DATA CAPTURING USING PHOTOGRAMMETRY

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SCIENTIST

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(ORSAC)

What is Photogrammetry?

Photogrammetry

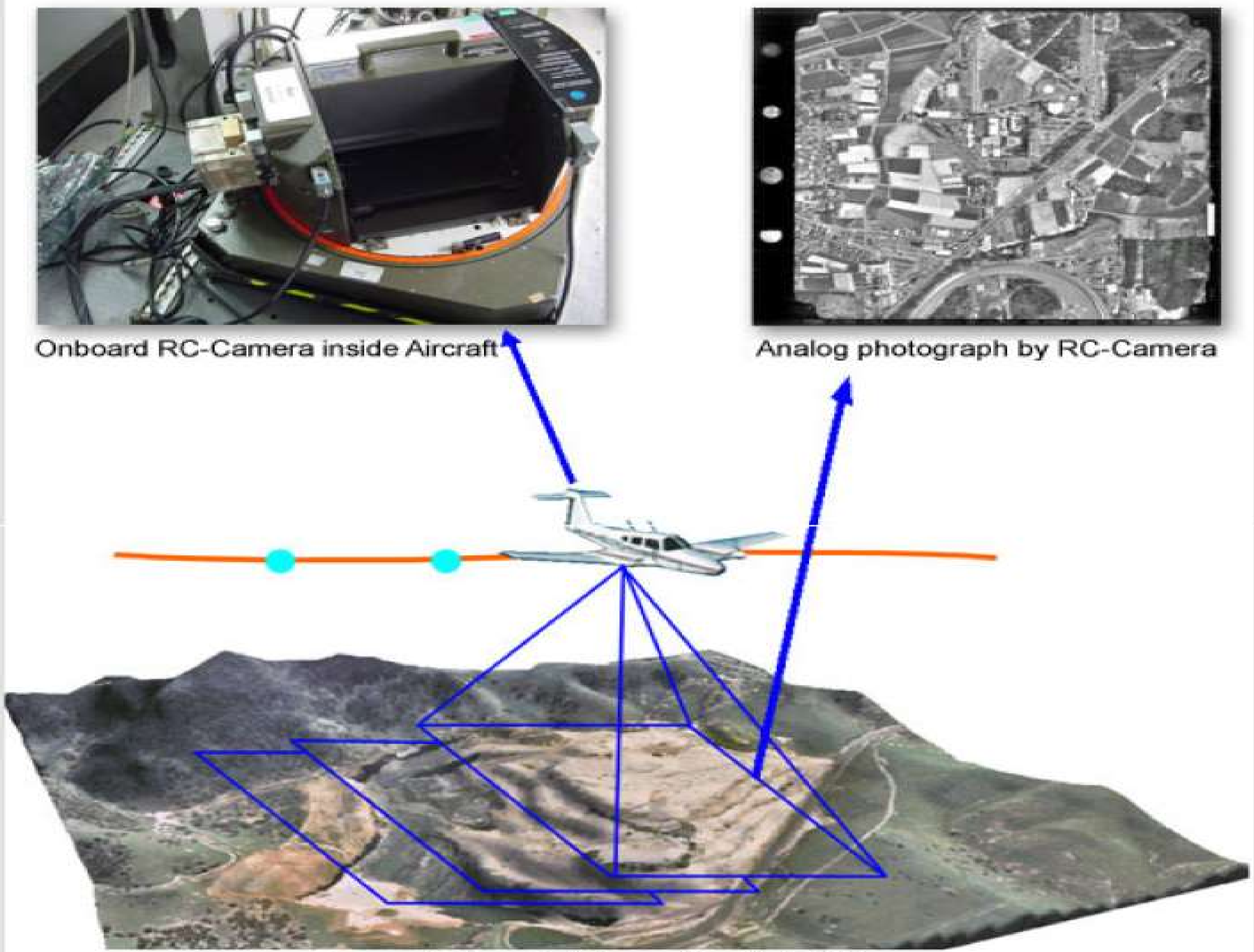
Photo : Light

Gram : To draw

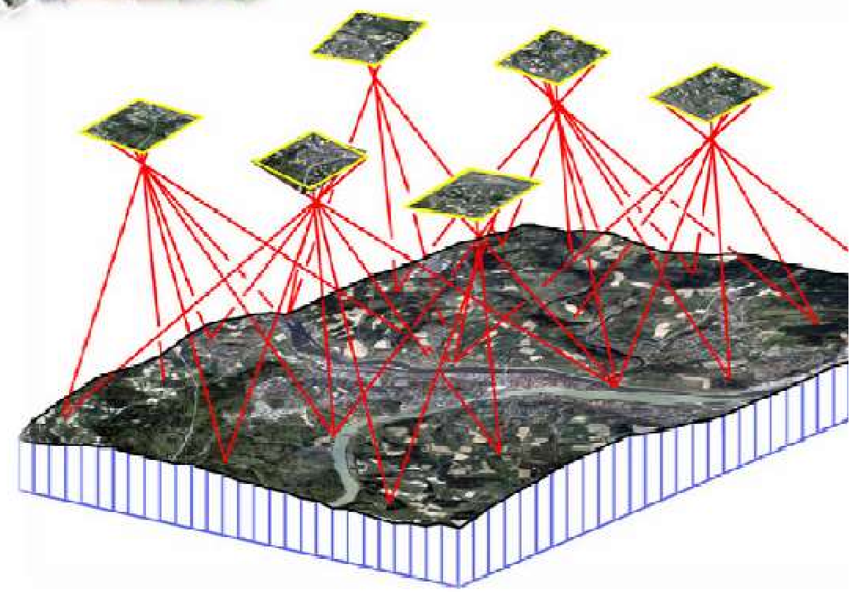
Metron : To measure

What is Photogrammetry?

- Photogrammetric surveying or photogrammetry is the branch of surveying in which maps are prepared from photo-graphs taken from ground or air stations.
- With the advancement of the photogrammetric techniques, photographs are being used for generation of resource maps in 2D and 3D.
- Is the science of making measurements from photographs, especially for recovering the exact positions of surface points.
- 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.



A general view of photographing by RC-Camera



Broadly Photogrammetry Requires:

- Planning & taking the photographs
- Processing the photographs
- Measuring the photographs & Reducing the measurement to produce end results.

Field Application of Photogrammetry :

- Used to conduct topographical survey or engineering surveys.
- Suitable for mountainous and hilly terrain with little vegetation
- Used for geological mapping which includes identification of land forms, rock type & rock structures.
- Used for projects demanding higher accuracy, since it provides accurate measurement.
- Used in urban and regional planning applications.
- Used mostly in Planning/designing in transport planning, bridge, pipeline, hydropower, urban planning, security and strategic planning, disaster management, natural resources management, city models, conservation of archaeological sites etc.
- Used for generation of 3D Datasets like Digital Elevation Model / Digital Surface Model.

Why Photogrammetry??

- Very precise
- Time effective
- Cost effective
- Based on well established and tested algorithms
- Less manual effort
- Corrects all sorts of distortions
- Provides a reasonable geometric modeling alternative when little is known about the geometric nature of the image data.

Why Photogrammetry??

- Provide an integrated solution for multiple images or photographs simultaneously

- Achieve a reasonable accuracy without a great number of GCPs.

- Create a three-dimensional stereo model or to extract the elevation information

Types of Photogrammetry

- Based on Camera Position
  - Terrestrial
  - Aerial
  - Satellite

- Based on Application
  - Interpretative
  - Metric

Close Range/ Terrestrial photogrammetry

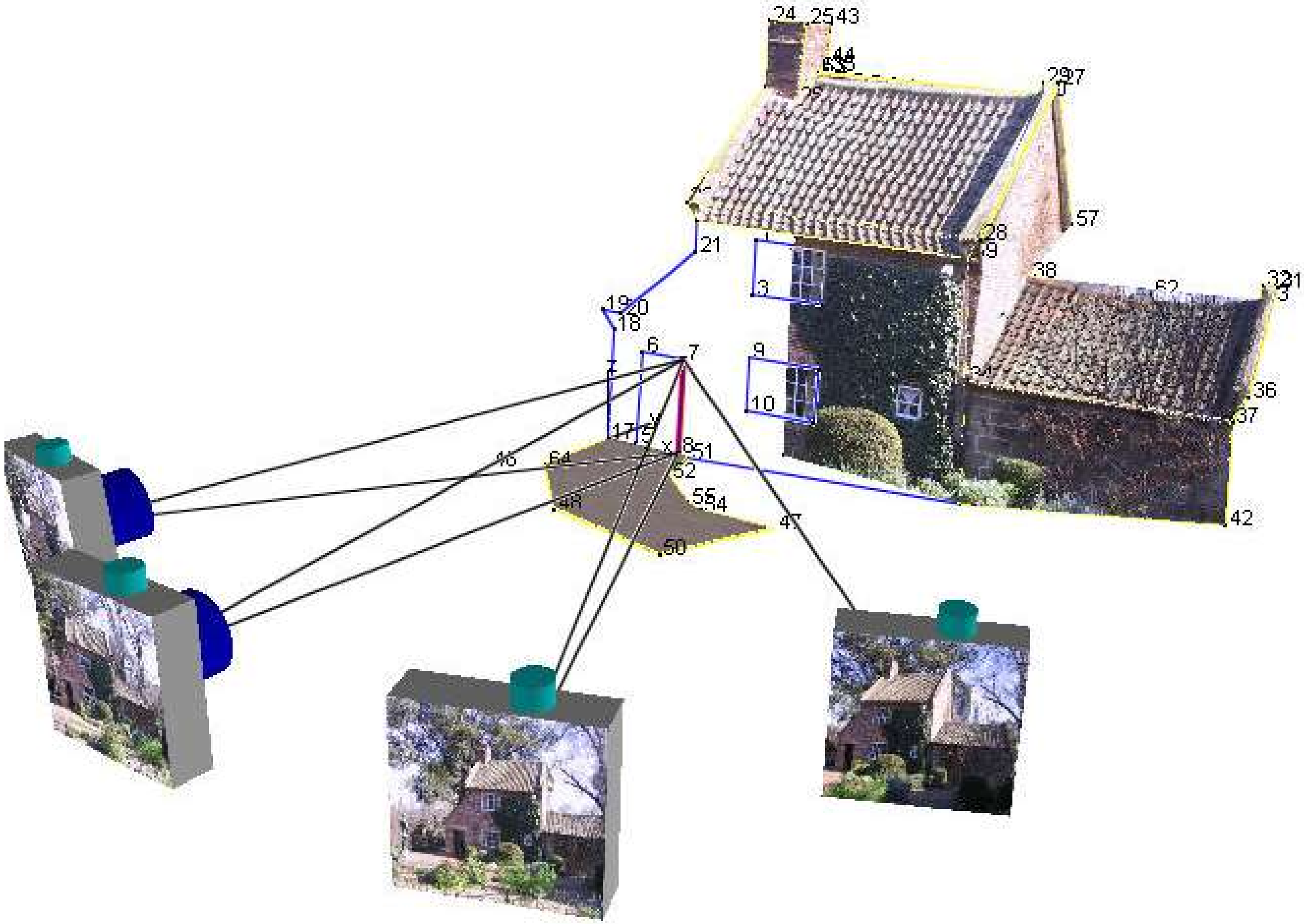


Photo Theodolite

Aerial Photogrammetry

AERIAL PHOTOGRAPHS

According to the direction of the camera axis at the time of exposure aerial photographs may be classified into:

- **Vertical photographs**
- **Oblique photographs**

Vertical photographs

- These photographs are taken from the air with the axis of the Camera vertical or nearly vertical .
- A truly vertical Photograph closely resembles a map.
- These are utilized for the compilation *of* topographic and engineering surveys on various scales.

