LECTURE NOTES ON
REMOTE SENSING & GIS
IV B. Tech II semester (JNTU (A)-R13)

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GPCET
Pioneering Innovative Education

G.PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY

CIVIL ENGINEERING

OBJECTIVES:

1. *To understand the Photogrammetric techniques, concepts, components of Photogrammetry*

OUTCOMES:

On completion of the course the students will have knowledge on

- *Principles of Photogrammetry*
- *Analysis of RS and GIS data and interpreting the data for modeling applications*

UNIT – I

INTRODUCTION TO PHOTOGRAMMETRY:

Principles& types of aerial photograph, geometry of vertical aerial photograph, Scale & Height measurement on single vertical aerial photograph, Height measurement based on relief displacement, Fundamentals of stereoscopy, fiducially points, parallax measurement using fiducially line.

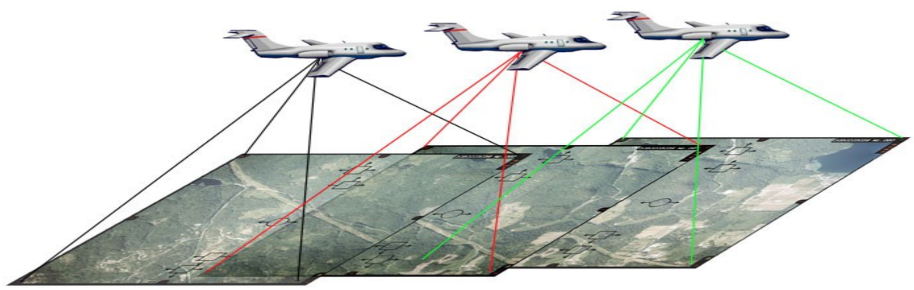
TEXT BOOKS:

1 Remote Sensing and GIS by B.Bhatta, Oxford University Press,New Delhi.
2 Fundamentals of remote sensing by gorge Joseph , Universities press, Hyderabad

UNIT-1

Photogrammetry

Photogrammetry is the science of making measurements from photographs, especially for recovering the exact positions of surface points. Moreover, it may be used to recover the motion pathways of designated reference points located on any moving object, on its components and in the immediately adjacent environment. Photogrammetry may employ high-speed imaging and remote sensing in order to detect, measure and record complex 2-D and 3-D motion fields. Photogrammetry feeds the measurements from remote sensing and the results of imagery analysis into computational models in an attempt to successively estimate, with increasing accuracy, the actual, 3-D relative motions within the researched field.



Its applications include satellite tracking of the relative positioning alterations in all Earth environments (e.g. tectonic motions etc.), the research on the swimming of fish, of bird or insect flight, other relative motion processes. The quantitative results of photogrammetry are then used to guide and match the results of computational models of the natural systems, thus helping to invalidate or confirm new theories, to design novel vehicles or new methods for predicting or/and controlling the consequences of earthquakes, tsunamis, any other weather types, or used to understand the flow of fluids next to solid structures and many other processes.

Photogrammetry is as old as modern photography, can be dated to the mid-nineteenth century, and its detection component has been emerging from radiolocation, multilateration and radiometry while its 3-D positioning estimative component (based on modeling) employs methods related to triangulation, trilateration and multidimensional scaling.

In the simplest example, the distance between two points that lie on a plane parallel to the photographic image plane can be determined by measuring their distance on the image, if the scale (s) of the image is known. This is done by multiplying the measured distance by $1/s$.

Algorithms for photogrammetry typically attempt to minimize the sum of the squares of errors over the coordinates and relative displacements of the reference points. This minimization is known as bundle adjustment and is often performed using the Levenberg–Marquardt algorithm.

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- The photogrammetry has been derived from three Greek words:
- Photos: means light
- Gramma: means something drawn or written
- Metron: means to measure

This definition, over the years, has been enhanced to include interpretation as well as measurement with photographs.

Definition:The art, science, and technology of obtaining reliable information about physical objects and the environment through process of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and phenomenon .Originally photogrammetry was considered as the science of analysing only photographs.

- But now it also includes analysis of other records as well, such as radiated acoustical energy patterns and magnetic phenomenon

Definition of photogrammetry includes two areas:

(1) **Metric:** It involves making precise measurements from photos and other information source to determine, in general, relative location of points.
Most common application: preparation of plannimetric and topographic maps.

