence and accommodation are at two different distances, and this type of observation is, therefore, very tiring. Large photographs can be used conveniently by this method, but due to strain on the eye, this method is not used in practice.

2. **Observation with parallel eye axes:**
   This method is possible without any optical aids, but is tiring as well as the eyes are converged on infinity, yet accommodating at approximately 250 mm (Fig. 16(b). It is less tiresome if positive lenses are placed between the eyes and the photographs so that the photos are placed at the focal length of the lenses. The accommodation then corresponds with the convergence and the eyes are viewing naturally. The 'pocket-stereoscope' was developed on this principle.

3. **Observation with convergent eye axes:**
   When the accommodation and convergence are at the same distance the viewing is least tiring and this is the normal method of viewing. But in order to view the photos stereoscopically they must be superimposed, such that the point A and the corresponding point A' on the other photo lie at the point of convergence (Fig.16(c).

   The images have to be separated so that left eye sees only the left hand photographs and the right eye only the right hand photograph. The resulting stereoscopic perception is similar to that of normal 3 dimensional perception. The separation may be achieved by colour filters or by polarized filters. There is an interesting phenomenon in Stereoscopy. In viewing terrain in aerial photography a reversal of the relief is sometimes obtained by the eyes. Such a phenomenon is known as pseudoscopic illusion or Pseudoscopy. Such an impression can be obtained by viewing the photos with crossed eye axes. Sometimes, viewing with the shadows in case of excessive relief (e.g. hills) away from the observer can also result in pseudoscopy. So, in the initial stages, to avoid pseudoscopic view, it is desirable to view the photographs with shadows of objects falling towards the observer.

**Parallax in aerial photography**

The term parallax is applied to the apparent change in the position of an object caused by change of position in the observer. The term is widely used in optics, astronomy and other sciences and has different significance in each case. In photogrammetry we are generally concerned with stereoscopic...
parallax. The aerial camera does not take aerial photographs continuously but takes them at certain exposure intervals. Suppose instead of the negative film there was a ground glass on which ground images could be seen, then it will be seen on changing with respect to the camera frame. Consider that at one instant the airplane is at 01, vertically above a point P. The image of P will appear at p on the ground-glass (Fig below). After sometime when the plane is at 02, it will appear at p'. This shift pp' in the position of the image of P on the ground glass is the parallax of P. Similarly for any other point Q will be qq'.

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Again it will be seen that images of the higher points in the terrain will move across the ground glass more rapidly than the images of lower points in the valley. Thus the separation (Parallax) of the images of a higher point would be more than the separation (parallax) of lower points (during the same interval of time). That means, points at higher elevation exhibit a greater parallax than those at the lower elevation.

Assuming that there is no tilt and flight is level, two photographs are taken with image of an object point A a1 and a2 on them respectively. If the two photographs are put on top of the other with their principal point’s p1 and p2 and flight direction in coincidence, then by definition a2 a1 is the absolute stereoscopic parallax (Fig below:1st).

If now we put the pair of photographs under a stereoscope for fusion, they will have to be separated at a convenient distance p1p2 say a distance represented by 'S' (Fig above second).  

The parallax of A, PA = p1 p2 - a1 a2  
= S - a1 a2  
Similarly parallax of another point Q,  
PO = S - q1 q2  
Considering ‘A’ as the reference point, the parallax difference between ‘A’ and ‘Q’ is  
\[ \Delta p = PQ - PA \]  
= a1 a2 - q1 q2  

In practice, direct measurement of parallax is seldom done, instead we measure the parallax difference (\( \Delta p \)) with the help of parallax bar or parallax wedge. Generally, graduations on parallax bar are marked in such a way that if the separation between corresponding images decreases (i.e. ‘d’ decreasing - Fig. 2nd), the reading on parallax bar increases - the point with larger parallax gives a higher reading, and correspond to a point of higher elevation. In such a case the parallax difference  
\[ \Delta P = (\text{Parallax bar reading for Q} - \text{Parallax bar reading for A}) \]  
= q1 q2 - a1 a2  

Where parallax formula assume that:

- there is no distortion in the photographic material
- photographs are free from tilt,
- the flight altitude above the datum remains unchanged,
- the photographs are a central projections, with centre of projection at the perspective centre, i.e., there is no lens distortion,
4.2. Causes of y-parallax and vertical exaggeration

- Change in position of an object from one image to the next, perpendicular to the flight line is referred to as y-parallax
- Source for y-parallax:

1. Unequal flying height between adjacent exposures: This effect cause a difference in scale between the left and right images.

2. Flight line misalignment during image collection: It cause differences in image orientation between two overlapping images.