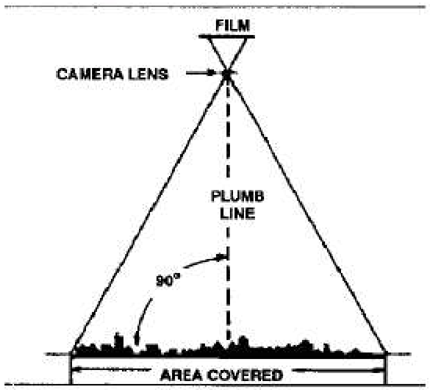
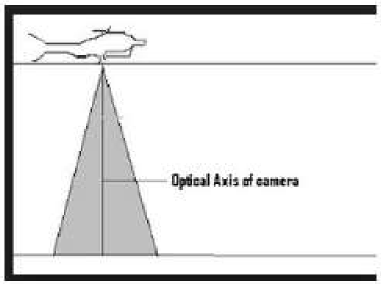
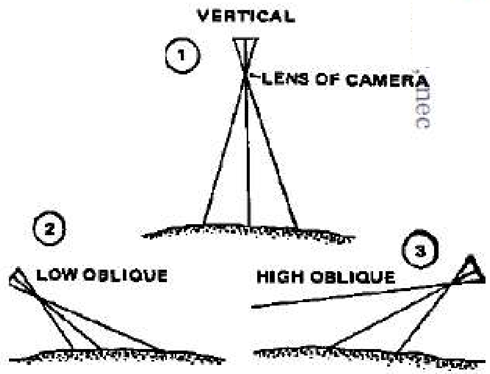
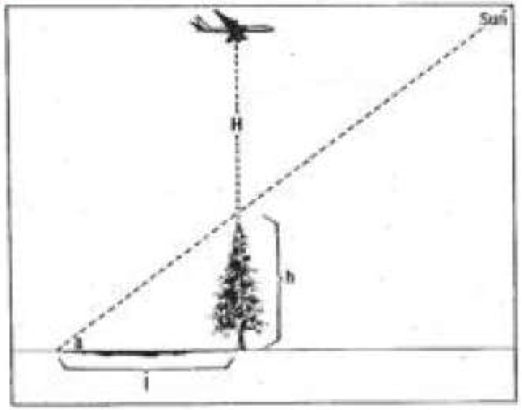
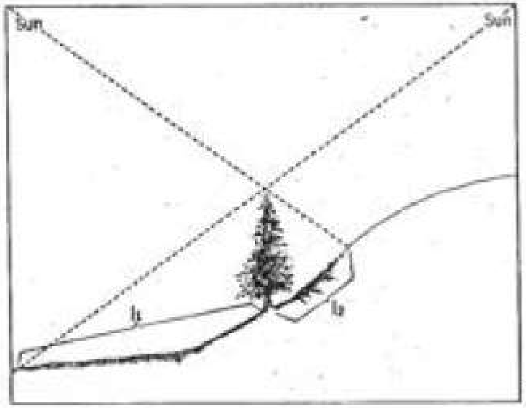


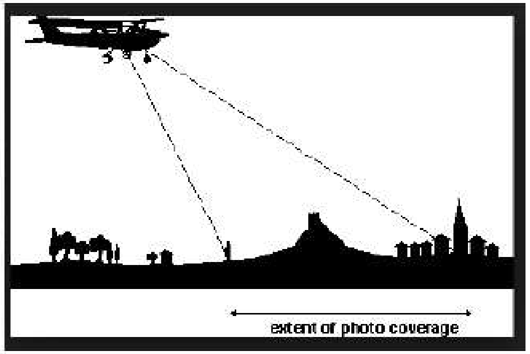
Figure 8-1. Relationship of the vertical aerial photograph with the ground.





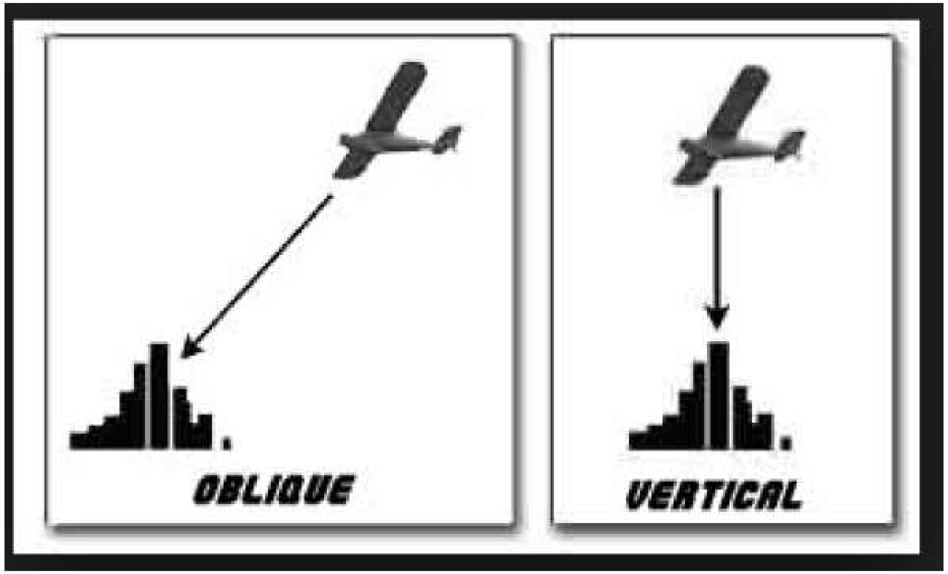


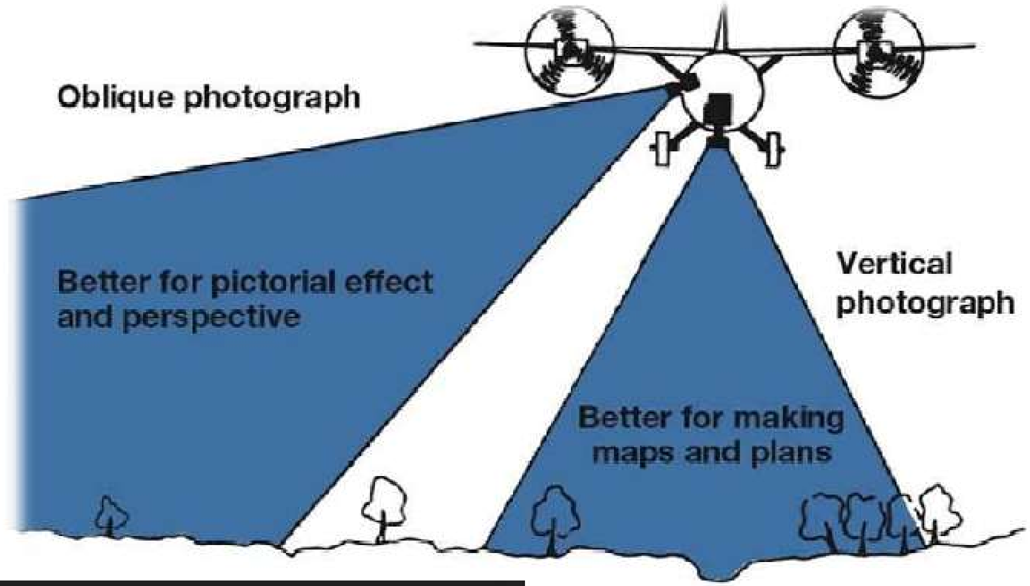


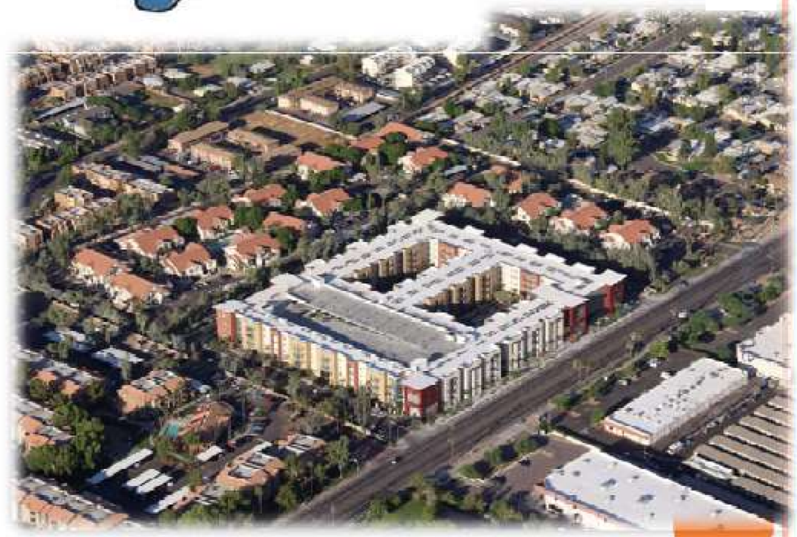


Vertical photographs

Oblique photographs





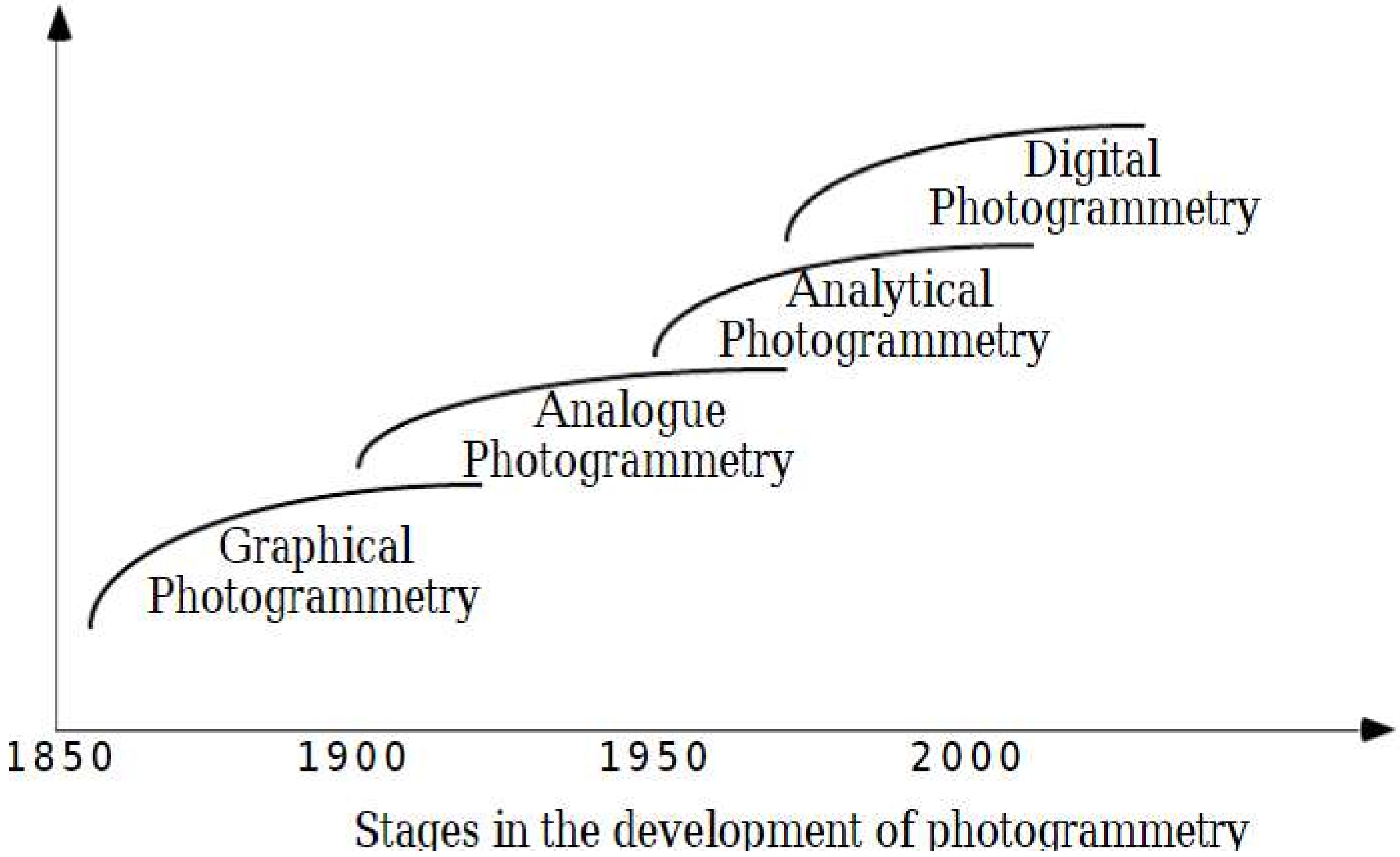


Vertical photo

OBLIQUE AERIAL PHOTOGRAPHY


405
73
55
John
Wayne
Airport
Vertical Photo
John
Wayne
Airport
55
73
405
Oblique Photo

Branches & Stages of Photogrammetry



Branches & Stages of Photogrammetry

GRAPHICAL PHOTOGRAMMETRY:

In the beginning, photogrammetric restitution was achieved by graphical constructions on a drawing board following the principles of descriptive geometry. The camera served as a photographic theodolite. Large image formats provided higher accuracy. This technique was widely used in architectural photogrammetry by the Royal Prussian Photogrammetric Institution in Berlin, founded in 1885 in order to preserve cultural monument.

Branches & Stages of Photogrammetry

ANALOGUE PHOTOGRAMMETRY:

In analogue photogrammetry, the imaging geometry is reconstructed through optical or mechanical devices. Two images can be oriented in such a way, that a three-dimensional model of the object is formed. A human operator can move a floating mark in this model and control this movement under stereoscopic vision. This enables to map directly structural lines of the object as well as contour lines. Through progress in optics and mechanics analogue photogrammetric instruments have been improved step by step in the course of many de-cades, and thus reached very high accuracy. During this stages of development photo-grammetry has been a technique to avoid calculations. The stereophotogrammetric plot of the bust of Queen Nofretete at the Egyptian Museum in Berlin is a typical example for the application of analogue techniques in close-range photogrammetry [Wölpert 1969].

Analogue Photogrammetry

The main product during this phase was topographic maps.

Branches & Stages of Photogrammetry

ANALYTICAL PHOTOGRAMMETRY:

Through the evolution of computers it became possible to develop the so-called analytical plotters. In such photogrammetric systems the relations between image points and object points are described through numerical calculations based on the collinearity equations. This offers high accuracy, great flexibility and efficiency, in particular since the systems support the operator during the orientation and restitution processes. Furthermore the results may be directly transferred into CAD systems [Albertz and Wiedemann 1995]. It is evident, that because of these advantages the analytical plotter replaced the analogue instruments more and more.

Analytical Photogrammetry

Outputs of analytical photogrammetry can be topographic maps, but can also be digital products, such as digital maps and DEMs

Branches & Stages of Photogrammetry

DIGITAL PHOTOGRAMMETRY:

The measurement of image coordinates in scanned images on the screen is the first step towards digital photogrammetry. Through the application of digital image data photogram-metry becomes a special field of digital image processing, providing still more flexibility and an enormous potential for automation. Digital stereophotogrammetric systems are already on the market or under development [Ebner et al., 1991]. Research activities at many institutions are devoted to the automation of orientation and photogrammetric restitution. How-ever, the already operational stereoscopic systems are well suited for aerial photogrammetry but not for close range application.