(2) **Interpretative**: It involves recognition of objects and judging their significance through careful and systematic analysis. It includes photographic interpretation which is the study of photographic images. It also includes interpretation of images acquired in Remote sensing using photographic images, MSS, Infrared, TIR, SLAR etc.

Aerial photography: It is the taking of photographs of the ground from an elevated/direct-down position. Usually the camera is not supported by a ground-based structure.

Terrestrial photogrammetric: In this kind of photogrammetry, a camera is used in a stationary position. The camera is positioned on an elevated level. The tilt and other specifications of the camera are all controlled.

Photographic interpretation: It is "the act of examining photographic images for the purpose of identifying objects and judging their significance" (Colwell, 1997). This mainly refers to its usage in military aerial reconnaissance using photographs taken from reconnaissance aircraft.

Applications of photogrammetry: Photogrammetry has been used in several areas. The following description gives an overview of various applications areas of photogrammetry

1)Geology: Structural geology, investigation of water resources, analysis of thermal patterns on earth's surface, geomorphological studies including investigations of shore features.

2) Forestry: Timber inventories, cover maps, acreage studies

(3) Agriculture: Soil type, soil conservation, crop planting, crop disease, crop-acreage

(4) Design and construction: Data needed for site and route studies specifically for alternate schemes for photogrammetry. Used in design and construction of dams, bridges, transmission lines.

(5) Planning of cities and highways: New highway locations, detailed design of construction contracts, planning of civic improvements.

(6) Cadastre: Cadastral problems such as determination of land lines for assessment of taxes. Large scale cadastral maps are prepared for reapportionment of land.

(7) Environmental Studies: Land-use studies.

(8) Exploration: To identify and zero down to areas for various exploratory jobs such as oil or mineral exploration.

(9) Military intelligence: Reconnaissance for deployment of forces, planning man oeuvres, assessing effects of operation, initiating problems related to topography, terrain conditions or works.

(10) Medicine and surgery: Stereoscopic measurements on human body, X-ray photogrammetry in location of foreign material in body and location and examinations of fractures and grooves, biostereometrics.

(11) Miscellaneous: Crime detection, traffic studies, oceanography, meteorological observation, Architectural and archaeological surveys, contouring beef cattle for animal husbandry etc.

Types of photogrammetry

Photogrammetry is divided into different categories according to the types of photographs or sensing system used or the manner of their use as given below:

On the basis of orientation of camera axis:

i)Terrestrial or ground photogrammetry: When the photographs are obtained from the ground station with camera axis horizontal or nearly horizontal

ii) Aerial photogrammetry: If the photographs are obtained from an airborne vehicle. The photographs are called vertical if the camera axis is truly vertical or if the tilt of the camera axis is less than 3o. If tilt is more than, the photographs are called oblique photographs.

On the basis of sensor system used: Following names are popularly used to indicate type of sensor system used in recording imagery.

- Radargrammetry: Radar sensor
- X-ray photogrammetry: X-ray sensor
- Hologrammetry: Holographs
- Cine photogrammetry: motion pictures
- Infrared or colour photogrammetry: infrared or colour photographs

On the basis of principle of recreating geometry

When single photographs are used with the stereoscopic effect, if any, it is called monoscopic photogrammetry. If two overlapping photographs are used to generate three dimensional views to create relief model, it is called stereophotogrammetry. It is the most popular and widely used form of photogrammetry.

On the basis of procedure involved for reducing the data from photographs

Three types of photogrammetry are possible under this classification:

(a)Instrumental or analogue photogrammetry: It involves photogrammetric instruments to carry out tasks.

(b) Semi-analytical or analytical: Analytical photogrammetry solves problems by establishing mathematical relationship between coordinates on photographic image and real world objects. Semi-analytical approach is hybrid approach using instrumental as well analytical principles.

(**c) Digital Photogrammetry or softcopy photogrammetry:** It uses digital image processing principle and analytical photogrammetry tools to carry out photogrammetric operation on digital imagery.

On the basis of platforms on which the sensor is mounted:

If the sensing system is spaceborne, it is called space photogrammetry, satellite photogrammetry or extra-terrestrial photogrammetry. Out of various types of the photogrammetry, the most commonly used forms are stereophotogrammetry utilizing a pair of vertical aerial photographs (stereopair) or terrestrial photogrammetry using a terrestrial stereopair.