3. Erroneous sensor model information: Inaccurate sensor model information creates large difference in y-parallax between two images

Vertical exaggeration (VE) in stereo viewing

- In stereo model, under normal condition, vertical scale will appear to be greater than horizontal scale i.e. object appear to be greater in height. This apparent scale disparity is vertical exaggeration.
- Source of VE: lack of equivalence of photographic base height ratio and ratio of stereo viewing base height ratio

Floating marks

- It is reference marks used for precise measurement on stereo pair.
- Under stereo scope, two identical marks (half marks) are placed
- During binocular view, both half marks are perceived to be single mark called floating mark
- The left mark seen with left eye and so on. These marks shifted in position to form single mark. If these moves close together, parallax of the half mark increased and if they move apart, parallax decreased

Preparation of aerial photo for interpretation/ or steps

1. Alignment of line of flight using PPs and CPPs
2. Determination of effective area/ and area of interest using base maps( topographic map)
3. Use of key elements
4. Field checking
5. Post photo interpretation ( assessment of accuracy of the identification of features)
**Interpretation types**

- Field Observation: Go to field taking photo
- Direct recognition: Use of experience
- Interpretation using inference (assumption): Use of visible distribution. Need complete knowledge of the link between the proxy and the mapped distribution. E.g. soil types near to forest/agriculture land
- Probabilistic interpretation: Integrating non image information for interpretation. For example use of ecological zones for identification of species
- Deterministic interpretation: Precise approach because it used quantitatively expressed relationships that tie image characteristics

**Key for aerial photo interpretation**

Aerial photographs are different from "regular" photos in at least three important ways:

- Objects are taken from an overhead or aerial position. Most are used to seeing objects from the ground, and not from the air.
- Photos are taken at scales most people are not used to seeing.
- Sometimes, images obtained from satellites and high-altitude aircraft use color-infrared photography. Color-infrared photography allows scientists to see things that are not visible to the human eye. This provides scientists with a tool to study landforms, environmental pollution, and other effects of human activities on the planet's surface.

These “basic elements" can aid in identifying objects in aerial photographs are:

**Tone (also called Color or Hue):** Tone refers to the relative brightness or color of elements on a photograph. Some objects appear darker and more crisp than others. It is, perhaps, the most basic of the interpretive elements because without tonal differences none of the other elements could be discerned.

**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.

**Shape:** Shape refers to the general outline of 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 can be identified almost solely on the basis of their shapes.

- The Pentagon Building
- Football fields
- Cloverleaf highway interchanges
**Texture:** The impression of "smoothness" or "roughness" of image features 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".

**Pattern (spatial arrangement):** The patterns formed by objects in a photo can be used to identify those objects. For example, consider the difference between (1) the random pattern formed by an unmanaged area of trees and (2) the evenly spaced rows formed by a tree orchard.

**Shadow:** Shadows aid interpreters in determining the height of objects in aerial photographs. However, they also obscure objects lying within them.

**Site:** Site refers to topographic or geographic location. This characteristic of photographs is especially important in identifying vegetation types and landforms. For example, large circular depressions in the ground are readily identified as sinkholes in central Florida, where the bedrock consists of limestone. This identification would make little sense, however, if the site were underlain by granite.

**Association:** Some objects are always found in association with other objects. The context of an object can provide insight into what it is. For instance, a nuclear power plant is not likely to be found in the midst of single-family housing. A vegetated area within an urban setting may be a park or a cemetery. Wetlands may be located next to rivers, lakes, or estuaries. Commercial centers will likely be located next to major roads, railroads, or waterways.

---

**Forest trees interpretation elements**

<table>
<thead>
<tr>
<th>Species</th>
<th>Crown shape</th>
<th>Edge of crown</th>
<th>Tone</th>
<th>Pattern</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cedar</td>
<td>Conical with sharp spike</td>
<td>Circular and sharp</td>
<td>Dark</td>
<td>Spotted grain</td>
<td>Hard and coarse</td>
</tr>
<tr>
<td>Pine</td>
<td>Cylindrical with shapeless crown</td>
<td>Circular but unclear</td>
<td>Light and unclear</td>
<td>Irregular spotted</td>
<td>Soft but coarse</td>
</tr>
<tr>
<td>Fir/spruce</td>
<td>Conical with wide crown</td>
<td>Circular with zig zag edge</td>
<td>Dark and clear</td>
<td>Irregular</td>
<td>Coarse</td>
</tr>
<tr>
<td>Deciduous</td>
<td>Irregular shape</td>
<td>Unclear</td>
<td>Lighter</td>
<td>Irregular</td>
<td>Coarse</td>
</tr>
</tbody>
</table>
Unit: 5

Mapping with vertical aerial photography

Things to be aware before proceeding photogrammetry

- **Photogrammetry**: The science and art of determining the size and shape of objects as a consequence of analyzing images recorded on film or electronic media is photogrammetry.

- **Orthophoto**: Orthophotos are orthographic photographs, where orthographic is the representation of related views of an object as if they were all geometrically projected upon a plane with a point of projection infinity. They do not contain the scale, tilt, and relief distortion characterizing normal aerial photographs.

- **Planimeter**: An instrument used to measure the area of any figure by passing tracer around its boundaries and recording the area encompassed.

- **Pass point**: A photo control point whose position is determined photogrammetrically and which is used in map control extension.

- **Planimetric maps**: Those maps that show the correct horizontal or plan position of natural and cultural features.

- **Topographic maps**: Maps that show elevation differences.

**Planimetric mapping by direct tracing orthophoto**

- Photo control points (PCP) are uniformly distributed over photo at a equal interval scale to increase the accuracy of measurement, where PCP is a reference point precisely located on photograph.