Digital Photogrammetry

The output products are in digital form, such as digital maps, DEMs, and digital orthophotos saved on computer storage media

AERIAL PHOTOGRAPH / CAMERA (PU2006)

An aerial camera consists of following essential parts

- lens assembly consists of lenses, the diaphragm, shutter and the filter.(Fig-6,8,9)
- Camera cone which supports the entire lens assembly including the filter. (fig - 5)
- focal (2) plane exactly above the collimation mark.
- camera body (3) provided at the top of cone which acts as an integral part to preserve the interior orientation.
- Drive mechanism which is housed in camera body & used for winding and tripping the shutter, operating the vaccum system for flattering the film, winding the film.
- The magazine (1) which holds the exposed and unexposed films & houses the film flattening device at the focal plane.

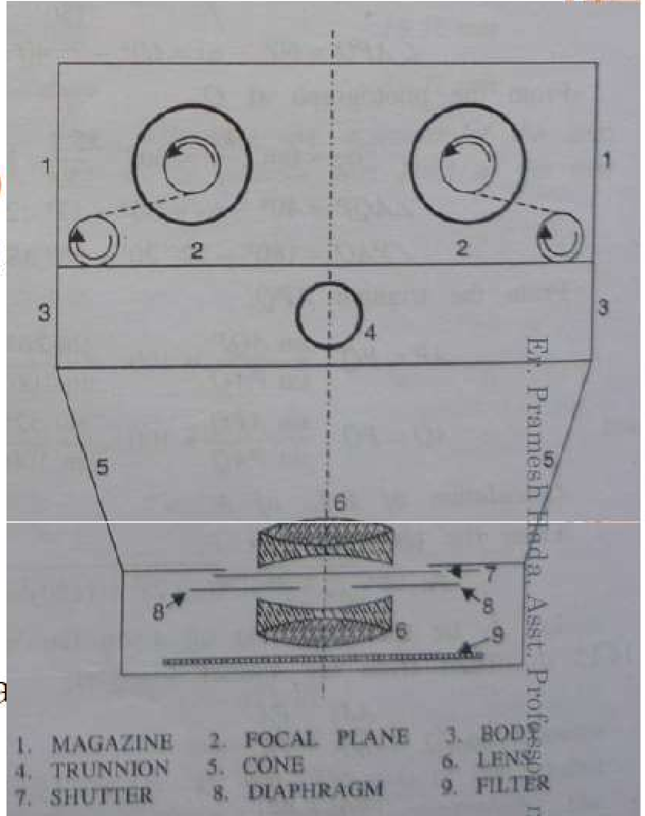


FIG. 14.16 SCHEMATIC DIAGRAM OF AERIAL CAMERA

[Japanese aerial cameras](#)

[Gowland Deluxe 4x5 Aerial Camera with Focus Tube](#)

There are three types of Aerial Camera :

- Super wide angle camera – f=100mm

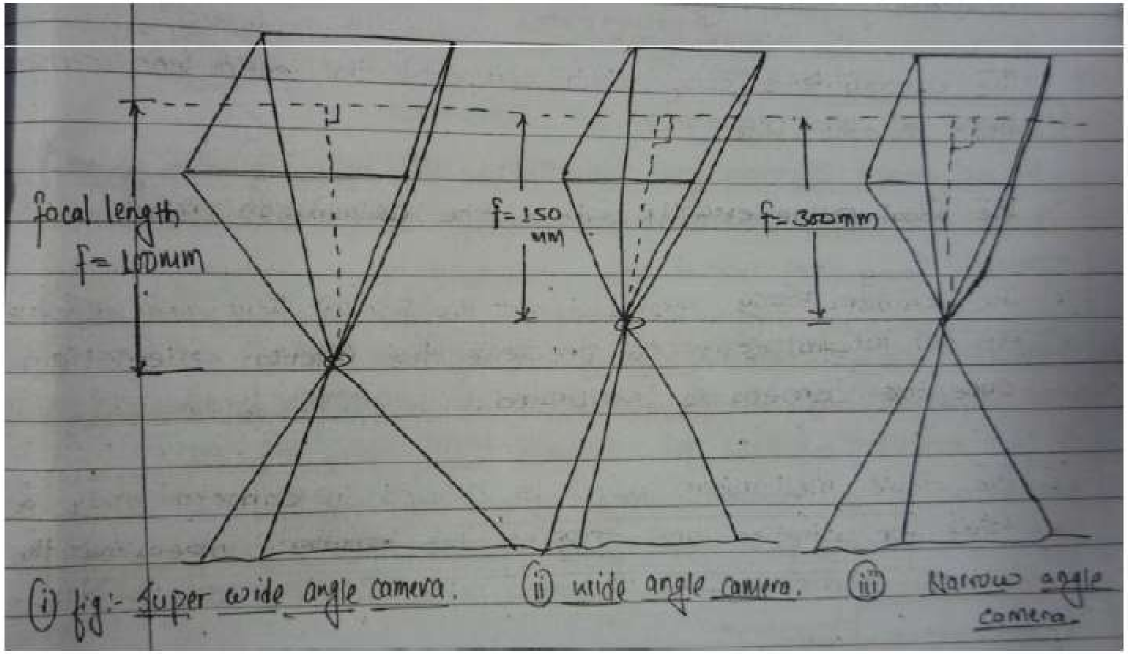
(used in flat areas like terai of nepal & in plain areas)

- Wide angle camera – f=150mm

(Used in hilly areas)

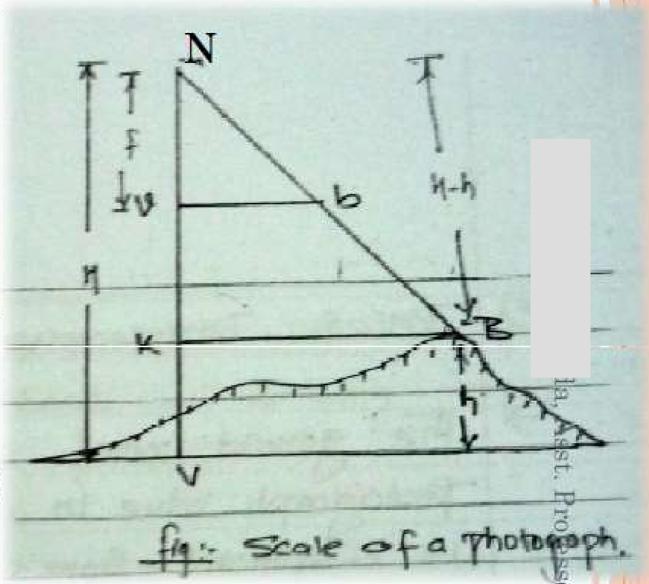
- Narrow angle camera – f=300mm

(Used in higher himalayas, sky scrappers & city like New york)



DETERMINATION OF A SCALE OF THE VERTICAL PHOTOGRAPH (PU 2004,2009,2010) IMP (NUMERICAL IMP)

- The scale of the vertical photograph is the ratio of a distance on the photo to the corresponding distance to the ground.
- Let N = Perspective centre
- H= flying height of the camera
- f = focal length of camera
- h= height of ground above mean sea level



Construction :

Draw BK perpendicular to NV meeting at K

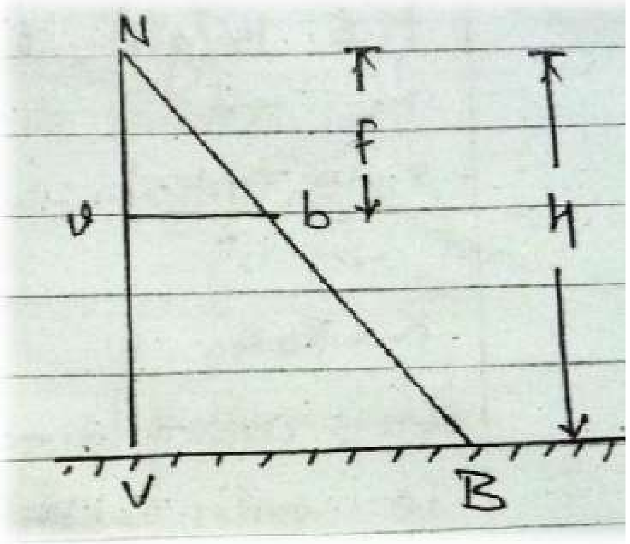
From similar triangles Nvb and NKB,

$$\frac{vb}{KB} = \frac{Nv}{NK} = \frac{f}{H-h}$$

- Scale of Photograph (S^A) = $\frac{f}{H-h}$

SCALE OF THE VERTICAL PHOTOGRAPH

- If the terrain is perfectly flat or plane at the mean sea level then , h=0,
- So, Scale of photograph = $\frac{f}{H}$



This shows, the scale of vertical photographs over the flat terrain is the ratio of the photo distance to the ground distance.

Note : Relation between Photoscale & Mapscale

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

Relief Displacement

- The scale of an aerial photograph is partly a function of flying height.
- Thus, variations in elevation cause variations in scale on aerial photographs.
- Specifically, the higher the elevation of an object, the farther the object will be displaced from its actual position away from the principal point of the photograph (the point on the ground surface that is directly below the camera lens).
- The lower the elevation of an object, the more it will be displaced toward the principal point. This effect, called relief displacement, is illustrated in the diagram below.
- Note that the effect increases with distance from the principal point.

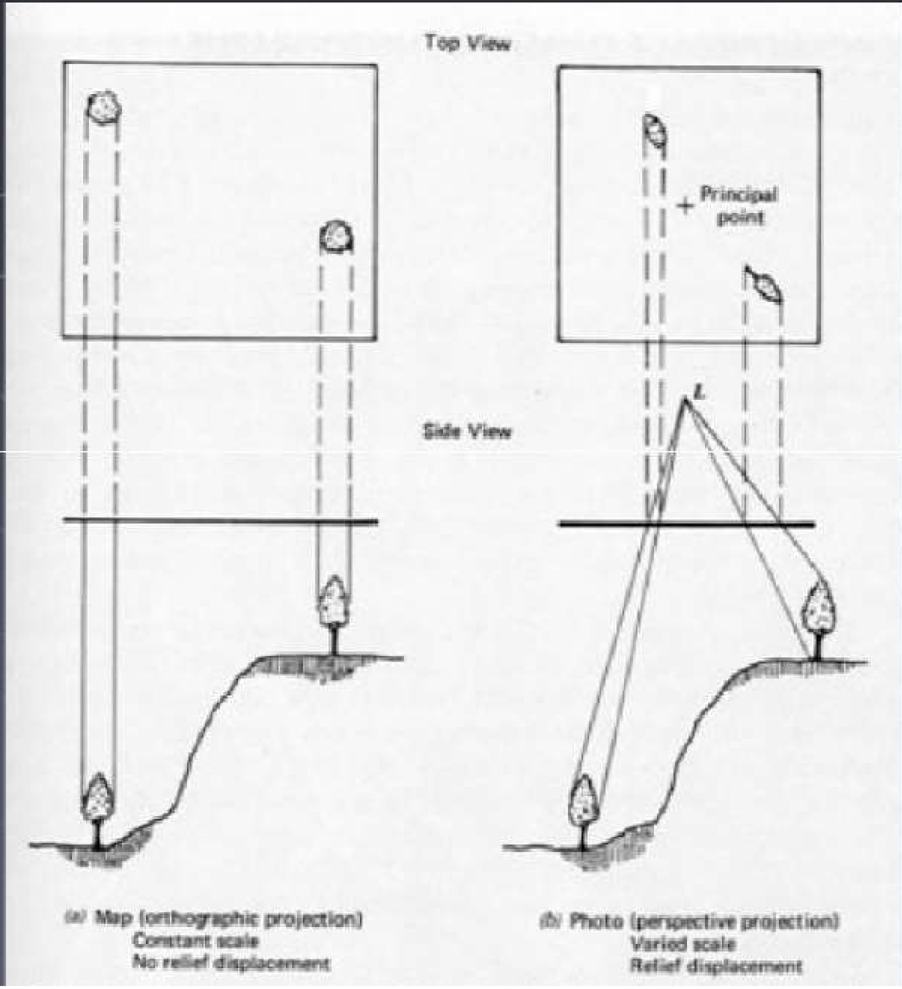
Relief Displacement

- It is the shift or displacement in the photographic position of an image caused by relief of the object i.e elevation above or below a selected datum

