Chapter 6

Remote Sensing, Photogrammetry GIS and GPS

CHAPTER HIGHLIGHTS

- *Photogrammetry*
- *Remote sensing*
- *Geographic information system (GIS)*
- *Global positioning system (GPS)*

PHOTOGRAMMETRY

Introduction

Photogrammetric surveying or photogrammetry is the science and art of obtaining accurate measurements by use of photographs, for various purposes such as the construction of plainmetric and topographic maps, classification of soils, interpretation of geology, acquisition of military intelligence etc. The scale and flying height concepts of photogrammetry are focused in this chapter.

Definitions

- **Vertical photograph:** It is an aerial photograph made with the camera axis (or optical axis) coinciding with the direction of gravity.
- **Tilted photograph:** It is an aerial photograph made with the camera axis unintentionally tilted from the vertical by a small amount ($< 3^0$).
- **Oblique photograph:** This is also an aerial photography taken with camera axis tilted intentionally. If the horizon is shown in the photograph, it is said to be high oblique. If the apparent horizon is not shown, it is said to be low oblique.
- **Terrestrial photogrammetry:** Photographs taken from a fixed position on or near the ground.
- **Aerial photogrammetry:** Photographs are taken from a camera mounted in an aircraft flying over the area.
- **Phototheodolite:** It is a combination of theodolite and terrestrial camera.
- **Camera axis:** Line passing through centre of camera lens perpendicular both to camera plate (negative) and picture plane (photograph).
- **Picture plane:** Positive plane, perpendicular to camera axis.
- **Principal point:** Point of intersection of camera axis with either picture plane or the camera plate.
- **Focal length:** Perpendicular distance from centre of camera lens to either to picture plane or camera plate. It satisfies the relation

$$\frac{1}{f} = \frac{1}{u} = +\frac{1}{v} \Rightarrow f = \frac{uv}{u+v}$$

- **Nodal point:** It is either of two points on the optical axis of a lens so located that when all object distances are measured from one point, and all images distances are measured from other. They satisfy the simple lens relation

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

- **Principal plane:** It is a plane which contain principal line and optical axis.

Scale of a Vertical Photograph

- If the elevation of points vary, the scale of the vertical photograph will vary from point to point on the photograph

$$\boxed{\text{Scale} = S = \frac{\text{Map distance}}{\text{Ground distance}} = \frac{f}{H-h}}$$

Where
h = Height of exposure station (or the air plane) above the mean seal level.
H = Height of ground above MSL
f = Focal length of camera

- If A and B are two points on ground having elevations h_a and h_b above MSL, the average scale of the line joining A and B is

$$\boxed{S = \frac{f}{H - h_{avg}}} \quad \boxed{h_{avg} \frac{h_a + h_b}{2}}$$

Datum scale $\boxed{S = \dfrac{f}{H}}$

- Scale of a photograph $\boxed{S_h = \dfrac{l}{L}}$

$$\frac{\text{Phote scale}}{\text{Map scale}} = \frac{\text{Photo distance}}{\text{Map distance}}$$

Where
l = Distance in photograph
L = Distance on ground

Computation of length of the line between points of different elevations from measurement on a vertical photograph:

- If A and B be two ground points having elevations h_a and h_b above MSL and coordinates (X_a, Y_a) and (X_b, Y_b)
- Let a and b be the position of corresponding points in photograph and (x_a, y_a) and (x_b, y_b) be the corresponding coordinates, then

$$\frac{x_a}{X_a} = \frac{y_a}{Y_a} = \frac{f}{H - h_a}$$

$$\frac{x_b}{X_b} = \frac{y_b}{Y_b} = \frac{f}{H - h_b}$$

$$X_a = \frac{H - h_a}{f} \cdot x_a \quad X_b = \frac{H - h_b}{f} \cdot x_b$$

$$Y_a = \frac{H - h_a}{f} \cdot y_a \quad Y_b = \frac{H - h_b}{f} \cdot y_b$$

- Length between AB is given by

$$L = \sqrt{(X_a - X_b)^2 + (Y_a - Y_b)^2}$$

Relief Displacement on a Vertical Photograph

When the ground is not horizontal the scale of the photograph varies from point to point. The ground relief is shown in perspective on the photograph. Every point on the photograph is therefore, displaced from true orthography position. This displacement is called relief displacement.