- Transparent sheet overlay on orthophoto, which have been placed on a light table superimpose over a vertical.

- Transparent sheet adjusted in position so that the plotted control points nearest the feature to be traced matches its corresponding photo image.

- Traced map has scale equal to photo.

**Radial Line Triangulation (RLT)**

- Construction of new map from vertical photo using radial line is radial line triangulation.

- A radial line plot is a photogrammetrical triangulation procedure, usually controlled by ground surveys, by which the photo images are oriented and placed in proper relationship to one another.

- Ground control points dictate the nature of the base map.
RLT Theory

- On vertical or near vertical photography, the PP, isocenter and nadir are assumed to occupy the same location.

- Thus, a line drawn radially from the PP to a given object will pass through the true location of the object.

- Or, expressed in another way, any displacement of photo images will occur along lines radiating from the center of the photographs.

- This concept is the basis for the construction of maps controlled by radial line plots.

Method of graphical RLT

- Two overlapping prints are necessary.

- If a straight line is drawn from the PP of each photo through images of the same object, the two lines will intersect at the correct position of the object when the prints are overlapped with flight lines superimposed.

- By repetition of this procedure for several selected wing points on each photography, the entire group of prints can be correctly oriented.

- Where, wing points are any selected photo features in the side lap and overlap zone that can be easily pinpointed on all prints.

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Resection and Intersection

- Process of locating true planimetric map position of principal points is resection.
- Or process of locating PP of photo on plane map sheet (trace sheet) using ground control points in overlapped area. It includes the phenomena of intersection to identify it.
- It requires a minimum of two horizontal ground control points within the overlapped portion of a stereo scopic pair of photos, but ≥3 ground control points are desirable

Ground controls for aerial photo (vertical and horizontal)

- Topographic maps are prepared with the aid of aerial photography
- The compilation of topographic maps are largely depend upon on field survey
- A network of horizontal and vertical ground controls are required for accurate stereo plotting
- Ground control points are carefully located positions that shows longitude, latitude and elevation (from the sea level)
- Horizontal control is needed to control scale, position and orientation of the map
- Vertical control is needed for the correct location of the contours
- Thus, ground controls (either vertical or horizontal) are the framework of the map preparation which determines the accuracy of the features in the map drawn from photography

Flight planning and specification

After all the relevant information regarding the aerial photography has been obtained, the photographic flying mission has to be carefully planned. The fundamental requirement of flight planning is adequate stereoscopic coverage with the least number of pictures consistent with desired accuracy. The main factors affecting flight planning are selection of aerial camera, flight altitude, forward overlap, lateral overlap, flight plan, selection of aircraft, aerial film, and navigation instruments. On finalization of flight planning the actual flight takes place when the weather conditions are ideal and the time and season of photography is desired. Occurrence of clouds, avoidance of crabs, water surfaces and gaps are also considered.

Selection of aerial camera

If the aerial camera and focal length of the lens have already been specified by the inventor, then these should be used. If not, the focal length of the lens and aerial camera has to be decided by Survey of India, who is responsible for design of photographic specifications. Aerial cameras may be of different format size. For reasons of economy, the larger format size should be used as far as possible.

Flight altitudes and focal length

The scale of aerial photographs to be flown which is to be indicated by the user is defined as the ratio of focal length (f) and the flying height (H) i.e. f/H. Thus, the photo scale over an area can be
constant if in other words the terrain height is constant. Usually in nature, there is altitude variations in the terrain and therefore, the scale also vary from photo to photo or even point to point. Thus, the given photo scale is only the mean scale which is designed to be achieved by computing the flight altitude above mean ground level. The flying height above mean ground level is important as it in intimately connected with the ceiling height of the aircraft which is the maximum altitude above mean sea level at which the aircraft can fly safely. If the height of mean ground level above mean sea level is \( h \) and ceiling height of the aircraft above mean sea level \( CH \), then maximum flying height above mean ground level \( H \) for particular aircraft is given by, \( H = CH - h \). However, the flying height above mean sea level which is the height of the aircraft above mean ground level added to the height of the mean ground level above mean sea level and is given by \( H + h \) is important for the pilot as he has to maintain the height of his aircraft at this level.

Scale variation
As explained earlier the photo scale is not constant over the entire area and the expected scale variations can be computed according to terrain height variations. However, it is also difficult to keep the flying height constant. The determined height can be held within \( \pm 50 \) feet while the flight is in progress. Actual flying height shall generally be within \( \pm 2\% \) for \( \pm 200 \) feet of the computed flying height.

Alternatively it is possible to maintain a near constant photo scale over an area with terrain variations by computing different flying height for each strip. The constant photo scale is not so important for photogrammetry as it is for preparation of semi-controlled photo-mosaics. If the photo scale is kept constant, scaling of individual photographs by means of photographic enlargers or rectifiers can be avoided while preparing semi-controlled mosaics.

In order to obtain a constant scale, flying height is determined by means of flight altimeters that are accurately calibrated to international standard atmosphere. This calibration has to be carried out periodically on the test bench and has to be duplicated or repeated during flight.