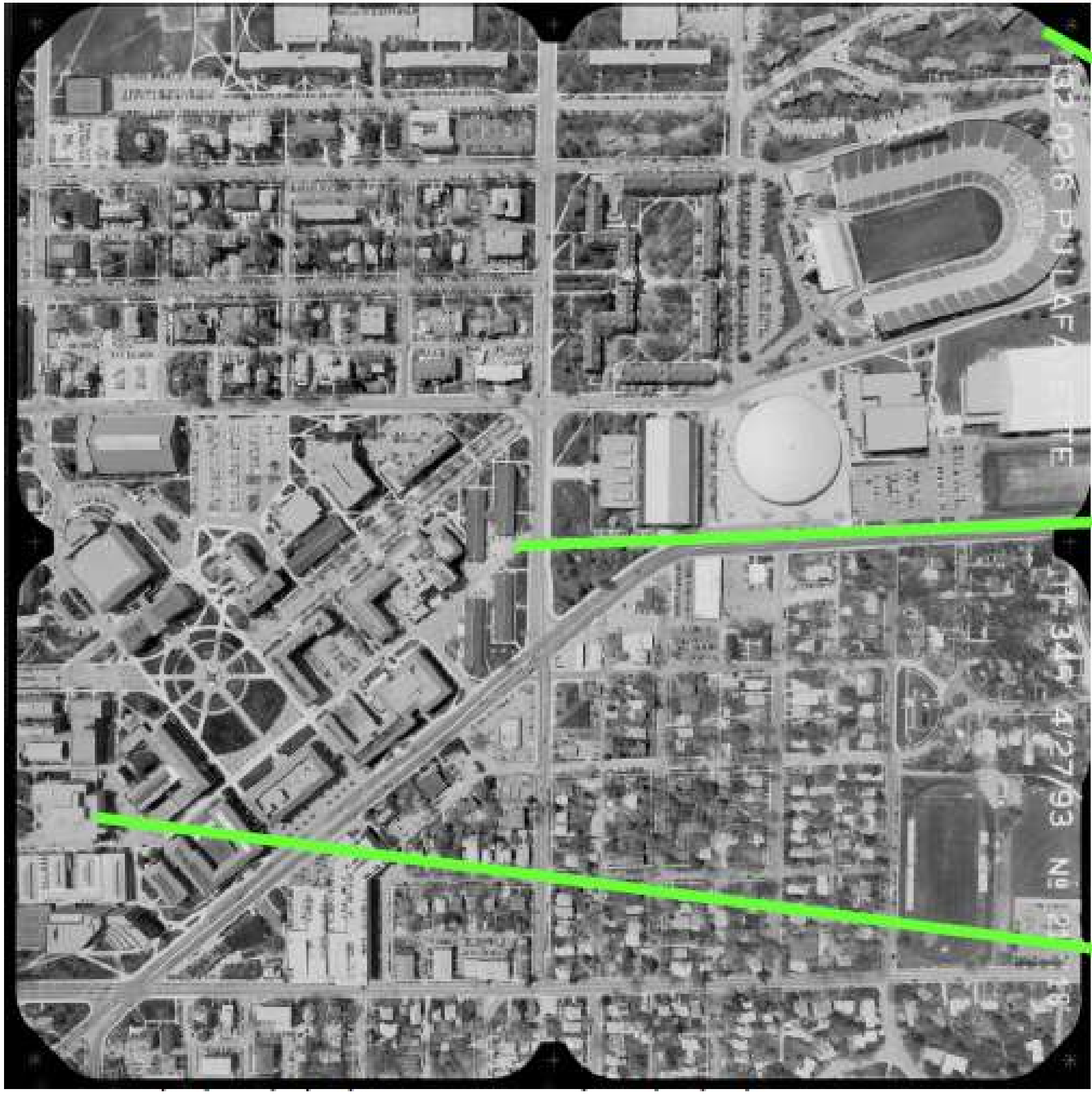
- Even though relief displacement constitutes a source of errors in measuring horizontal distances on vertical aerial photographs, it helps in determining the height of objects (or difference in elevation between objects) and viewing in 3- dimension by viewing stereoscopic pairs of aerial vertical photographs.

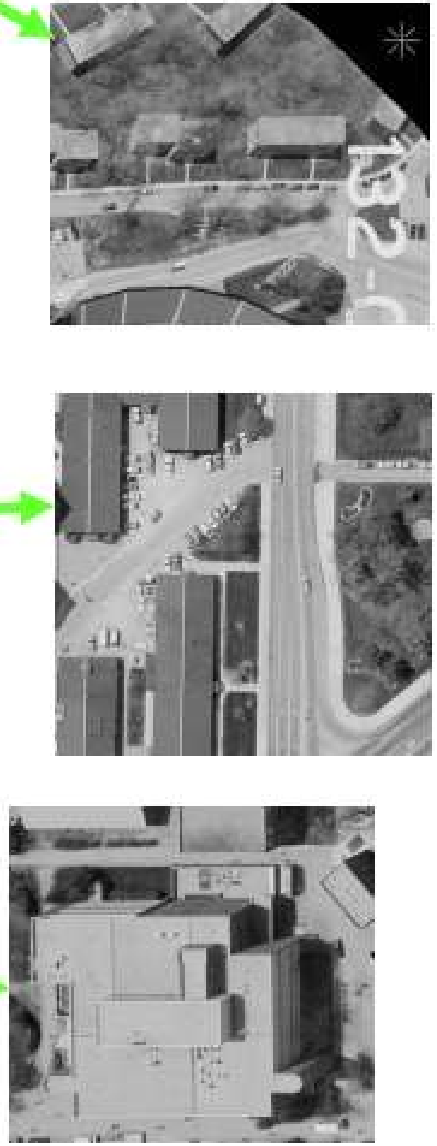
- Relief displacement on aerial vertical photographs also allows us to make topographic maps.

Relief Displacement



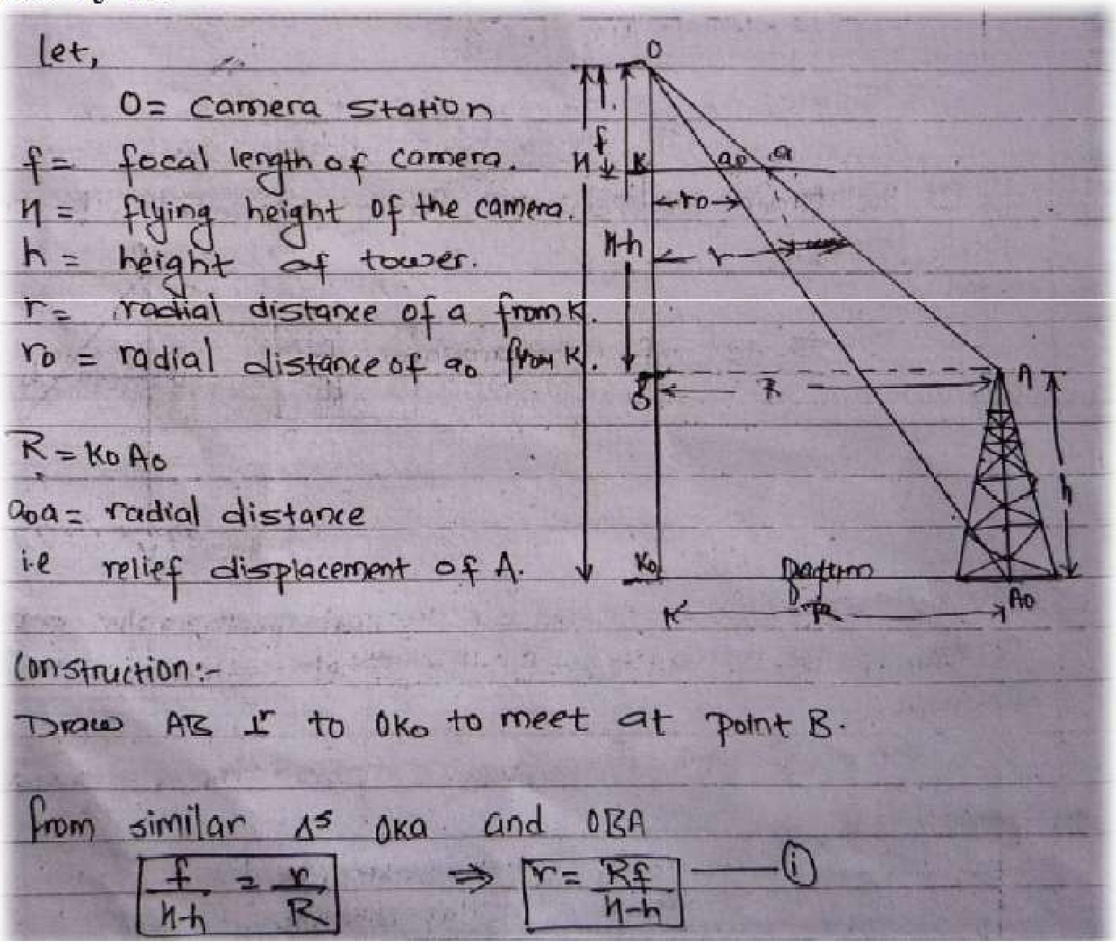
Relief Displacement





Determine an expression for determining the relief displacement on a vertical photograph

- Ground relief is shown in perspective on the photograph due to which every point on the photograph is displaced from their true orthographic position.
- This Displacement is called relief displacement.
- It is denoted by d.


let,

O = Camera station

f = focal length of camera.

H = flying height of the camera.

h = height of tower.

r = radial distance of a from K.

r_0 = radial distance of a_0 from K.

$R = K_0A_0$

a_0a = radial distance

i.e relief displacement of A.

Construction:-

Draw AB ⊥r to OK_0 to meet at point B.

From similar Δs OKa and OBA

$$\frac{f}{H-h} = \frac{r}{R} \Rightarrow r = \frac{Rf}{H-h} \quad \text{—— (i)}$$

Determine an expression for determining the relief displacement on a vertical photograph (

From similar Δs OKa_0 and OKA_0

$$\frac{f}{H} = \frac{r_0}{R}$$

$$\Rightarrow r_0 = \frac{Rf}{H} \quad \text{---} (2)$$

Hence, Relief displacement $(d) = r - r_0$

$$\text{or,} \quad d = \frac{Rf}{H-h} - \frac{Rf}{H}$$

$$\text{or,} \quad d = \frac{HRf - HRf + Rfh}{H(H-h)}$$

$$\text{or,} \quad d = \frac{Rfh}{H(H-h)} \quad \text{---} (3) \quad d = \frac{r_0 h}{(H-h)}$$

But, $R = \frac{r(H-h)}{f} = \frac{r_0 H}{f}$ [from eqn (1), (2)]

Substituting the value of R in eqn (3)

$$d = \frac{r(H-h)}{f} \times \frac{fh}{H(H-h)} = \frac{rh}{H}$$

$$\text{Also,} \quad d = \frac{r_0 H}{f} \times \frac{fh}{H(H-h)} = \frac{r_0 h}{(H-h)} \quad \text{---} (4)$$

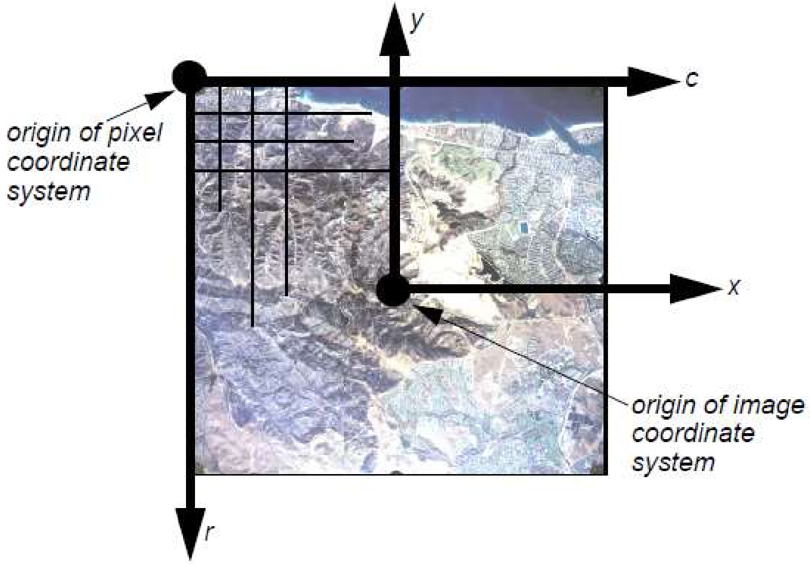
From eqn (3) and (4) we conclude that,

From equations (3) and (4) above, we conclude the following :

- Relief displacement increases as the distance from the principal point increases.
- Relief displacement decreases with the increase in the flying height.
- For point above datum, the relief displacement is positive being radially outward.
- For point below datum (having negative value), relief displacement is negative, being radially inward.
- Relief displacement of the point vertically below the exposure station is zero.

Type of Coordinate System

- Pixel Coordinate System
  - The file coordinates of a digital image are defined in a pixel coordinate system.
  - A pixel coordinate system is usually a coordinate system with its origin in the upper-left corner of the image,
  - the x-axis pointing to the right, the y-axis pointing downward, and the units in pixels, as shown by axes c and r

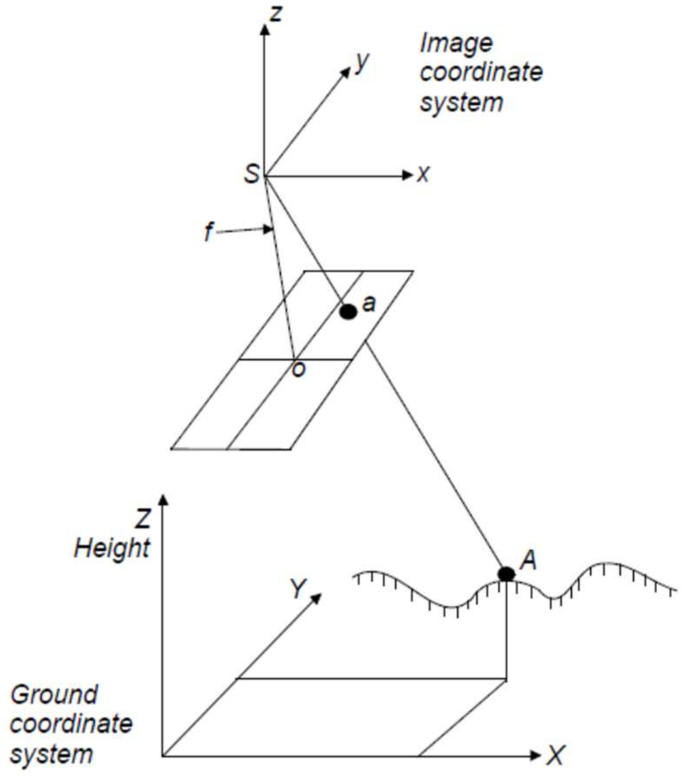


Type of Coordinate System

- Image Coordinate System
  - An image coordinate system or an image plane coordinate system is usually defined as a two-dimensional (2D) coordinate system occurring on the image plane with its origin at the image center.
  - The origin of the image coordinate system is also referred to as the principal point.
  - On aerial photographs, the principal point is defined as the intersection of opposite fiducial marks as illustrated by axes x and y.
  - Image coordinates are used to describe positions on the film plane. Image coordinate units are usually millimeters or microns.