$$\text{Relief displacement, } d = \frac{Rfh}{H(H-h)}$$

$$d = \frac{rh}{H} = \frac{r_0\, h}{H - h}$$

1. The relief displacement increases as the distance from the principal point increases.
2. $d \propto \dfrac{1}{H}$

Scale of a Tilted Photograph

$$S_h = \frac{f\sec t - mn \sin t}{H - h} = \frac{f\sec t - y' \sin t}{H - h}$$

$$y' = -x \sin\theta + y' \cos\theta + f \tan t$$

Where
$\theta = 180 - s$
s = Swing
t = Tilt
f = Focal length
H = Flying height above datum
h = Height of ground above datum

It can be seen that the tilt and relief displacements tend to cancel in the upper part of the photograph while they are cumulative in the lower part.

Overlap in the Photographs

Longitudinal overlap = 55 to 65%
Lateral overlap = 15 to 35%

For maximum rectangular area, to be covered by one photograph, the rectangle should have the dimension in the flight to be one half the dimension normal to the direction of flight.

$W = 2B$; $W = 1.22H$
W = Width of ground
% overlap ≈ 60% in longitudinal direction.

Number of Photograph to Cover a Given Area

Number of photographs required $\boxed{N = \dfrac{A}{a}}$

Where

A = Total area to be photographed

a = Net ground area covered by each photograph

$$a = L \times W$$
$$L = (1 - P_l)s \cdot l$$
$$W = (1 - P_w)s \cdot l$$
$$a = lws^2(1 - P_l)(1 - P_w)$$

Where

l = Length of photograph in direction of flight

W = Width of photograph

P_l, P_W = % overlap in longitudinal and lateral directions.

- If instead of total areal A, the rectangular dimensions $L_1 \times L_2$ (parallel and transverse to flight) are given, then the number of photographs required are as follows.
- Let L_1, L_2 = dimension of area parallel and transverse to the direction of flight.
  N_1 = Number of photographs in each strip
  N_2 = Number of strips required
  Total number of photographs to cover the whole area, $N = N_1 \times N_2$

$$N_1 = \frac{L_1}{(1 - P_l)s \cdot l} + 1$$

$$N_1 = \frac{L_2}{(1 - P_w)s \cdot l} + 1$$

Interval Between Exposures

$$T = \frac{3600 \times L}{V}$$

V = Ground speed of airplane, in km/h

L = Ground distance covered by each photograph in the direction of flight

$= (1 - P_l)s \cdot l \ldots$ in km

Elevation of a Point by Photographic Measurement

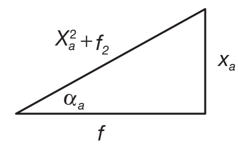
$$\tan \alpha_a = \frac{X_a}{f}$$

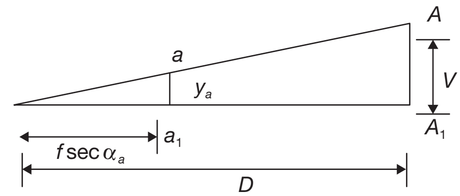
$$\tan \beta_a = \frac{Y_a}{Oa_1} = \frac{y_a}{f \sec \alpha_a} = \frac{Y_a}{f} \cos \alpha_a$$

If V = Elevation of point A above horizontal plane through camera axis. From similar triangle

$$\frac{y_a}{f \sec \alpha_a} = \frac{V}{D}$$

So, $V = \dfrac{y_a D}{f \sec \alpha_a} = \dfrac{y_a D}{\sqrt{f^2 + x_a^2}} = \dfrac{yD}{\sqrt{f^2 + x^2}}$





So, $\boxed{V = \dfrac{yD}{f} \cos \alpha = \dfrac{yD}{\sqrt{f^2 + x^2}}}$

Elevation of point A,

$$h = H_c + V + C$$

Where

H_c = Elevation of camera

V = Elevation of point A

C = Correction for curvature and refraction.