Classification of Photographs

The following paragraphs give details of classification of photographs used in different applications

(1)On the basis of the alignment of optical axis

(a) **Vertical :** If optical axis of the camera is held in a vertical or nearly vertical position.

(b) **Tilted :** An unintentional and unavoidable inclination of the optical axis from vertical produces a tilted photograph.

(c) **Oblique :** Photograph taken with the optical axis intentionally inclined to the vertical. Following are different types of oblique photographs:

(i)High oblique: Oblique this contains the apparent horizon of the earth.

(ii)Low oblique: Apparent horizon does not appear.

(iii) Trimetrogon: Combination of a vertical and two oblique photographs in which the(central photo is vertical and side ones are oblique. Mainly used for reconnaissance.

(iv) Convergent: A pair of low obliques taken in sequence along a flight line in such a manner that both the photographs cover essentially the same area with their axes tilted at a fixed inclination from the vertical in opposite directions in the direction of flight line so that the forward exposure of the first station forms a stereo-pair with the backward exposure of the next station.

Comparison of photographs:

Type of photo	**Vertical**	**Low oblique**	**High oblique**
Coverage	Least	Less	Greatest
Area	Rectangular	Trapezoidal	Trapezoidal
Scale	Uniform if flat	Decreases from foreground to background	Decreases from foreground to background
Difference with map	Least	Less	Greatest
Advantage	Easiest to map	-	Economical and illustrative
Characteristics	Tilt < 3^o	Horizon does not appear	Horizon appears

(2). On the basis of the scale

(a) Small scale - 1 : 30000 to 1 : 250000, used for rigorous mapping of undeveloped terrain and reconnaissance of vast areas.

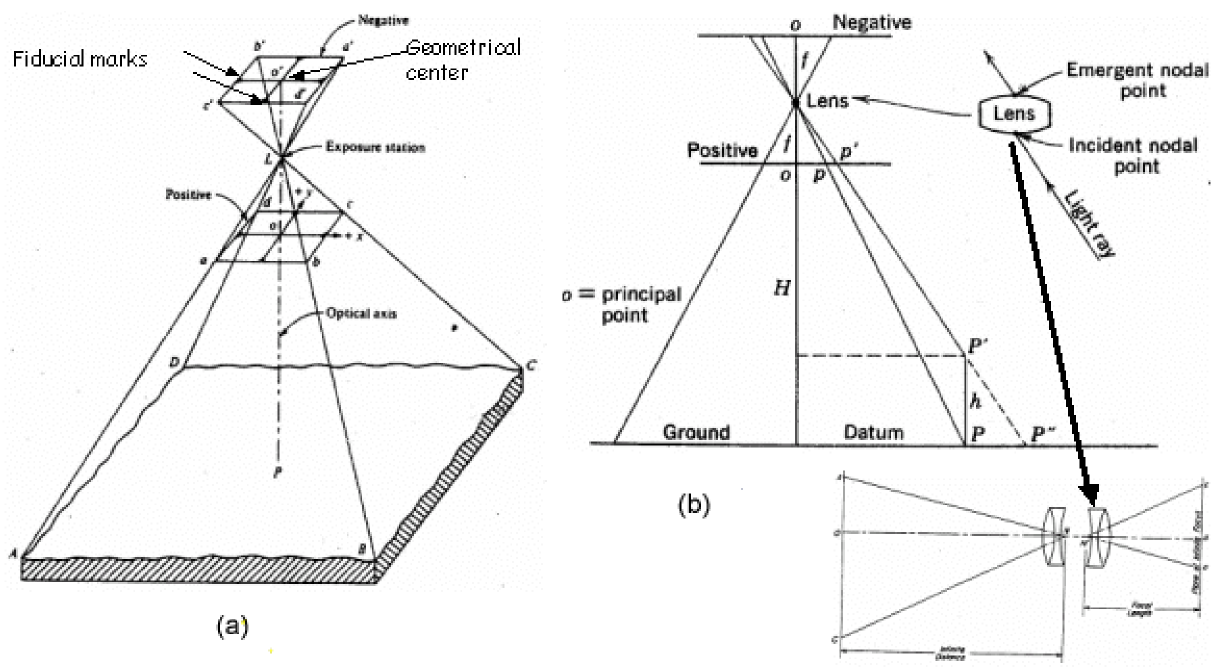
(b) Medium scale - 1 : 5000 to 1 : 30000, used for reconnaissance, preliminary survey and intelligent purpose.