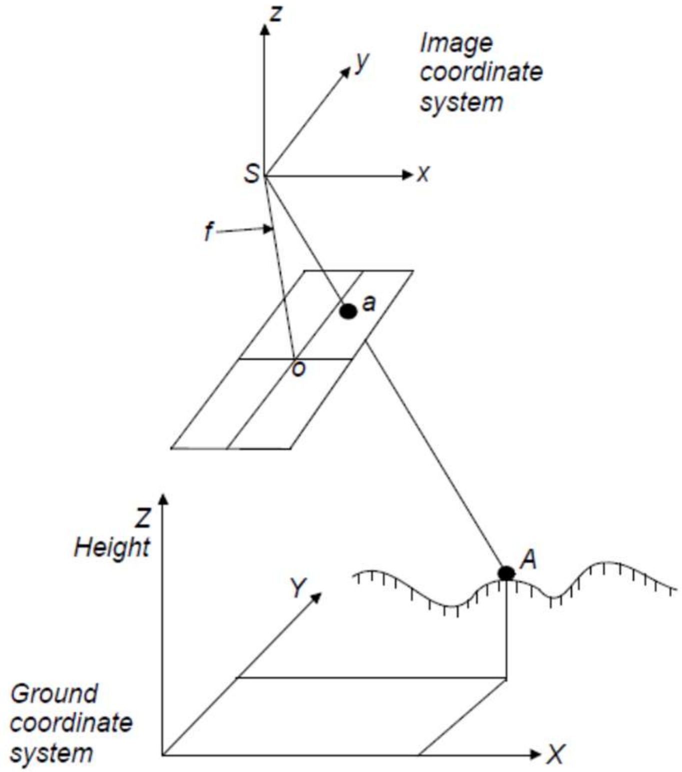
Type of Coordinate System

- Image Space Coordinate System
  - An image space coordinate system is identical to an image coordinate system, except that it adds a third axis (z) to indicate elevation.
  - The origin of the image space coordinate system is defined at the perspective center S.
  - The perspective center is commonly the lens of the camera as it existed when the photograph was captured.
  - Its x-axis and y-axis are parallel to the x-axis and y-axis in the image plane coordinate system. The z-axis is the optical axis, therefore the z value of an image point in the image space coordinate system is usually equal to -f (the focal length of the camera).
  - Image space coordinates are used to describe positions inside the camera and usually use units in millimeters or microns.



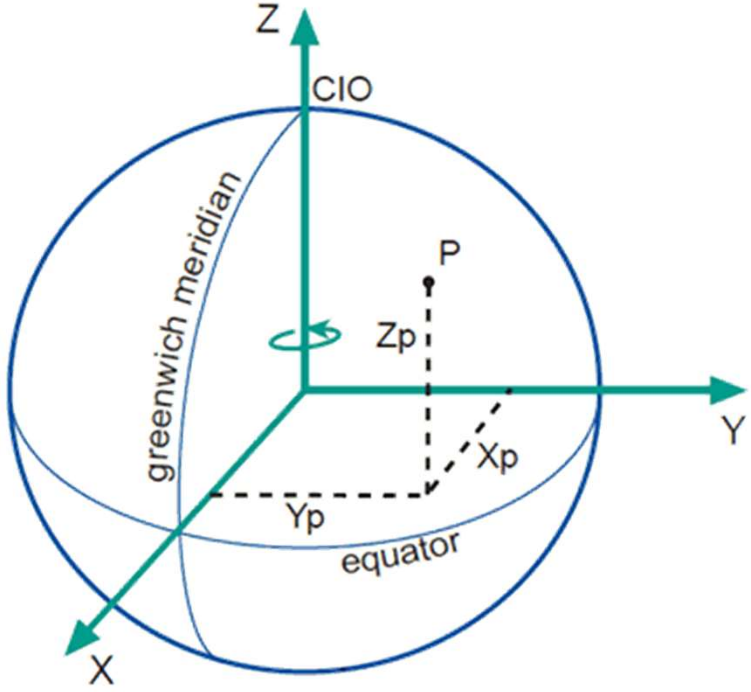
Type of Coordinate System

- Ground Coordinate System
  - A ground coordinate system is usually defined as a 3D coordinate system that utilizes a known geographic map projection.
  - Ground coordinates (X,Y,Z) are usually expressed in feet or meters.
  - The Z value is elevation above mean sea level for a given vertical datum.



Type of Coordinate System

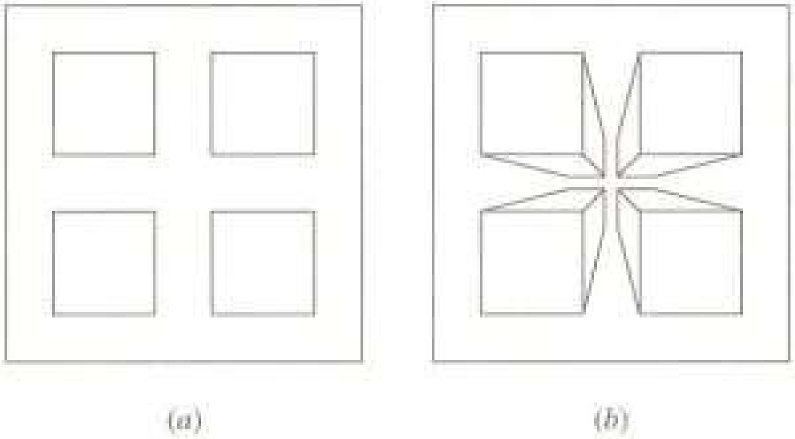
- Ground Coordinate System
  - Geocentric Coordinate System
    - A geocentric coordinate system has its origin at the center of the Earth ellipsoid.
    - The Z-axis equals the rotational axis of the Earth, and
    - the X-axis passes through the Greenwich meridian.
    - The Y-axis is perpendicular to both the Z-axis and X-axis,

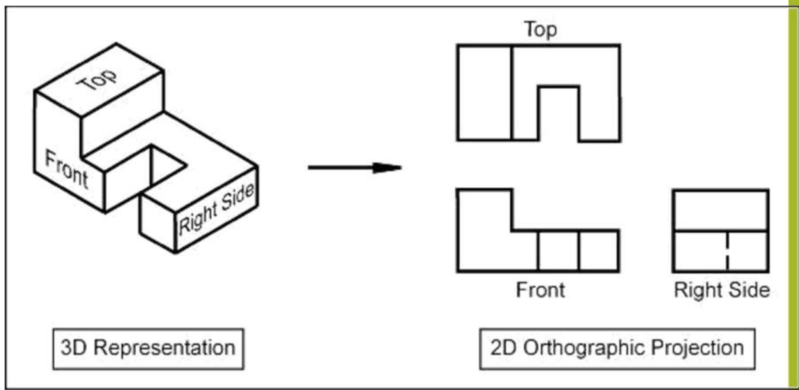


Ortho Photos

- An orthophoto is a photo reproduction that has been corrected for tilt, topographic displacement, and sometimes camera lens distortion.

- Orthophotos are produced from stereoscopic pairs of aerial photographs by a process called differential rectification so that the resulting photographic images are in a correct orthographic position.

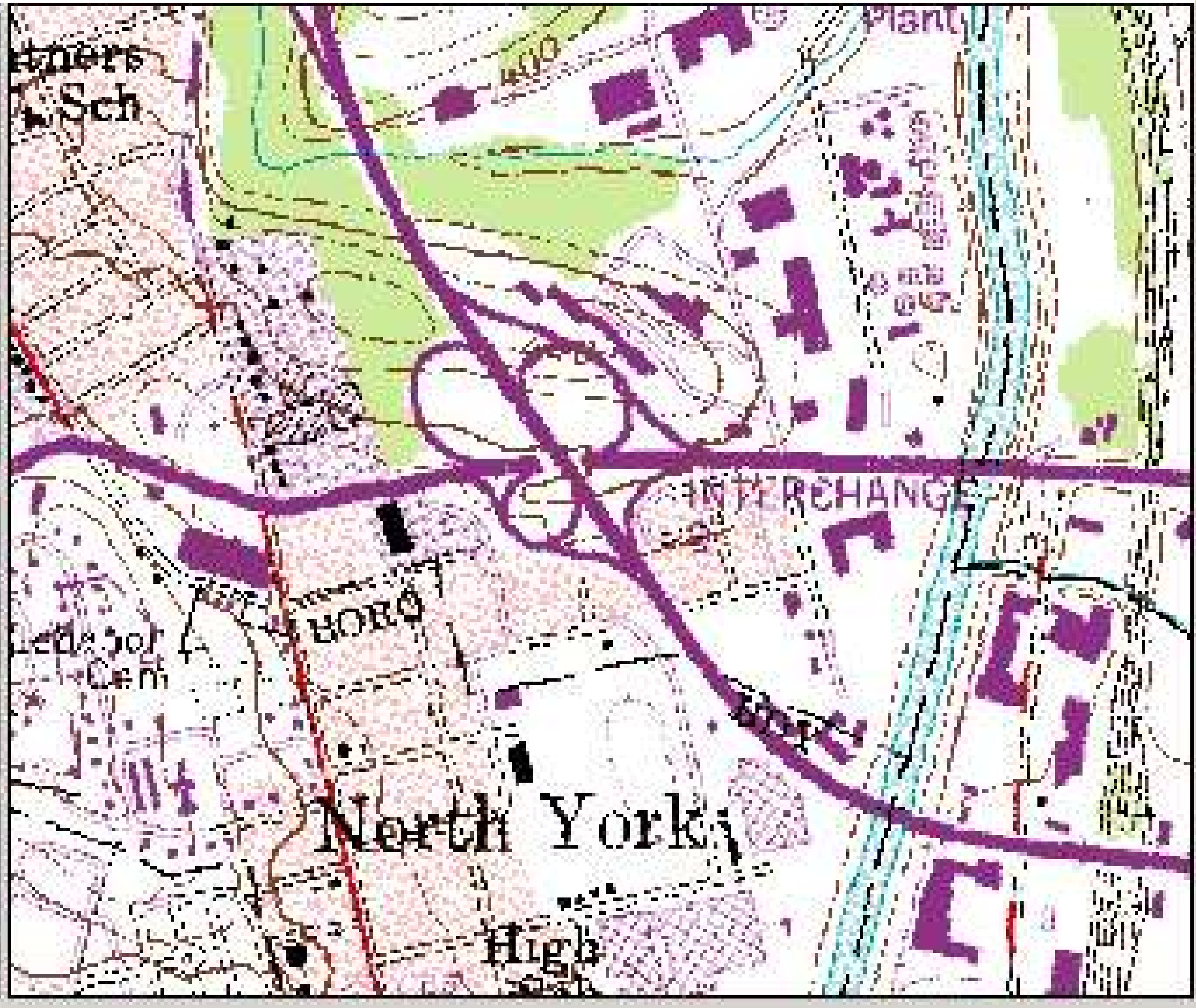




Ortho Photos

- Orthophoto are “best of both worlds”
- Orthophoto are used as best base map for GIS
- Orthophoto doesn’t have contour and so don’t convey topographic information
- But if contours information is overprinted on it is is known as “topographic orthophotomap”

Ortho Photos



Ortho Photos

Orthorectification

- Orthorectification generates planimetrically true orthoimages in which the displacement of objects due to sensor or camera orientation, terrain relief, and other errors associated with image acquisition and processing has been removed.