Season of photography
- Nature of feature or object to be mapped, the film to be used, minimum sun angle or feature illumination determine the season scheduling for aerial photography
- A photography day is define as one with 10% cloud cover or less which can be obtained from local weather station
- For topographic mapping, photo is taken either in spring of fall, when deciduous foliage is absent and ground is essentially free from snow
- For vegetation mapping, during the growing season of plant, particularly when deciduous plant constituent an important component of vegetation cover.
- Specifically, when there is deciduous, evergreen and mixed of both, either infrared (IR) black and white or IR color film is recommended
Time of day

- Combination of season and time of day is important
- The angle at which the sun strikes the earth surface affects not only the quantity of light being reflected to the aerial camera but also the spectral quality of light.
- In clear weather, solar illumination depends on latitude (it drops off as it increase), season of the year, and hours before or after local apparent noon.
- Because heavily vegetated land are poor light reflector, they should be photographed within two hours of noon
- In general, temperate zone should be scheduled within 2 to 3 hr of local apparent noon
- This timing assures maximum subject illumination and helps avoid the troublesome

Overlap
Forward:

For stereoscopic viewing of photographs there should be certain amount of overlap between two consecutive photographs. The overlap in flight direction shall be 60-65 % as expressed with respect to average terrain datum. In no case, however, less than 53% and also in no case the forward overlap between photo number 1,3,5 and etc. Be less than 6% at the highest point. Other forward overlap percentages can be specified if other special requirements have to be fulfilled. In cases of block photography where saving in ground control is envisaged a fore lap of 80% to 90% is used and suitable photographs having matching edges with photographs of adjacent strips, but having at least 60% overlap amongst the photographs of the same strip, are chosen for actual work. Where the end of the strips of one block overlap the end of strips of another block, the overlap shall be at least 3 photographs and preferably 6 photographs. This is necessary to make use of the control points of the existing photography for the new photography. The above recommendations can be used for all normal cases but in cases of mountainous terrain with large relief variations, the tolerance of 5% in forward overlap may not be sufficient if the highest ground points are to have a minimum overlap of 53%. Thus, it will be safer to have a slightly more forward overlap i.e. 60% to 65% in such cases.

Lateral:
The lateral overlap between strips only requires being sufficient to provide certainty of identification of common detail and to allow for the lateral tilt and slight deviations from course in the length of the strip. In general, a minimum lateral or side overlap should be aimed at, for reasons of economy. In majority of cases, an average lateral overlap 20% of the photo format size can be specified. Tolerance must be allowed at about 5% for navigational uncertainties and 5% for small terrain height differences. In terrain with relief variation not more than 5% of flying height, lateral overlap specifications may be stated as the lateral or side overlap shall be 20% ñ 10% of the photo format size. This results in maximum value of 30% and minimum value of 10% lateral overlap. The effect of relief in mountainous terrain is to cut out the effective coverage due to the scale of photography being larger on hilltops than in valleys and therefore adequate provision should be made for relief at the planning stage. Based on past experience in the Himalayas, it has been found that a lateral overlap of 35% caters for the terrain relief variations in these areas. In mountainous areas the specifications for lateral overlap may also be given as 20% + 10% + times relief percentage, where percentage relief is
Extreme difference in ground height in the overlap area

\[
\text{height of aircraft above lowest ground} \times 100
\]

Selection of aircraft

The selection of aircraft is done by the flying agency. The two factors, which are required to be considered for the selection, are, the ceiling height of the aircraft and its flying range. An aircraft, to be suitable for aerial photography, should have requisite speed, a high rate of climb, and good stability while in flight and unobstructed view in all directions for ease of navigation. It should have a ceiling height equal to or higher than the highest flying altitude specified. It should be able to remain in the air long enough to take advantage of suitable photographic time, roomy enough to carry its full load to the maximum flying height specified.

Navigation instruments and crew

If any navigation instruments e.g., radar or Decca navigator, inertial navigation system, global positioning system is being used, these should be checked before installation. All the spare magazines should be checked. Aerial camera and viewfinder should also be checked for satisfactory operation. The photographic crew i.e., the pilot and aerial photographer-cum-navigator should be well qualified for the photographic task assigned to them.

Position of flight lines

Lines should be parallel, oriented in a compass direction. Lines usually run from N-S, or E-W. Roughly, parallel to the long direction.

Aerial film

A fine-grain emulsion aerial film manufactured by any of the established manufacturers, e.g. Agfa, Gaevert, Ilford or Kodak should be used.

Flight instruments and aircraft calibration

According to the ICAO standards, the flight instruments shall be calibrated at least once in every 1.5 years. This applies in particular to the barometric altimeter, temperature gauge, and radar altimeter and for any other available scale or altitude reference system, the magnetic compass, and direction gyro. The calibration shall consist of individual calibration of each instrument and of a calibration of the total instruments system in flight in order to determine and to correct for installation errors and for operational performance errors.