(c) Large scale - 1 : 1000 to 1 : 5000, used for engineering survey, exploring mines.

(3). On the basis of angle of coverage

The angle of coverage is defined as the angle, the diagonal of the negative format subtendsat the real node of the lens of the apex angle of the cone of rays passing through the front nodal point of the lens.

Name	Coverage angle	Format size (cm)	Focal length (cm)
Standard or normal angle	60°	(i) 18 (ii) 23	(i) 21 (ii) 30
Wide angle	90°	(i) 18 (ii) 23	(i) 11.5 (ii) 15
Super wide or ultra wide angle	120°	(i) 18 (ii) 23	(i) 7 (ii) 8.8
Narrow angle	< 60°	-	-



Aerial photographs showing various elements as defined

(a) Elements of vertical photograph (b) Section of imaging geometry showing various elements

X-axis of photo: Line on photo between opposite collimation marks, which most nearly parallels the flight direction.

Y-axis: Line normal to x-axis and join opposite collimation marks

Principalpoint(o) The point where the perpendicular dropped from the front nodal point strikes the photograph or the point in which camera axis pierces the image plane.

Camera axis It is a ray of light incident at front nodal point in the object space and at right angles to the image plane.

Fiducial marks or collimation marks

Index marks usually four in number, rigidly connected with the camera lens through the camera body and forming images on the photographs to which the position on the photograph can be referred.

Photographs center The geometrical center of the photograph as defined by the intersection of the lines joining the fiducial marks.

Format: It is the planar dimension of photograph (9" x 9", 7" x 7", 23 cm x 23 cm, 18 cm x 18 cm, 15 cm x 15 cm).

Photogram Photograph taken with a photogrammetric camera having fixed distance between negative plane and lens and equipped with fiducial or collimating marks. For photograms the bundle of rays on the object side at the moment of exposure can be reproduced. To achieve this the following data known as the elements of interior orientation must be known:

- Calibrated focal length
- Lens distortion data
- Location of the principal point with reference to the photograph center (normally these two coincide)

Hence, a photogram is a photograph with known interior orientation

Difference between near vertical photographs and map

Production: Quickest possible and most economical method of obtaining information about areas of interest. Boon for difficult areas. Enlarging and reducing easier in case of photographs than maps.

Content: Map gives an abstract representation of surface with a selection from nearly infinite number of features on ground. Photograph shows images of surface itself. Maps often represent non-visible phenomenon this may make interpretation difficult for photograph. Special films like color and infrared films can bring about special features of terrain.

Metric accuracy: Map is geometrically correct representation, photos are generally not. Maps are orthogonal projections, photo is central projection. Map has same scale throughout photo has variable scale. Bearing on photographs may not be true.

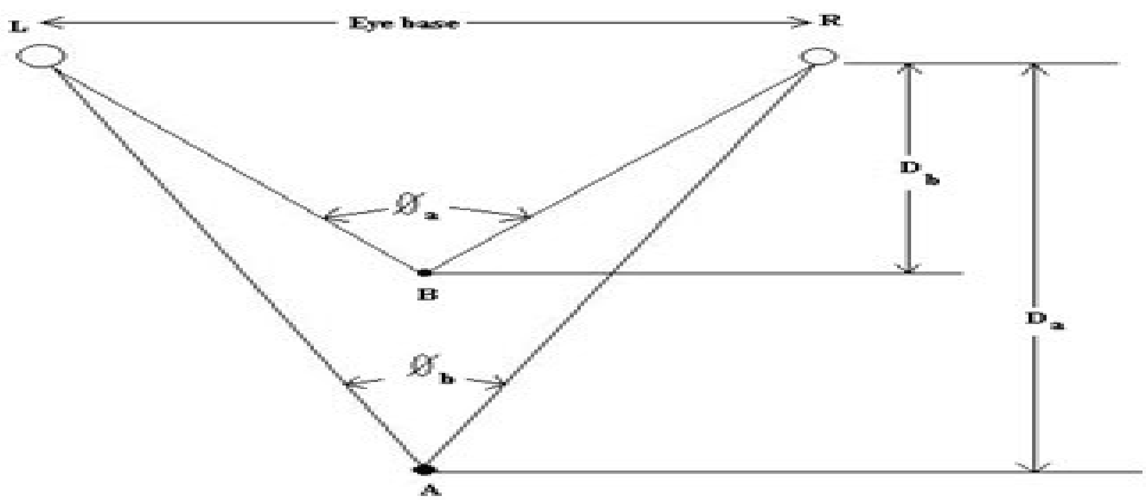
Training requirement: A little training and familiarity with the particular legend used in the map enables proper use of map. Photo-interpretation requires special training although initially it may appear quite simple as it gives a faithful representation of ground.