Orthorectification

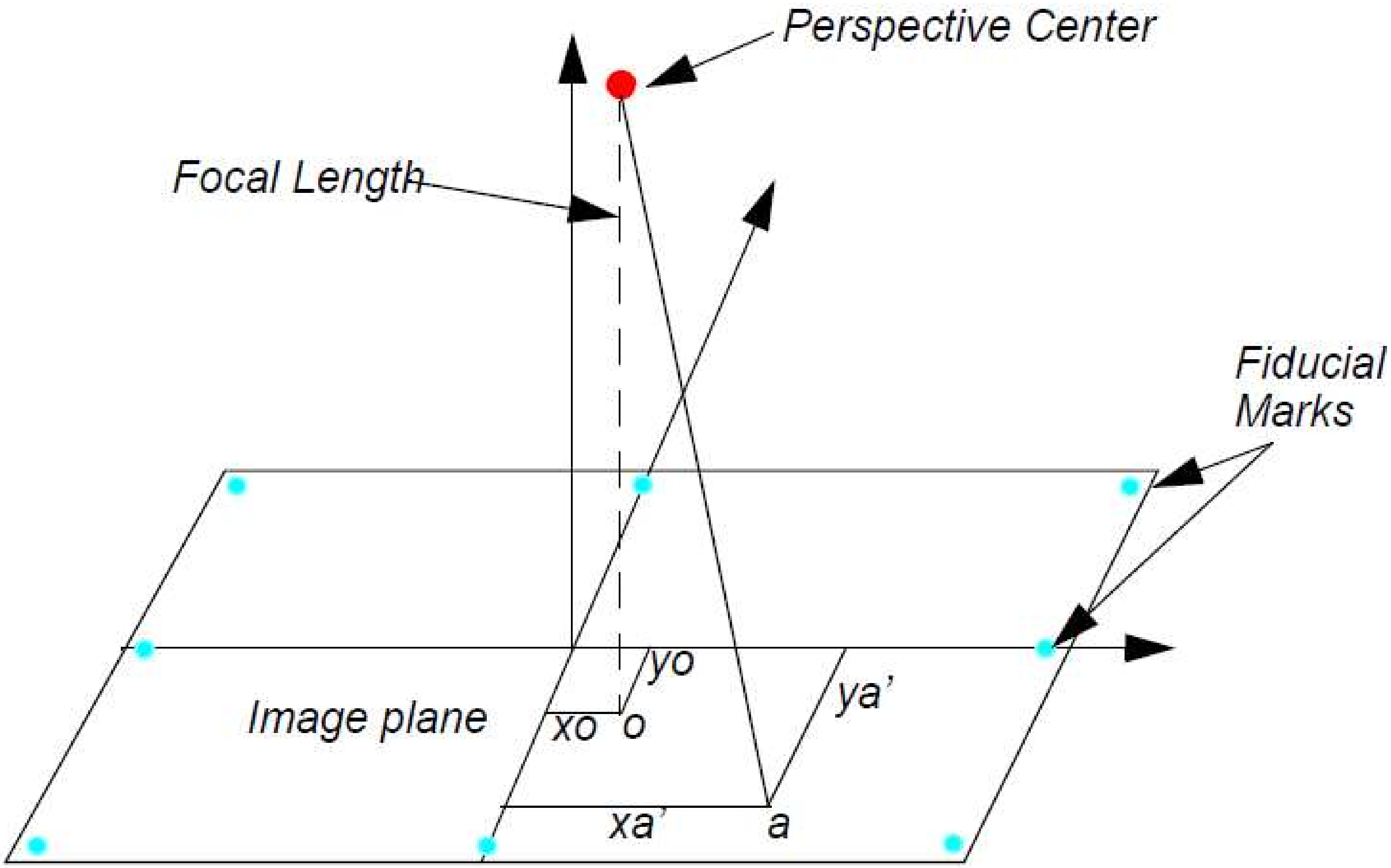
- Workflow of Photogrammetry
  - Orientation
    - Interior Orientation
    - Exterior Orientation
    - Relative Orientation
    - Absolute Orientation
  - Block Adjustment/ Bundle Block Adjustment
  - DEM Generation
  - DEM Editing
  - Orthophoto Generation

Orthorectification- Interior Orientation

- Interior orientation defines the internal geometry of a camera or sensor as it existed at the time of image capture

- Interior orientation is primarily used to transform the image pixel coordinate system or other image coordinate measurement system to the image space coordinate system.

Orthorectification- Interior Orientation



Orthorectification- Interior Orientation

- The measured image coordinates of the fiducial marks are referenced to a pixel or file coordinate system.
- The pixel coordinate system has an x coordinate (column) and a y coordinate (row).
- The origin of the pixel coordinate system is the upper left corner of the image having a row and column value of 0 and 0.
- Using a 2D affine transformation, the relationship between the pixel coordinate system and the image space coordinate system is defined

Orthorectification- Exterior Orientation

- Objective of EO is to establish a relationship between the digital image (pixel) co-ordinate system and the real world (latitude and longitude) co-ordinate system.

- It defines the position and angular orientation of the camera that captured an image.

- The variables defining the position and orientation of an image are referred to as the ***elements of exterior orientation***.

- The elements of exterior orientation define the characteristics associated with an image at the time of exposure or capture.

Orthorectification- Exterior Orientation

- The positional elements of exterior orientation include *Xo, Yo,* and *Zo.* They define the position of the perspective center (*O*) with respect to the ground space coordinate system (*X, Y,* and *Z*).

- *Zo* is commonly referred to as the height of the camera above sea level, which is commonly defined by a datum.

- Three rotation angles are commonly used to define angular orientation. They are ***omega (ω), phi (ϕ), and kappa (κ).***

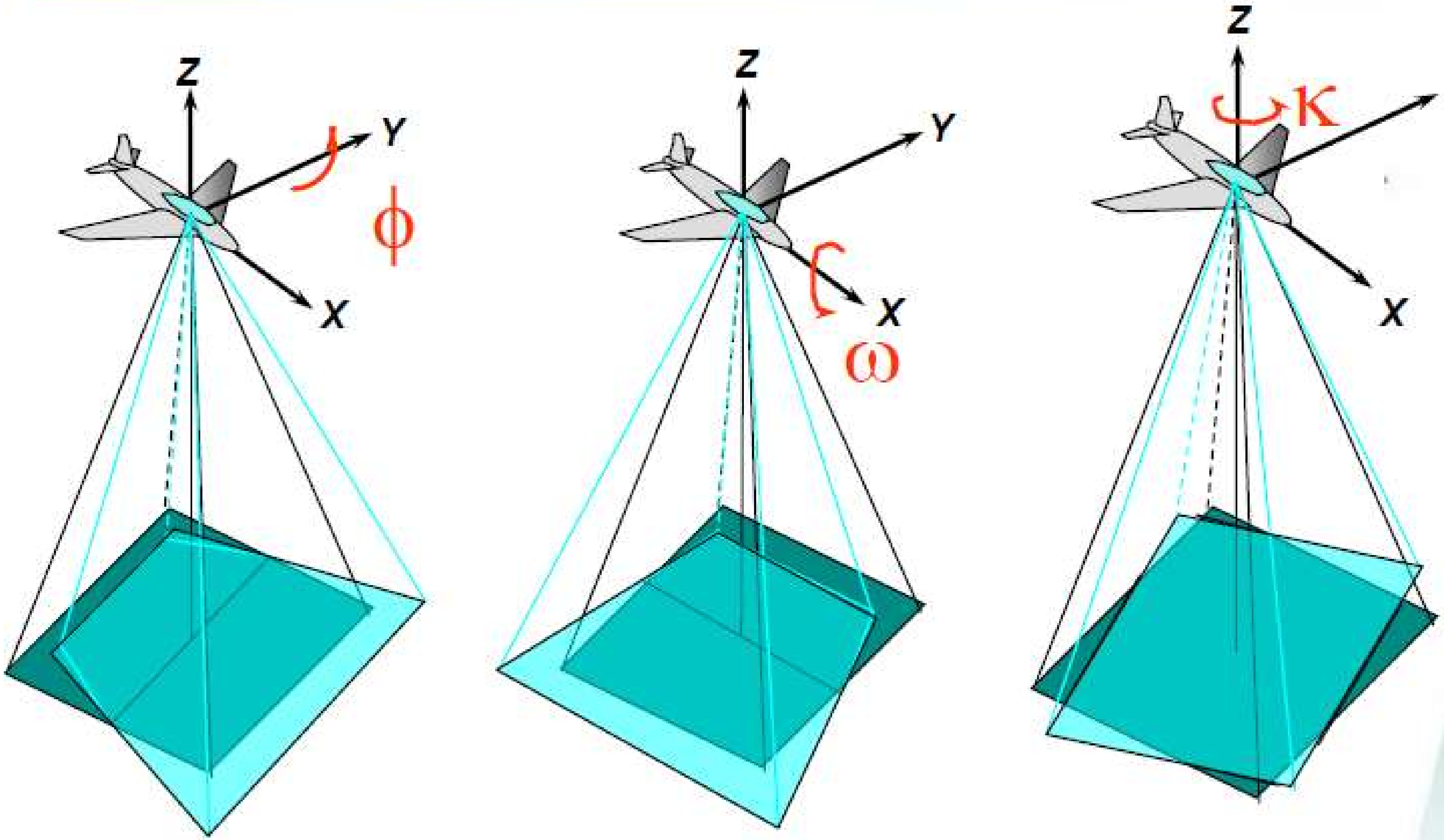
- Rotations are defined as being positive if they are counterclockwise when viewed from the positive end of their respective axis.

Orthorectification- Exterior Orientation

- The aircraft carries a camera or scanner and one or more GPS receivers tied to an inertial navigation system.

- As each frame is exposed precise information is captured (or calculated in post processing) on the x, y, z and roll, pitch, yaw of the aircraft

Orthorectification- Exterior Orientation



Rational Polynomial Functions

- Aerial photograph made with a framing camera captures each location in the image at same time from a single camera position.

- So coordinate transformation from 2-D image coordinates to 3-D Earth-surface coordinates can be expressed mathematically using relatively simple expressions.

- Remote sensing satellite images are built up of groups of scan lines acquired as the satellite moves forward in its orbit. So different parts of the same image are acquired from different sensor positions.

Rational Polynomial Functions

- Rational Polynomial satellite sensor models are simpler empirical mathematical models relating image space (line and column position) to latitude, longitude, and surface elevation.

- The name Rational Polynomial derives from the fact that the model is expressed as the ratio of two cubic polynomial expressions.

- A single image involves two such rational polynomials, one for computing line position and one for the column position.

- The coefficients of these two rational polynomials are computed by the satellite company from the satellite's orbital position and orientation and the rigorous physical sensor model.

GCP(Ground Control Point)

- The main component of establishing an accurate relationship between the images in a project, the camera/sensor, and the ground is GCPs.

- GCPs are identifiable features located on the Earth's surface whose ground coordinates in X, Y, and Z are known.

  - A full GCP has associated with it X, Y, and Z (elevation of the point) coordinates.

  - A horizontal GCP only specifies the X, Y coordinates.

  - A vertical GCP only specifies the Z coordinate.

GCP(Ground Control Point)

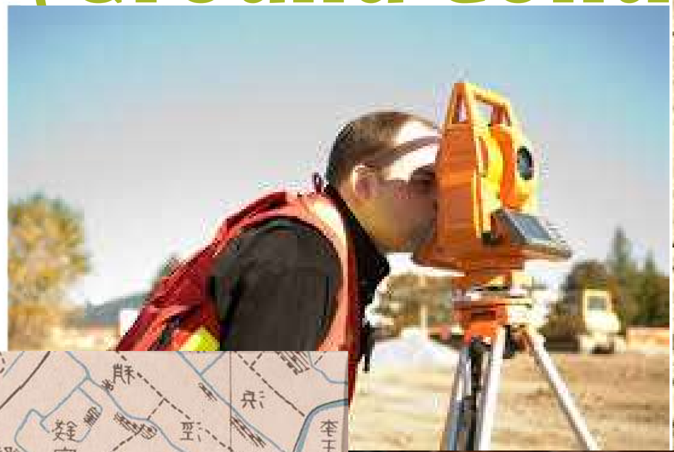
- The following features on the Earth's surface are commonly used as GCPs:
  - intersection of roads
  - utility infrastructure (e.g., fire hydrants and manhole covers)
  - intersection of agricultural plots of land
  - survey benchmarks

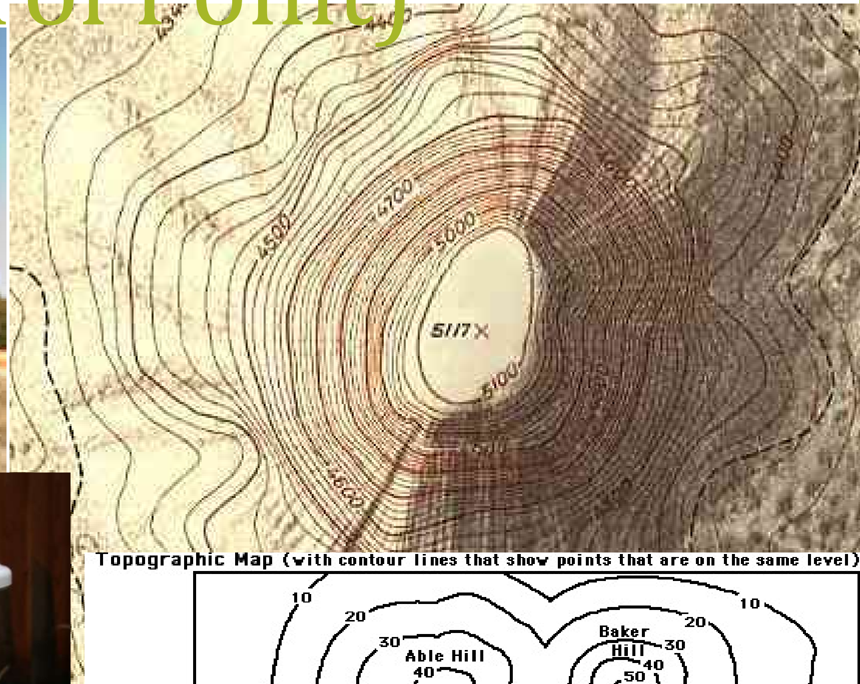
GCP(Ground Control Point)