Tilt

- The angle between the optical axis of camera and the vertical is called angle of tilt
- Tilt should not exceed 2-3 degree for a single exposure or average more than 1 degree for the entire project

Crab and drift

- The condition caused by failure to orient the camera with respect to the track of the airplane, which is indicated in aerial photo by the sides of the photo not being parallel to the principal point base line
- Drift is the deviation of aircraft from its planned flight path. The deviation may be due to side wind. The drift may cause photo gap
**GPS application in aerial photography**

- Geographic Position System (GPS) record the X, Y, and Z of any discrete features
- Use of GPS is for base map or topographic map preparation from aerial photography
- GPS points are used as source of accuracy while preparing maps
- GPS are taken as ground control points while preparing maps so that photo could represents corresponding features in the ground
Unit 6

Application of Aerial photography

Application in Geological interpretation

Factors which affect the photographic appearance of rock.

- Climate
- Vegetation cover
- Soil cover
- Rate of erosion
- Color and reflectivity
- Composition
- Physical characteristics
- Depth of weathering
- Structure
- Texture

Geological interpretation

- Two types of geologic information can be obtained from aerial photographs: structural and lithologic
- The kinds and amounts of information that could be obtained from aerial photographs depend primarily on: 1) type of terrain, 2) climatic environment, 3) stage of the geomorphic cycle
- Areas underlain by sedimentary rocks yield more information than areas underlain by igneous and metamorphic rocks. Because the sedimentary rocks have strongly differing physical characteristics, whereas igneous rocks are relatively homogeneous over wide areas. Metamorphic rocks may show the least amount of information from aerial photographs
- Arid and semi-arid regions will yield the greatest amount of geologic information compared to the tropical regions. The arid and semi-arid regions might also show a greater number of significant plant-rock associations than other climatic areas, because weathered material in the arid and semi-arid regions is not excessively leached and a close relation of soil to parent rock formation exists.
Identification of rocks

**Sedimentary rocks**

- The most prominent feature of sedimentary rocks is **bedding**.
- As a result of differential erosion of sedimentary rocks, beds appear as banded patterns on aerial photographs.
- Bedding may be most prominent in the mature stage of geomorphic cycle.

**Metamorphic rocks**

*Topography*

Bold, domelike hills

The topographic relief of granitic intrusions typically shows as massive, rounded, domelike hills. The tops of the hills are softly rounded; the sideslopes are steeper. The weathering processes of pressure-release and exfoliation tend to maintain the domelike appearance. Debris and large boulders weathered into rounded shapes accumulate in drainage courses and depressions.

- It is difficult to identify metamorphic rocks from aerial photographs because large-scale distinguishing characteristics are generally absent.
- Because of physical changes in the rock units due to high pressure and/or high temperatures of the metamorphism
- Structural trends obtained from aerial photographs are **foliations rather than bedding**. Parallel alignments of ridges and intervening low areas may reflect regional cleavage, foliation or fold axis and may suggest metamorphic rocks.
Igneous rocks

- These can be recognized by drainage, texture, massive character of the rock

Drainage pattern for geological interpretation

Drainage patterns refers to the spatial arrangement of stream channels and show a close relationships to lithology, structures, and the geological history of the area. The basic drainage pattern area:

1. Dendritic
2. Rectangular
3. Parallel
4. Trellis
5. Radial
6. Annular
Application in Forest Interpretation

- **Aerial photography in land management:** Foresters use aerial photography for preparing forest boundaries, locating access roads, and other different property delineation. Also, sometimes forest managers use it for the management of disease, insect-prone area management. In addition to this application, aerial photography has been used for wildlife habitat and rangeland management in most of the countries.

- **The distribution of vegetation:** Distribution of forest vegetation may be governed by different factors like moisture, temperature, rainfall, soil types, topography, winds, elevation, etc. By knowing these elements of the given area, we can use aerial photo for identifying distribution of the appropriate species in the locality.

- **The classification of vegetation:** Aerial photography can be used to classify the forest types: Manmade forest and natural forest (e.g., broadleaf forest, conifer forest, mixed forest etc). For this, identification of crown size and character, foliage pattern, and shadow shapes etc.

- **Crown cover percentage calculation**
  - Usually done by ocular interpretation, by grouping stands into percent classes.
  - Key use for crown cover are: *texture, tone and relative sizes of crown*
  - Chances of overestimates or underestimates of crown cover
  - Crown cover % can be categorized as:
    - Very Sparse 1-9%
    - Sparse 10-29%
    - Low 30-49%
    - Medium 50-69%
    - Dense 70-84%
    - Very Dense 85-100%