SOLVED EXAMPLES

Example 1

A tower AB, 60 m high, appears in a vertical photograph taken at a flight attitude of 2500 m above mean sea level. The distance of the image of the top of the tower is 5.32 cm. Compute the displacement of the image of the top of the tower with respect to the image of its bottom. The elevation of the bottom of the tower is 1270 m.

Solution

Let H = Height of lens above the bottom of the tower.

The displacement d of the image of the top with respect to the image of the bottom is given by

$$d = \frac{hr}{H}$$

h = Height of the tower above its base = 60 m

$H = 2500 - 1270 = 1230$

$$d = \frac{60 \times 5.32}{1230} = 0.26 \text{ cm.}$$

Remote Sensing

It is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object area, or phenomenon under investigation. Remote sensing of each resources involves two basic processes:

1. Data-acquisition process
2. Data analysis

Observation Platforms

Two types of platforms have been in use in remote sensing.

1. Air borne platforms
2. Space based platforms

Air Borne Platforms

Air borne remote sensing was the well-known method used in initial years of development of remote sensing. Air crafts were mostly used as RS platforms for obtaining photographs. Aircraft carrying RS equipment should have maximum stability, free from vibrations and fly with uniform speed. Aircraft operations are very expensive for periodical monitoring of constantly changing phenomena like crop growth, vegetation cover, etc. Aircraft based platform cannot provide cost and time effective solutions.

Space Based Platforms

Space borne RS platforms, offer several advantages over airborne platforms.

It provides synoptic view (i.e., large area in a single image), systematic and repetitive coverage.

Satellite is a platform that carries the sensor and other payloads required in RS operation.

Space borne platforms are broadly divided into two classes.

1. **Low altitude near polar orbiting satellites:** These are the RS satellites which revolve around earth in a sun synchronous orbit defined by its fixed inclination angle from the earths NS axis.
2. **High attitude Geo-stationary satellites:** These are mostly communication/meteorological satellites which are stationary in reference to the earth. Its velocity is equal to the velocity with which earth rotates about its axis. Such satellites always cover the fixed area over earth surface and their attitude is about 36,000 km.

Sensors

RS sensors are designed to record radiations in one or more parts of the EM spectrum.

Sensors used in Indian RS Satellites (IRS)

1. Linear imaging and self scanning sensor (LISS I)
2. Linear imaging and self scanning sensor (LISS II)
3. Linear imaging and self scanning sensor (LISS III)
4. Panchromatic sensor (PAN)
5. Wide field sensor (WiFS)
6. Modular opto-electronic scanner (MOS)
7. Ocean colour monitor (OCM)
8. Multi-scanning microwave radiometer (MSMR)

Generally sensors are of two types:

1. **Active sensors:** These utilizes the man-made sources and detect the electro magnetic radiation of a specific wavelengths to illuminate the earth's surface are called active sensors.
2. **Passive sensors:** Sensors that sense natural radiations, either reflected or emitted from the earth, are called passive sensors.

Visual Image Interpretation

The data interpretation aspects of RS can involve analysis of photographs (images) and/or digital data. This can be performed by visual interpretation or with the help of computer assisted analysis techniques.

Photo interpretation means identifying and recognizing objects in the aerial photograph and then judging their characteristics and significance in the photograph.

The following characteristics of the photo images are studied:

1. **Shape:** This relates to general form, configuration or outline of an object. This is an important factor for recognizing objects form their photographic images.
2. **Size:** Objects can be misinterpreted, if the sizes are not properly evaluated.

   Example: A canal may be interpreted as a road side drain.
3. **Pattern:** Pattern means spatial arrangement of the objects photographed.

   Example: Building, roads, etc., have a particular pattern which can easily be recognized.
4. **Shadow:** The outline of a shadow gives the profile of an object, which aids in interpretation.
5. **Texture:** Texture is the frequency of the change in tone in photographic image.

   Example: Large leaf tree species can be distinguished from small leaf species on the basis of their coarser texture.
6. **Site:** The location of an object in relation to its surroundings is very helpful in identification.

   Example: A building in a forest might not be identified, whereas it can be easily identified in residential areas.