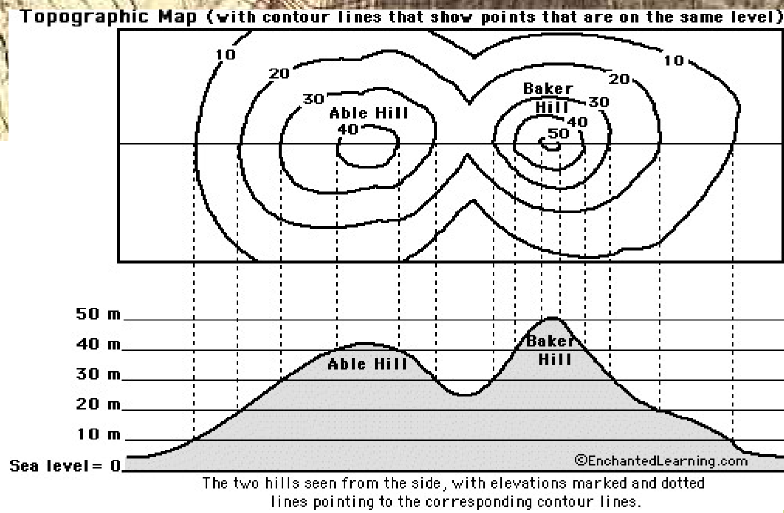
GCP(Ground Control Point)

- Depending on the type of mapping project, GCPs can be collected from the following sources:
  - theodolite survey (millimeter to centimeter accuracy)
  - total station survey (millimeter to centimeter accuracy)
  - ground GPS (centimeter to meter accuracy)
  - Planimetric and topographic maps (accuracy varies as a function of map scale, approximate accuracy between several meters to 40 meters or more)
  - digital orthorectified images (X and Y coordinates can be collected to an accuracy dependent on the resolution of the orthorectified image)
  - DEMs (for the collection of vertical GCPs having Z coordinates associated with them, where accuracy is dependent on the resolution of the DEM and the accuracy of the input DEM)

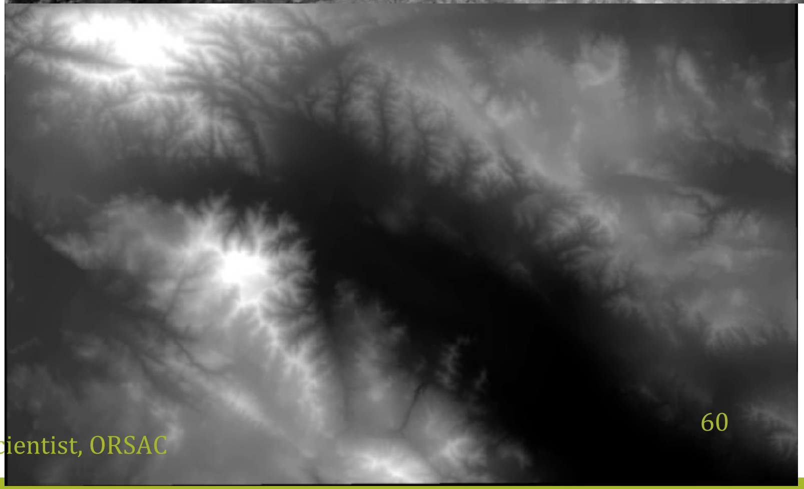
GCP(Ground Control Point)







GCP(Ground Control Point)



GCP(Ground Control Point)- Check Point

- A greater number of GCPs should be available than are actually used in the block triangulation.
- Additional GCPs can be used as check points to independently verify the overall quality and accuracy of the block triangulation solution.
- A check point analysis compares the photogrammetrically computed ground coordinates of the check points to the original values.
- The result of the analysis is an RMSE that defines the degree of correspondence between the computed values and the original values. Lower RMSE values indicate better results.

GCP Requirements

- To establishing a relationship between image space and ground space, the theoretical minimum number of GCPs is two GCPs having X, Y, and Z coordinates (six observations) and one GCP having a Z coordinate (one observation). This is a total of seven observations.

- To increase the accuracy of a mapping project, using more GCPs is highly recommended.

GCP Requirements- Single image

- When processing one image for the purpose of orthorectification (that is, a single frame orthorectification), the minimum number of GCPs required is three.

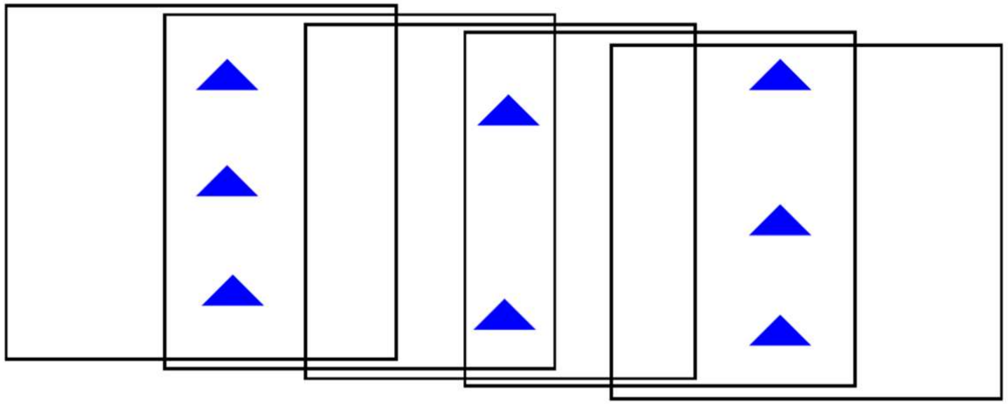
- Each GCP must have an X, Y, and Z coordinate associated with it.

- The GCPs should be evenly distributed to ensure that the camera/sensor is accurately modeled.

GCP Requirements- Multi Strip image

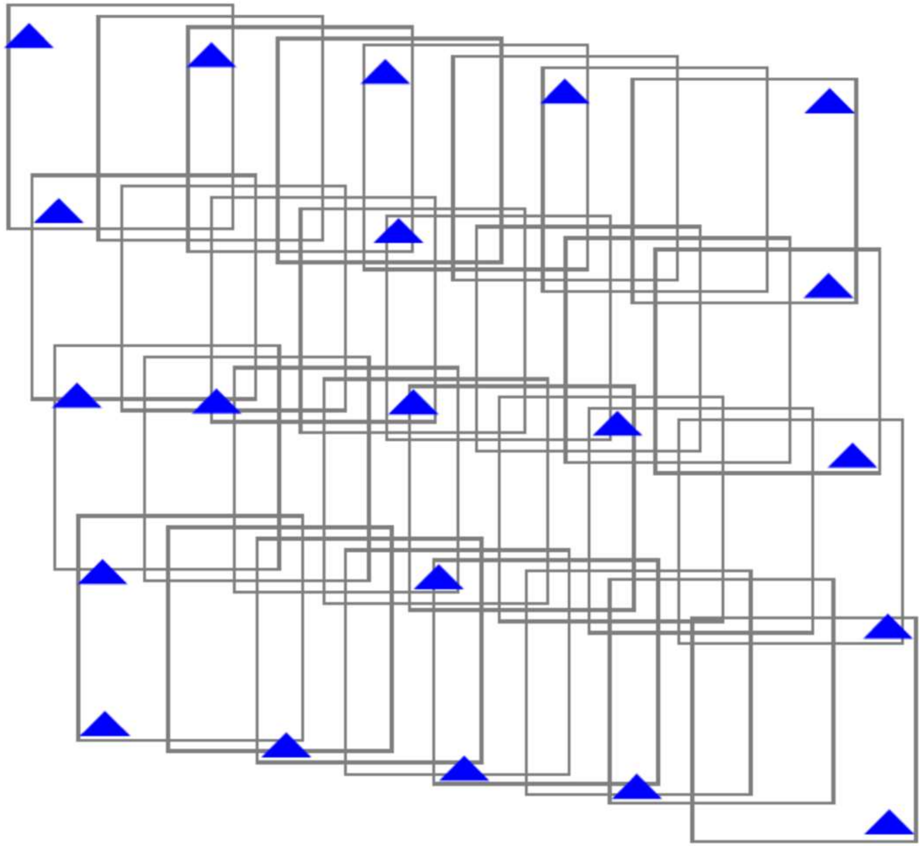
- When processing a strip of adjacent images, two GCPs for every third image are recommended.

- To increase the quality of Orthorectification, measuring three GCPs at the corner edges of a strip is advantageous.



GCP Requirements- Block image

- It is advantageous to have at least one GCP on every third image of a block.
-
- Additionally, whenever possible, locate GCPs that lie on multiple images, around the outside edges of a block and at certain distances from one another within the block.

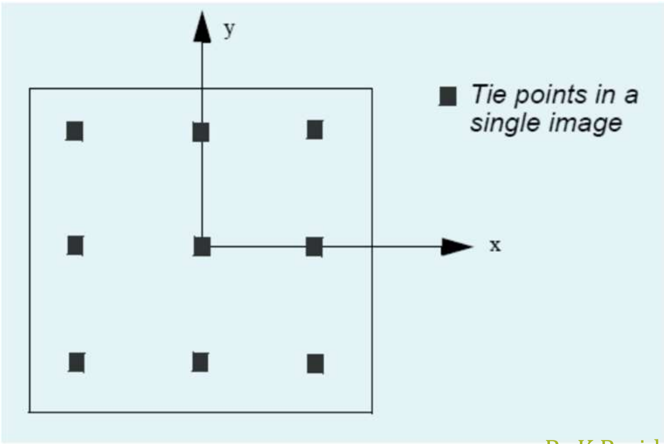


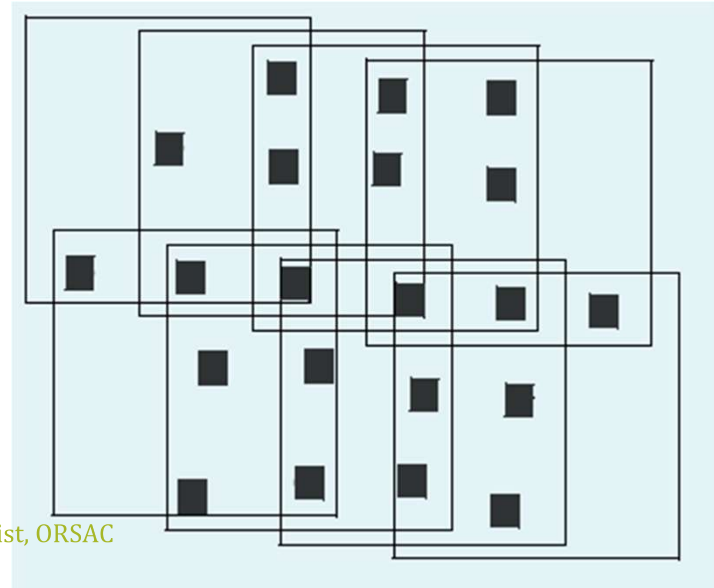
Tie Points

- A tie point is a point whose ground coordinates are not known, but is visually recognizable in the overlap area between two or more images.
- The corresponding image positions of tie points appearing on the overlap areas of multiple images is identified and measured.
- Ground coordinates for tie points are computed during block triangulation.
- Tie points can be measured both manually and automatically.

Tie Points

- They should show good contrast in two directions, like the corner of a building or a road intersection.
- Tie points should also be distributed over the area of the block.
- Typically, nine tie points in each image are adequate for block triangulation.

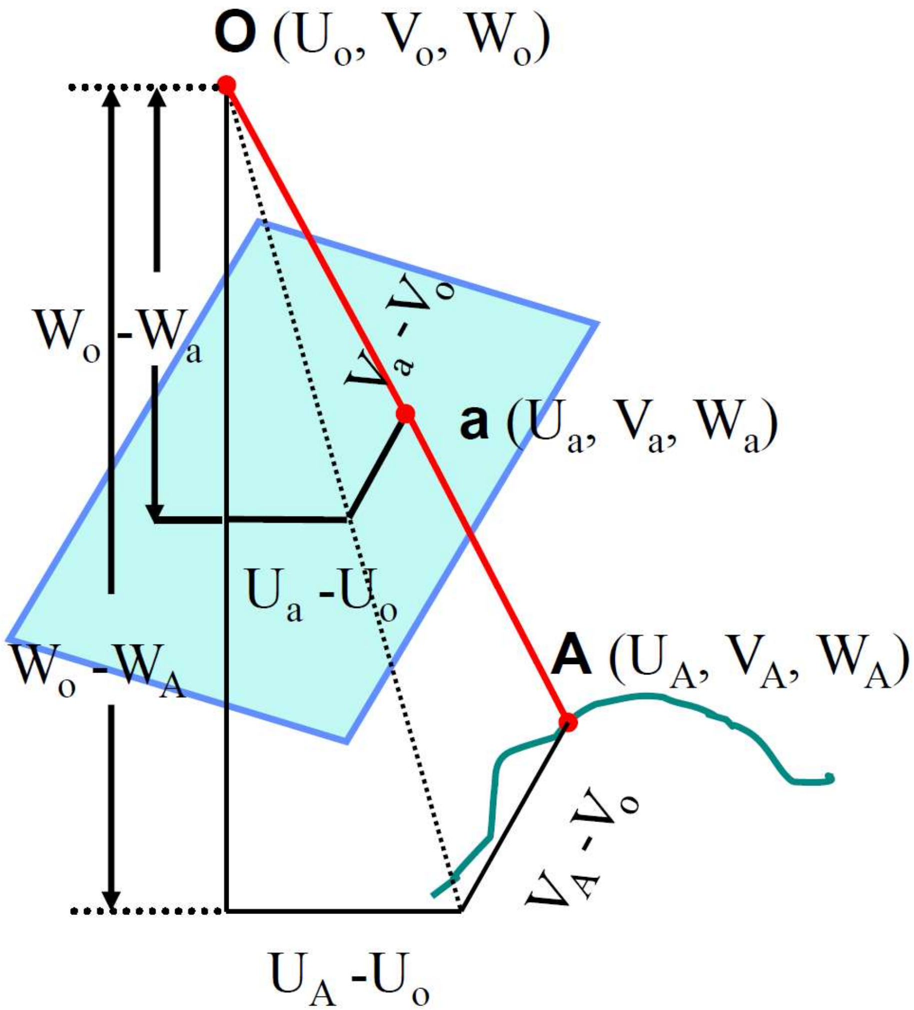




The Collinearity Equation

- It is defined as condition that the exposure station , any object point and its photo image all lie along a straight line in three dimensional space
- Most photogrammetric tools utilize the following formulas in one form or another.