- **Species Identification**
  - Easy in even aged pure stand but difficult in mixed forest
  - Individual plant can only be identified on large scale photography
  - There is relation between image scales and level of individual plant identification
  - 1:500-1:2500 identify individual range of plant and grassland whereas as 1:25000 for broad vegetation types
  - Require familiar with large number of species with their branching character, crown shapes, spatial distribution pattern, texture, plant height etc
  - Recognized by the configuration of their crown shadow falling on ground level
  - Please see the following sketch of crown (1st fig) and shadow types of species (2nd fig)
<table>
<thead>
<tr>
<th>CONIFERS</th>
<th>HARDWOODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light tip to center of cone with fine texture</td>
<td>Small light spots in crown</td>
</tr>
<tr>
<td>Layered branches</td>
<td>Small clumps</td>
</tr>
<tr>
<td>Wheel spokes</td>
<td>Small clumps with occasional long columnar branches</td>
</tr>
<tr>
<td>Columnar branches</td>
<td>(in young trees)</td>
</tr>
<tr>
<td>Layered triangular-shaped branches</td>
<td>Limbs show</td>
</tr>
<tr>
<td>Small clumps</td>
<td>Large masses of foliage</td>
</tr>
<tr>
<td>Small light spots in crown</td>
<td>divide crown (large older trees)</td>
</tr>
<tr>
<td>Small starlike top</td>
<td>Fine texture</td>
</tr>
<tr>
<td>Dark spot in center of cone of small clumps</td>
<td>Fine columnar branches</td>
</tr>
<tr>
<td>Fine texture with sharply long branches</td>
<td></td>
</tr>
</tbody>
</table>

Sketches of overhead views of tree crowns for several boreal species. (Courtesy U.S.
Inventory

- Stand maps developed from aerial photographs provide an inexpensive and accurate area control.
- Stand maps developed from aerial photographs provide a highly effective means of stratifying a ground.
- Use of aerial photographs in the field permits the field parties to obtain their data with a maximum of efficiency.
- Nonproductive areas may be left out: swamps and other areas of bad going may be bypassed.
- With photographs, the field party can keep themselves constantly located and can choose the **best route from one place to another**.

- **Crown diameter or areas:** The value of crown measurements in equation predicting tree volume depends on the relationship that exists between crown dimension and corresponding steam diameter or basal area. The photographic measurement of crown diameter is simply a linear measure, but measurement can be difficult because of the small sizes of tree. Various liner scales or magnifiers and crown wedges are available for photographic crown measurement. Measurement of crown diameter provides opportunity of calculating crown area.

**Application in Soil:** Based on the color, pattern and texture of land available on aerial photo, scientists are able to identify the soil types, soil moisture, oxidants and organic material of soil contents. As result, they can classify the soil types and hence, sustainable management of land system will be created. Drainage pattern can be identified from aerial photography and therefore, erosion can be managed in a time before disaster occurred.

Most important part of use of aerial photo is to identify the types of soil. As result, scientist can recommend appropriate agriculture or forest types for the plantation process. Typically, panchromatic aerial photographs at scales ranging from 1:15,840 to 1:40,000 have been used as mapping base. Major application of aerial photo is used for estimating yields of common agriculture crops, evaluating suitability of land, determining woodland productivity, assessing wildlife habitat conditions, judging suitability for various recreational uses, determining suitability for various development uses such as highways, local streets and roads, building foundations, and septic tank absorption fields.

**Water resource application**

- Water pollution detection
- Flood assessment
- Groundwater discharge area identification and conservation
- Wetland mapping

**Environmental impact assessment application**

- Construction of development infrastructure like highway, road etc
- Landfill side
- Timber harvesting area
Numerical Problem and some theories

Q) The Hatauda Campus area is covered by 200 dots/cm\(^2\) grid on a vertical photography. If the scale of vertical photography is 1:40000. Find out the ground area of Hatauda campus in hectare.

Answer:

Dot density = \(\frac{1}{200} \times 40000 \times 40000\) cm\(^2\) = 0.08 ha

Therefore area coverage = 0.08 \times 200 = 16 ha

Q) A circular field on a 1:25000 scale air photo has diameter of 0.2 cm. What is the actual size of the field on ground in hectares?

Use formula for circle after converting photo diameter to ground diameter.

Q) The ground distance between two points on a topographic map is 1180 m. The distance between the same points on the aerial photo is 9.43 cm. Find scale of photo and length of fence line that measure 4.29 m on the photograph.

Answer: Photo scale = \(\frac{0.0943}{1180} = \frac{943}{1180000} = \frac{1}{12513}\) or \(1/12500\)

Height estimation using parallax method

Q) In an aerial photography, assuming that the photo scale is 1:5000 and focal length is 210 mm. The parallax reading to the top and bottom of the building is 20.32 mm and 19.26 mm respectively. If absolute parallax is 71.75 mm, what is the height of the building?

Answer:

Height of the building = \(H \times \frac{dp}{P+dp}\)

Where, \(RF = \frac{f}{H}\) or \(H = 0.21\) m \(\times 5000 = 1050\) m

Differential parallax \((dp) = (20.32 - 19.26) mm = 1.06 mm\)

Absolute parallax \((P) = 71.75 mm\)

Now, height of building

= \(1050 \times \frac{0.001}{0.07 + 0.001}\)

= 14.78 m

Q) A study area is 20 km wide in the east-west direction and 30 km long in the N-S direction. A camera having a 152.4 mm focal length lens and a 23 cm format is to be used. The desired photo scale is 1:25,000 and the nominal endlap and sidelap are to be 60 and 30%. Beginning and ending flight lines are to be positioned along the boundaries of the study area. The only map available for
the area is at a scale of 1:50,000. This map indicates that the average terrain elevation is 500m above datum. Perform the computations necessary to develop a flight plan.