Definition of Stereoscopy

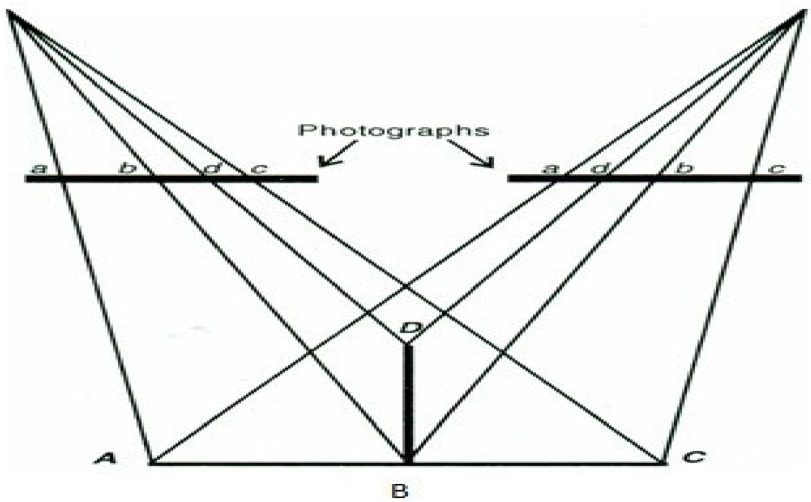
Stereoscopy, sometimes called stereoscopic imaging, is a technique used to enable a three dimensional effect, adding an illusion of depth to a flat image. In aerial photography, when two photographs overlap or the same ground area is photographed from two separate position forms a stereo-pair, used for three dimension viewing. Thus obtained a pair of stereoscopic photographs or images can be viewed stereoscopically. A stereoscope facilitates the stereoviewing process by looking at the left image with the left eye and the right image with the right eye. It is based on Porro-Koppe's Principle that the same light path can be generated in an optical system if a light source is projected onto the image taken by an optical system. Stereoscopic vision is constructed with a stereopair images using the relative orientation or tilt at the time of photography. Stereo viewing allows the human brain to judge and perceive in depth and volume. 3D representation of the earth's surface resulting in the collection of the geographic information with a greater accuracy compared to the monoscopic techniques.

Stereoscopic Vision

On our daily life we unconsciously perceive and measure depth using our eyes. This stereo effect is possible because we have two eyes or binocular vision. The perception of depth through binocular vision is referred to as stereoscopic viewing, which means viewing an object from two different locations. Monoscopic or monocular vision refers to viewing surrounding objects with only one eye. Depth is perceived primarily based on the relative sizes of objects, shadow; distant objects appear smaller and behind closer objects. In stereoscopic vision, objects are viewed with both eyes a little distant from each other (approximately 65 mm) helps in viewing objects from two different positions and angles, thus a stereoscopic vision is obtained. The angle between the lines of sight of two eyes with each object known as parallactic angle helps our brain in determining the relative distances between objects. Lesser the parallactic angle higher the objects depth. shows the human stereoscopic vision, parallactic angle $\emptyset_a > \emptyset_b$, helps the brain automatically to estimate the differences (D_a - D_b) in depths between the objects A and B. This concept of distance estimation in stereoscopic vision is applied to view a pair of overlapping aerial photograph.