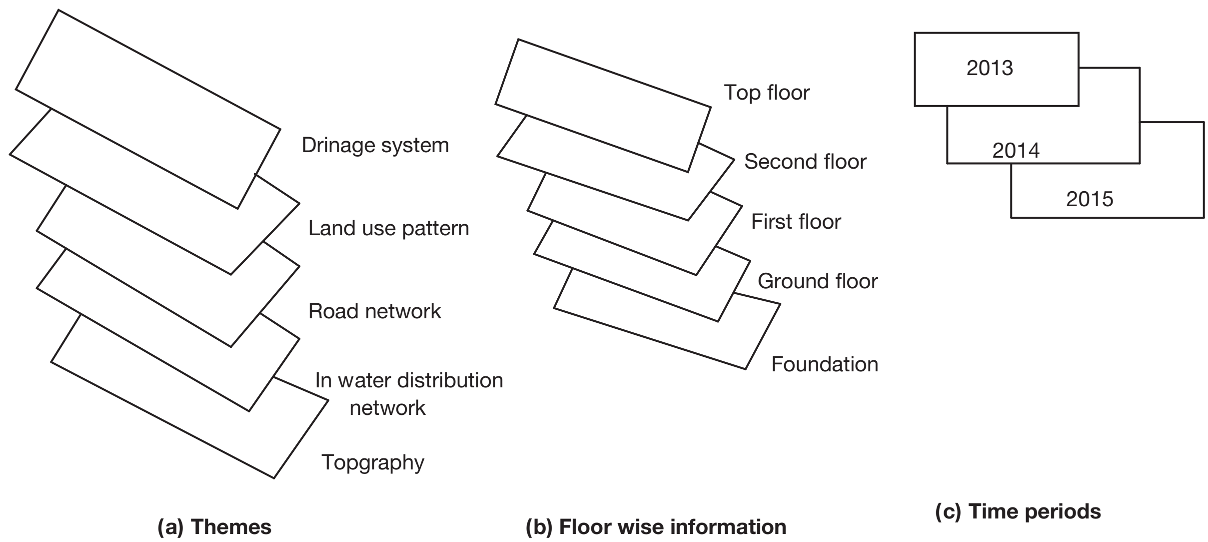
Applications of Remote Sensing

1. **Agriculture:** Crop growth profile, crop yield modeling, crop violations.
2. **Forestry:** Forest fire, deforestation, forest stock mapping, wild life habitat assessment.
3. **Land use/land cover analysis:** Soil categorization, mapping land use/cover, change detection, identifying degraded lands/erosion prone areas.

4. **Geology:** Drainage analysis, coal fire mapping, mineral exploration, oil field detection.
5. Environmental hazards
6. **Water resources:** Glacier inventory, surface water bodies monitoring and estimation of their spatial extent.

Geographic Information System (GIS)

- GIS is an information technology which stores, analyses and displays both spatial and non-spatial data.
- GIS is capable of acquiring spatially indexed data from a variety of sources, changing the data into useful formats, storing the data, retrieving and manipulating the data for analysis and then generating the output required by the user. The acquired specified indexed data are known as layers. Each layer represents a thematic approach to a particular purpose.



A layered database concept

The main advantage of GIS is rapid analysis and display of data with flexibility which is not possible using manual methods.

Data for GIS

The basic forms of the data for GIS:

1. **Spatial data:** Data that provide locations and shapes of features in a map.
2. **Tabular data:** Data that are collected or complied for a given area, GIS links this to features in a map.
3. **Image data:** Aerial photographs and products, satellite images, scanned data (photographic prints converted to digital format).

Representation of Features

1. Point data
2. Line and string data
3. Areal data
4. Pixels
5. Grid cells

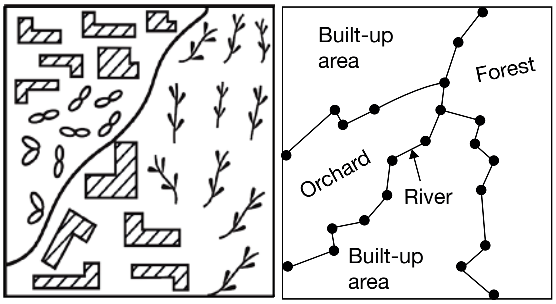
Data Structure for GIS

Data are frequently derived from a 'conventional' (non-digital) map or image. It is necessary to convert them into digital form suitable for use by a GIS.