**Formula for flight planning**

1. **Photo ground coverage** = photo format/Scale
2. **Ground separation (endlap) between photo** = 40% * side of photo coverage
3. **Time between exposure (sec)**: Ground separation distance/aircraft speed
4. **Distance between photo center**: time between exposure * aircraft speed
5. **Number of photo per line** = [Length of photo line (longest line)/distance between photo center] + 1 + 1
6. **Distance between flight lines**: 70% (assuming 30% side lap and line must be separated by 70%) * side coverage of photo (obtained from 1)
7. **Total Number of flight lines**: (width of study site/distance between flight lines) + 1
8. **Spacing between flight lines on the map** = distance between flight lines * Scale of map
9. **Total number of photo needed**: total flight line * photo per line

**Solutions of above question using the respective formulas**

1. **First identify the flight direction**: N-S flight direction
2. **Find flight height above terrain**: $H' = f/s = 0.1524m \times 25000 = 3810m$

   Therefore, $H$ (from sea level) = $H' + h$ (terrain height) = 3810 + 500 = 4310m
3. **Determine ground coverage by photo** (area of each photo)

   Coverage on photo = 0.23m * 25000 = 5750m on a side
4. **Determine ground separation between photos on a line for 40% advance per photo**:

   0.40 * 5750m = 2300m between photo center
5. **Assuming an aircraft speed of 160Km/hr**, the **time between exposure is**:

   $\frac{2300m}{(160Km/Hr)} = 2300m \times 3600sec/160000m = 51.75sec$
6. **Actual distance between photo centers** = 51 sec/photo * 160Km/Hr = 2267m
7. **Compute the number of photo for each line**:

   Flight line/length of photo = 30000m/2267m + 1 (first photo) + 1 (end photo) = 16 photo/line
8. **If the flight lines are to have a side lap of 30% of the coverage, they must be separated by 70%**:
0.70*5750m=4025m between flight lines

8. **Determine flight numbers**: \((20\text{Km}/4025m)+1=7\) (width/distance between flight lines)

Therefore, adjusted spacing between lines=20000m/6=3333m/space

9. **Find the spacing of flight lines on the map using scale** \((1:50,000)\)

= 3333m/50000=66.66mm

10. **Find the total number of photo needed**: \(7*16=112\) photos

**Aperture and shutter speed**

- An exposure is optimum at a shutter speed of 1/250 second and f-4. If the shutter speed is 1/1000 second, what should be corresponding f-stop to retain optimum exposure.
- **Answer**: standard format of shutter speed is= 1, 1/2, 1/4, 1/8.............1/125, 1/250, 1/500,1/1000
- Standard format of aperture (f-stop) is power of square root of 2. i.e. \((\sqrt{2})^0, (\sqrt{2})^1, (\sqrt{2})^2,\) or 1, 1.4,2,2.8,4,5.6,8,11,16,22......
- **Now the theory is**: Halving the shutter speed double the exposure. Therefore, here shutter speed is increased by two fold, hence f-stop is 2.

**Aperture and shutter speed**

Now,

- F-8/low shutter speed
- F- 2/ High shutter speed
Whether film exposure increase or decrease (Exam 062/63)

- Lens diameter increase: It gives larger aperture size (small f/stop number). Hence, low amount of light reduced shutter speed and hence, create low exposure of film.

- Shutter speed increase: More light and more film exposure

- Focal length decrease: Gives smaller aperture size and more light opportunity. Hence increase exposure.

- F-stop decrease: More light more exposure

- Brightness decrease: Decrease exposure

Please read it:

"think of a bucket of water with a hole in the bottom. If you have a large hole in the bottom of the bucket (large aperture), water will drain out quickly (fast shutter speed). Conversely, for the same amount of water, if you have a small hole in the bottom of the bucket (small aperture), the water will drain out slowly (slow shutter speed)."

A film in camera with 40mm focal length lens is properly exposed with lens opening diameter 5mm and an exposure time of 1/125 second. If the lens opening is increased to 10mm what exposure time should be used to maintain proper exposure?

Answer: Aperture= 40mm/5mm= 8 when an exposure is 1/125

When aperture is increased to 10mm, than aperture = 40mm/10mm=4 than exposure is 1/500

( standard format of shutter speed is= 1, 1/2, 1/4, 1/8............1/125, 1/250, 1/500,1/1000 and Standard format of aperture (f-stop) is power of square root of 2. i.e. (\(\sqrt{2}\))^0, (\(\sqrt{2}\))^1, (\(\sqrt{2}\))^2 or 1, 1.4,2,2.8,4,5.6,8,11,16,22......

The parallax difference between top and bottom of a tree is measured as 1.32mm on a stereo pair of photo taken at 3000ft above ground. Average photo base is 88mm. How tall is the tree.
Answer:

dp= 1.32mm  
Flight height=3000ft  
Average photo base=88mm  
Height of tree=?

Height of object \( (h_0) = \frac{H \cdot dp}{p+dp} \)

\[ = 3000 \frac{1.32}{1.32+88} \]

\[ = 44.33 \text{ft} \]

(Remember that absolute parallax is replaced by photo air base when photo air base is given and vice versa. Formula is same for both condition i.e. height= \( H \cdot \frac{dp}{\text{absolute parallax} \text{ (or air base)} + dp} \))

Where H is height above ground terrain).