L
Eye base
R
Ø a
B
D b
D a
Ø b
A

As an example, in two photographs overlap the same region, in which objects *A, B* and *C* are situated at the same altitude and object *D*ata different altitude, the four objects will be observed in a different sequence in the two photographs *a, b, d, c* in the left photograph and a, d, b, c in the right . In the same photograph, segments ab and bc are equal since they are at the same altitude, but segments ad and dc are not

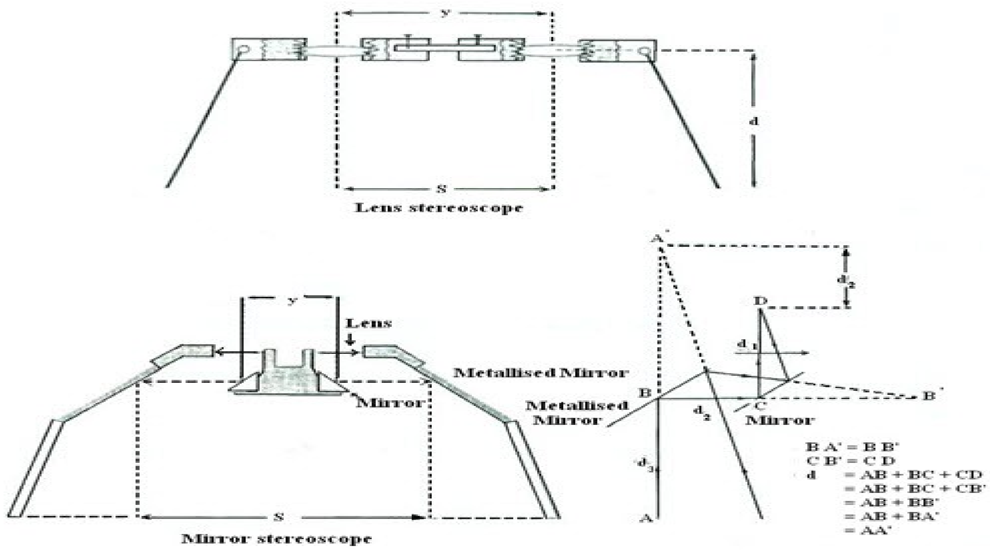


Perception of relief from two aerial photographs.

Stereoscopes

A stereoscope is used in conjunction with two aerial photographs taken from two different positions of the same area, (known as a stereo-pair) to produce a 3-D image. There are two types of stereoscopes: lens (or pocket) stereoscope and mirror stereoscope. Lens (or pocket) stereoscope has a limited view and therefore restricts the area that can be inspected where as in mirror stereoscope has wide view and enables a much larger area to be viewed on the stereo-pair. The most obvious feature when using a stereoscope is the enhanced vertical relief. This occurs because our eyes are only 65mm apart, but the air photos may be taken at 100s of meters apart, hence the difference in exposures is far greater than the difference between our eyes. Such an exaggeration also enables small features to become quite apparent and easily viewed.

A stereoscopeconsists of a double optical system (lenses, mirrors, prisms, etc.) mounted on a rigid frame supported on legs. In this way distance d is fixed and kept the focal distance. Thus the optical system creates a virtual image at infinity and consequently stereoscopic vision is obtained without eyestrain.



Lens and mirror stereoscopes

A simple lens stereoscope is made up of two achromatic convex lenses. The focal length is equal to *d* corresponding to the height of the stereoscope above the plane on which the stereo pair is placed. The lens spacing (y) can allowed varying within 45 to 75 mm to accommodate individual eye spacing. The disadvantage of lens stereoscope is that the features just underneath the lens only are viewable but it has some magnification power. A mirror stereoscope comprises two metalized mirrors, two prisms, two lenses and two eyepieces having little or no magnification power. It enables viewing the optical part fixed on an arm and the photographic pairs are arranged on two different planes. They facilitate analyses of several stereo pairs consecutively without changing the arrangement in the whole overlap region compared to the lens stereoscope.

Fiducial marks - Index marks, usually 4, at the center point of each side of an air negative or photo. These are rigidly connected with the camera lens through the camera body—which forms images on the negative. Usually are a hairline, across, or a half-arrowhead.

Principal Point - optical or geometric center of the photograph - the intersection between the projection of the optical axis (i.e., the perpendicular to the center of the lens) and the ground. Can be located by the intersection of lines between opposite side/corner *fiducial marks*.

Nadir - The nadir, also called *vertical point* or *plumb point*, is the image of the intersection between the plumb line directly beneath the camera center at the time of exposure and the ground. The nadir is important because relief displacement is radial from this point and is a function of the distance of the displaced image from it. Unlike the principal point, there are no marks on the photograph that permit to locate the nadir.

Isocenter - The point on the photo that falls on a line halfway between the principal point and the Nadir point.