The simple spatial objects are coded in two different formats–vector and raster–for storing and manipulating these in a GIS. These data structures are also called data models or data formats.

Vector Data Structure

Vector data depicts the real world by means of discrete points, lines and polygons and is sorted as a collection of x, y coordinates.



(a) Using standard Topographic symbols

(b) Vector representation

Land cover map of a region

The representation of vector data is governed by the scale of the input data. For example, a building that is represented as a polygon on a large-scale map will become a point on a medium-scale map and it will not be represented at all as an individual entity on a small-scale map.

Raster Data Structure

Also called cellular data structure depicts the real world by pixels or grid cells. It is not as accurate or flexible as the vector format, as each coordinate may be represented by a cell and each line by an array of cells.

0	3	0	0	0	0
0	3	0	0	0	0
0	3	3	0	0	0
0	0	3	0	0	0
0	0	3	3	3	0
0	0	0	0	0	0

Representation of raster data

Applications of GIS

1. Engineering geology
2. Surface hydrology
3. Hydro-geology
4. Environment management—models and map analysis for water supply and waste disposal sites.
5. Land resource and urban surveys

Global Positioning System (GPS)

GPS is a space-based all-weather radio system that provides quickly, accurately and inexpensively the time, position and velocity of the object anywhere. It uses the satellite signals, accurate time and sophisticated algorithms to generate distances in order to triangulate positions anywhere on earth.

GPS Surveying Techniques

The position of stationary or moving object can be determined through GPS.

When the position of a stationary or moving object is determined with respect to a well-defined coordinate by using a single GPS receiver and by making observations to four or more satellites, it is called point positioning or absolute positioning.If the coordinates of an unknown point are determined with respect to a known point, it is called relative positioning.

Static Surveying Techniques (Traditional Static Surveying)

- In this technique, one base receiver is placed over a point of known coordinates, while others are placed over new permanent stations to be positioned.
- The limitation of the method is the need of hours of observation required, which depends on the receiver, the satellites geometric configuration, the length of base and atmospheric conditions. This technique is used for long lines in geodetic control, control densification, and photogrammetric control for aerial surveys.

Dynamic Survey Technique (Kinematic Surveying)

This implies some sort of motion. The modeling of the orbit for GPS satellites is a dynamic procedure. As soon as the positions of the satellites are assumed to be known and given, positioning of a moving vehicle can be considered as kinematic procedure.

1. **Rapid static surveying:** This technique ideally requires one receives to be positioned on a station of known coordinates while others move from station to station. The real power of this technique is the ability to solve the base lines in a very short period of time without having to lock on a present number of satellites.
2. **Pseudo-static surveying**: This is also known as pseudo-kinematic/intermittent static/snapshot static. It is more flexible than kinematic technique, since lock on satellites need not be maintained while travelling between stations. But it is less accurate than using the rapid static technique. This works well when a large number of sites have to be visited as this tends to reduce waiting periods between station re-occupations.
3. **Kinematic surveying:** This reduces the amount of time needed to determine the GPS vector. Reference receiver is placed over a known point while a roving receiver moves around stopping momentarily on various points.

4. **Traditional kinematic technique:** This technique computes a relative differential position at present time intervals instead of at operator-selected points. This technique is used for road profiling, locating positions of ships and aircraft positioning.

Applications of GPS

1. **Navigation:** Marine and air navigation
2. **Surveying:** Measuring crustal deformations, volcanic uplift, plate tectonics and earth rotation.
3. **Mapping:** Generating road maps or any other kind of feature maps
4. Remote sensing
5. **Geographic information system:** GPS is an effective loop for GIS data capture.
6. Military and space
7. Agriculture

Exercises

1. Which one of the following surveys is required in observations of stars?
   (A) Astronomical survey
   (B) Cadastral survey
   (C) Aerial survey
   (D) Photogrammetric survey
2. **Assertion (A):** In a spherical triangle, the sum of the three sides is always less than the circumference of the great circle.