A 30 m tree caster 2mm shadow on an aerial photography of unknown scale. What will be the actual height of a building which caster 3mm shadow on the same photo.

Answer:

Using proportional method of calculation

\[ \frac{2 \text{mm}}{30 \text{m}} = \frac{3 \text{mm}}{\text{height of building}} \]

Or height of building=3mm*30m/2mm=45m

Calculate the approximate vertical exaggeration in a stereo model from photo taken with a 6 inch focal length camera, having a 9 inch square format, if photos are taken at 55% end lap.

Answer:

Vertical exaggeration=\( \frac{B}{H \cdot h/b_0} \)

Where,

\[ \frac{B}{H} = (1-\text{endlap}) \cdot \frac{d}{f} \]

Where \( d \)= photo format and \( f \)=focal length

\( B/H=0.6 \)

Now assuming \( b_0/h = 0.15 \) where \( b_0 \) is distance between two eye and \( h \) is distance from eye to stereo model perceived.

Therefore VE= \( 1/0.15 \cdot 0.6 = 4 \)

A vertical photography was taken at flying height of 5000m above mean sea level using a camera with 152mm focal length lens. Determine the photo scale at point A and B which lie at elevation of 1200m and 1950m respectively.

Answer:  Scale at A = \( f/H-h = 0.152m/3800m = 1/25000 \). Find similarly for B.
Relief Displacement Method

Any objects that are higher or lower than the principal point are displaced from its true planimetric (x,y) location on a vertical aerial photograph. This displacement is referred to as relief displacement, and is denoted by

\[ \Delta r = \frac{\Delta H \times r}{H^2}, \]

Where:

\( \Delta H \) is the height difference between two points, \( H \) is the flying height above the lower point, and \( r \) is the radial distance to the upper point from the photo centre.

Note that, relief displacement is outward from the principal point for objects whose elevations are above the local datum, and toward the principal point for objects whose elevation are below the local datum. The direction of relief displacement is radial from the principal point.

Height from Relief Displacement is, therefore, derived using the formula:

\[ h = \frac{d}{r} \frac{H}{r} \]

Where:

\( h \) is height of the object referenced to the local datum;
\( H \) is the altitude above the local datum;
\( d \) is object length from base to top on the image, namely, relief displacement;
\( r \) is radial distance from the photo nadir (principal point) to the top of the object.

Figure below provides an illustrative description of the derivation.
Assumptions

- Aerial photographs is vertical or near vertical (<3° of tilt). Namely, the principle point is the photo nadir;
- The top and the bottom of the object are visible; and,
- The object is on level base and vertical.

Determination of Height by Measuring Parallax Differences

This three dimensional view is made possible through the effect of horizontal parallax. Parallax is the optical illusion that two stationary points change their position relative to each other, due to the motion of an observer. By observing parallax, measuring angles, and using geometry; one can determine the distance to various objects. Parallax is the apparent displacement of the position of a body, with respect to a reference point or system, caused by a shift in the point of observation. Or, the apparent displacement of an object as seen from two different points that are not on a line with the object.

The two types of parallax significant to Aerial Photography are Absolute Parallax; and, Differential Parallax.

**Absolute Parallax (aP):** The algebraic difference (measured parallel to the flight line, positive in the direction of flight) between the distances of the principal points from corresponding image points in a stereoscopic pair of aerial photographs

**Differential Parallax (dP):** The difference in the absolute stereoscopic parallaxes of two points imaged on a pair of photographs.

Parallax Height Measurement
This is the most used method of measuring heights on air photos, and is derived using the below formula.

That is,

$$\Delta H = \frac{dP * \bar{H}}{b + dP}$$

Where:

$H$ is Platform height or altitude above ground datum

$dP$ is Differential Parallax

$b$ is the photo base (substitutes $aP$, Absolute Parallax).

Assumptions

Photos are perfectly vertical;

Both photos of the stereo pair were taken from the same flying height;

Both principle points are at essentially the same ground elevation; and,

The base of the objects to be measured is, essentially, at the same elevation as that of the principle point.

![Figure: Derivation of Height using Parallax](image)
A Note on Measuring Differential Parallax

We cannot use a ruler to measure the tiny displacement components of differential parallax, hence Differential parallax ($dP$) is usually measured stereoscopically with a parallax wedge or parallax bar (stereometers) that incorporates the “floating-mark” principal. Floating Mark Principal - If a small dot is inked at precisely the same location on both prints of a stereopair, the two dots will merge into one when viewed through a stereoscope. Had one pair of dots been placed on level ground and another pair on top of a building, each pair would merge into a single mark; the first pair would appear to lie at ground level, while the second pair (being slightly closer together) would appear to “float” in space at the elevation of the object on which the dots were inked. If the distance between each pair of corresponding dots can be precisely measured, the algebraic difference will be a measure of differential parallax. The function of a stereometer is to measure such changes in parallax that are too small to be determined by direct linear measurement.