   Reason (R): The sum of the three angles of a spherical triangle is greater than two right angles, but less than six right angles.
   (A) Both A and R are true and R is the correct explanation of A.
   (B) Both A and R are true but R is not a correct explanation of A.
   (C) A is true but R is false.
   (D) A is false but R is true.
3. The relationship between the air-base B, photographic base 'b', flying height H and focal length 'f' of lens in a vertical photograph is given by
   (A) $B = \dfrac{bH}{f}$ (B) $B = \dfrac{f}{bH}$
   (C) $B = \dfrac{b}{fH}$ (D) $B = \dfrac{b}{H - f}$
4. Consider the following statements:

   IRS series satellites are:
   I. Low orbiting satellites
   II. Geostationary satellites
   III. Meteorological satellites
   IV. Resource survey satellites

   Which of the IES statements are correct?
   (A) I and IV (B) II and III
   (C) I, II and IV (D) II, III and IV
5. Match List I (Phenomenon) with List II (Method of survey) and select the correct answer using the code given below the lists:

	List I		List II
a.	Crab and drift	**1.**	Triangulation
b.	Stadia intercept	**2.**	Astronomical survey
c.	Culmination and elongation	**3.**	Aerial photogrammetry
d.	Baseline measurement	**4.**	Tacheometric survey

Codes:

	a	b	c	d		a	b	c	d
(A)	3	1	2	4	(B)	2	4	3	1
(C)	3	4	2	1	(D)	2	1	3	4

6. Consider the following statements:

   In aerial photogrammetry the 'filter' is placed in front of the lens to:
   I. Reduce the effect of atmospheric haze.
   II. Protect the lens from dust.
   III. Provide uniform light distribution over the format.

   Which of the IES statements is/are correct?
   (A) I and II only
   (B) II only
   (C) I and III only
   (D) I, II and III
7. 'Iso-centre' is the point
   (A) in which the tilted axis of the camera meets the vertical photograph.
   (B) in which the bisector of the angle of tilt meets the vertical photograph.
   (C) in air space, the location of the optical centre of the lens of the camera at the time of exposure.
   (D) where the perpendicular from the nodal point meets the photograph.
8. Match the following related to Electromagnetic distance measurement (EDM):

	List I		List II
i.	Short range	**a.**	less than 3 km
ii.	Medium range	**b.**	less than 100 km
iii.	Long range	**c.**	less than 25 km

Codes:

	i	ii	iii		i	ii	iii
(A)	b	c	a	(B)	a	c	b
(C)	c	a	b	(D)	a	b	c

9. If an overlapping pair of vertical photographs taken with a 150 mm focal length camera has an air base of 2100 m and elevation of the control point *A* on its is 900 m above MSL and the parallax of point is 75 mm, then the flying height above MSL of stereo pair will be

(A) 3000 m
(B) 3150 m
(C) 5100 m
(D) 5250 m

Previous Years' Questions

1. The minimum number of satellites needed for a GPS to determine its position precisely is **[GATE, 2016]**

(A) 2
(B) 3
(C) 4
(D) 24

2. The system that uses the Sun as a source of electromagnetic energy and records the naturally radiated and reflected energy from the object is called **[GATE, 2016]**

(A) Geographical Information System
(B) Global Positioning System
(C) Passive Remote Sensing
(D) Active Remote Sensing

3. Optimal flight planning for a photogrammetric survey should be carried out considering **[GATE, 2016]**

(A) only side-lap
(B) only end-lap
(C) either side-lap or end-lap
(D) both side-lap as well as end-lap

4. A tall tower was photographed from an elevation of 700 m above the datum. The radial distances of the top and bottom of the tower from the principal points are 112.50 mm and 82.40 mm, respectively. If the bottom of the tower is at an elevation 250 m above the datum, then the height (expressed in m) of the tower is ________. **[GATE, 2016]**

Answer Keys

Exercises

1. A **2.** A **3.** A **4.** A **5.** C **6.** D **7.** B **8.** B **9.** C

Previous Years' Questions

1. C **2.** C **3.** D **4.** 120.4