The Collinearity Equation



- **O: Projection centre**
- **A: Point on the ground**
- **a: Image of A on the photograph from similar triangles**:

$$\frac{U_A - U_o}{U_a - U_o} = \frac{V_A - V_o}{V_a - V_o} = \frac{W_A - W_o}{W_a - W_o} = s_a$$

or:

$$\begin{bmatrix} U_A - U_o \\ V_A - V_o \\ W_A - W_o \end{bmatrix} = s_a * \begin{bmatrix} U_a - U_o \\ V_a - V_o \\ W_a - W_o \end{bmatrix}$$

The Collinearity Equation

$$x = -c \cdot \frac{r_{11} \cdot (U - U_o) + r_{12} \cdot (V - V_o) + r_{13} \cdot (W - W_o)}{r_{31} \cdot (U - U_o) + r_{32} \cdot (V - V_o) + r_{33} \cdot (W - W_o)} + x_{PP}$$

$$y = -c \cdot \frac{r_{21} \cdot (U - U_o) + r_{22} \cdot (V - V_o) + r_{23} \cdot (W - W_o)}{r_{31} \cdot (U - U_o) + r_{32} \cdot (V - V_o) + r_{33} \cdot (W - W_o)} + y_{PP}$$

Position of a point in the image: x, y

Position of the corresponding terrain point: U, V, W

Known after interior orientation: x_{PP}, y_{PP}, c

From Exterior orientation: U_o, V_o, W_o,

r_{11}, r_{12}, r_{13}, r_{21}, r_{22}, r_{23}, r_{31}, r_{32}, r_{33} (computed from of κ, φ, ω)

- For each point in the terrain its position in the image can be computed from these two equations. (Different for the left and the right image.)

Photogrammetric Solutions- Space Resection

- Space resection is commonly used to perform single frame orthorectification, where one image is processed at a time.
- If multiple images are being used, space resection techniques require that a minimum of three GCPs be located on each image being processed.

Photogrammetric Solutions- Space Forward Intersection

- Space forward intersection is a technique that is commonly used to determine the ground coordinates X, Y, and Z of points that appear in the overlapping areas of two or more images based on known interior and exterior orientation parameters.

- The collinearity condition is enforced, stating that the corresponding light rays from the two exposure stations pass through the corresponding image points on the two images, and intersect at the same ground point.

Photogrammetric Solutions- Bundle Block Adjustment

- The use of space intersection and space resection techniques is limited for mapping projects having more than two images.

- This is due to the lack of information required to perform these tasks.

- It is fairly uncommon for the exterior orientation parameters to be highly accurate for each photograph or image in a project, since these values are generated photogrammetrically.

- Airborne GPS and INS techniques normally provide initial approximations to exterior orientation, but the final values for these parameters must be adjusted to attain higher accuracies.

Photogrammetric Solutions- Bundle Block Adjustment

- There are rarely enough accurate GCPs for a project of 30 or more images to perform space resection (90 points).

- To minimize the costs of a mapping project, fewer GCPs are collected and used.

- To ensure that high accuracies are attained, an approach known as bundle block adjustment is used.

Photogrammetric Solutions- Bundle Block Adjustment

- A bundled solution is computed including the exterior orientation parameters of each image in a block and the X, Y, and Z coordinates of tie points and adjusted GCPs.

- A block of images contained in a project is simultaneously processed in one solution.

- A statistical technique known as least squares adjustment is used to estimate the bundled solution for the entire block while also minimizing and distributing error.

Photogrammetric Solutions- Bundle Block Adjustment

- Block triangulation is the process of defining the mathematical relationship between the images contained within a block, the camera or sensor model, and the ground.

- Once the relationship has been defined, accurate imagery and geographic information concerning the Earth's surface can be created.

- When processing frame camera, digital camera, videography, and nonmetric camera imagery, block triangulation is commonly referred to as **aerial triangulation (AT).**

- When processing imagery collected with a pushbroom sensor, block triangulation is commonly referred to as **triangulation**.

Least Squares Adjustment

- Least squares adjustment is a statistical technique that is used to estimate the unknown parameters associated with a solution while also minimizing error within the solution.

- With respect to block triangulation, least squares adjustment techniques are used to:

  - estimate or adjust the values associated with exterior orientation
  - estimate the X, Y, and Z coordinates associated with tie points
  - estimate or adjust the values associated with interior orientation
  - minimize and distribute data error through the network of observations

Least Squares Adjustment

- Data error is attributed to the inaccuracy associated with the input GCP coordinates, measured tie point and GCP image positions, camera information, and systematic errors.

- The least squares approach requires iterative processing until a solution is attained.

- A solution is obtained when the residuals, or errors, associated with the input data are minimized.

- The least squares approach involves determining the corrections to the unknown parameters based on the criteria of minimizing input measurement residuals.

Least Squares Adjustment

- The residuals are derived from the difference between the measured (i.e., user input) and computed value for any particular measurement in a project.

- In the block triangulation process, a functional model is formed based upon the collinearity equations.

- The residuals, which are minimized, include the image coordinates of the GCPs and tie points along with the known ground coordinates of the GCPs.

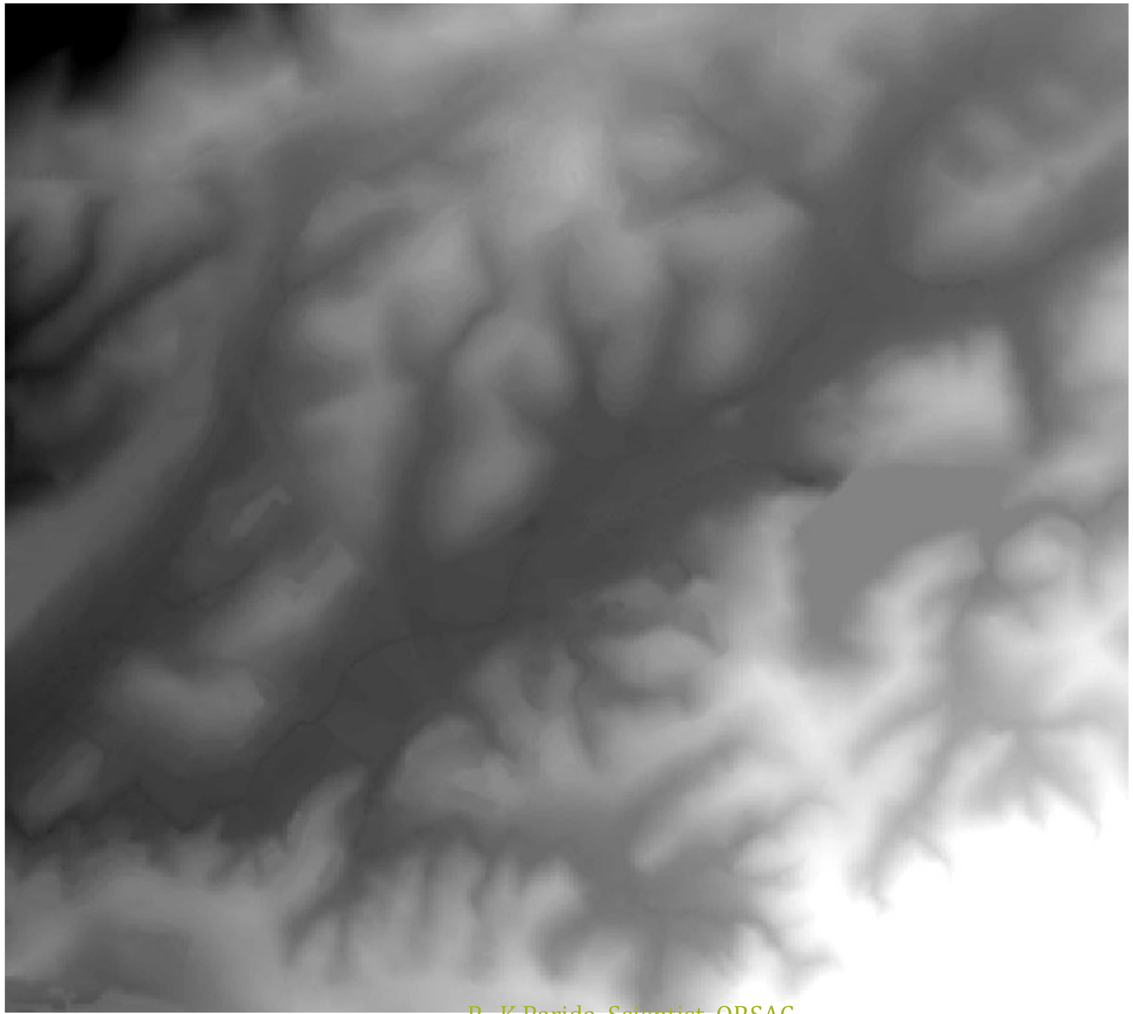
DEM (Digital Elevation Model)

- A Digital Elevation Model (DEM) provides a digital representation of a portion of the earth's terrain over a two dimensional surface.

- A DEM is normally generated by sampling a regular array of elevation values derived from topographic maps, aerial photographs etc.

- The basic data for a DEM is based on terrain elevation observations that are derived generally from one of three sources: digitized contours, photogrammetric data capture (including aerial photography and digital satellite imagery), and surveying.

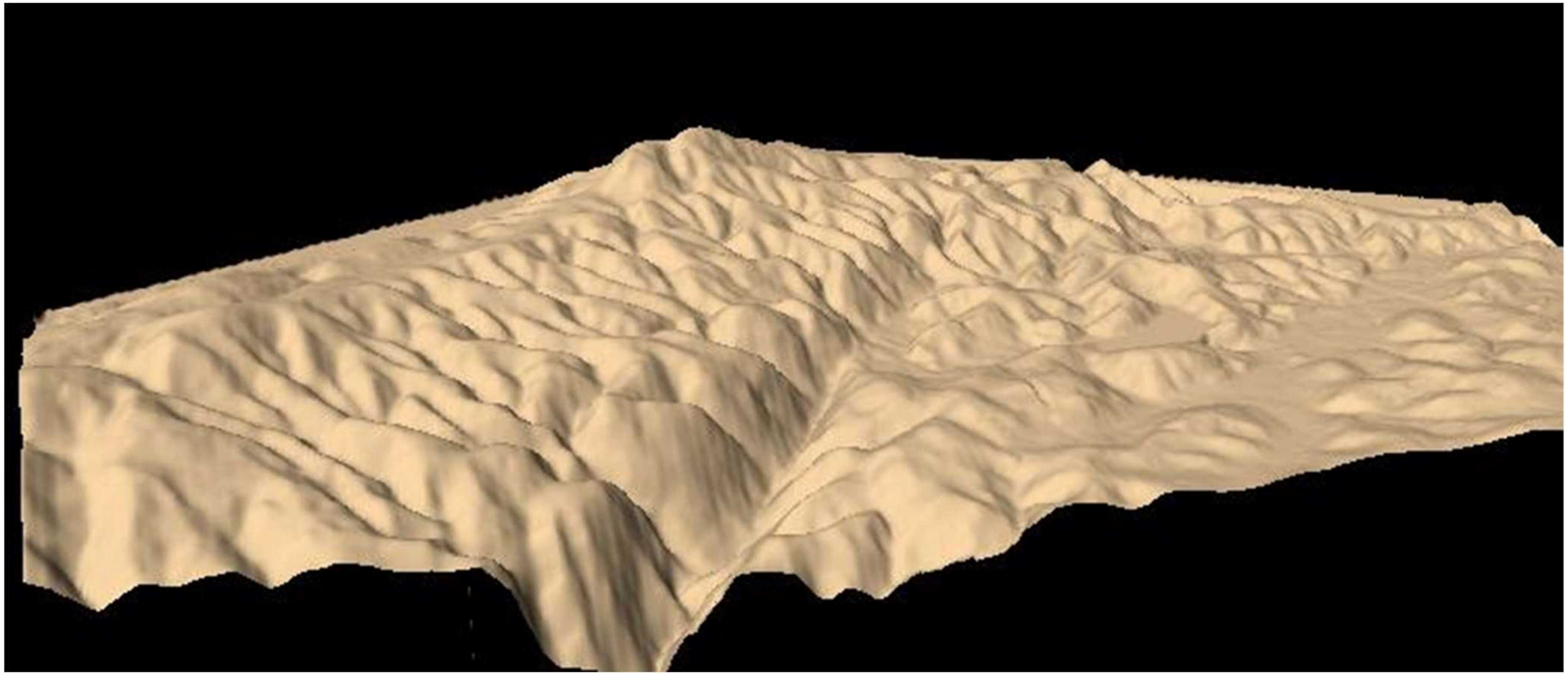
DEM (Digital Elevation Model)



DTM(Digital Terrain Model)

- A digital terrain model is a topographic model of the bare earth – terrain relief - that can be manipulated by computer programs.
- The data files contain the spatial elevation data of the terrain in a digital format which usually presented as a rectangular grid.
- Vegetation, buildings and other man-made (artificial) features are removed digitally - leaving just the underlying terrain
- DTM is the sum of all terrain specific information you have about an area including the elevation data itself.

DTM(Digital Terrain Model)



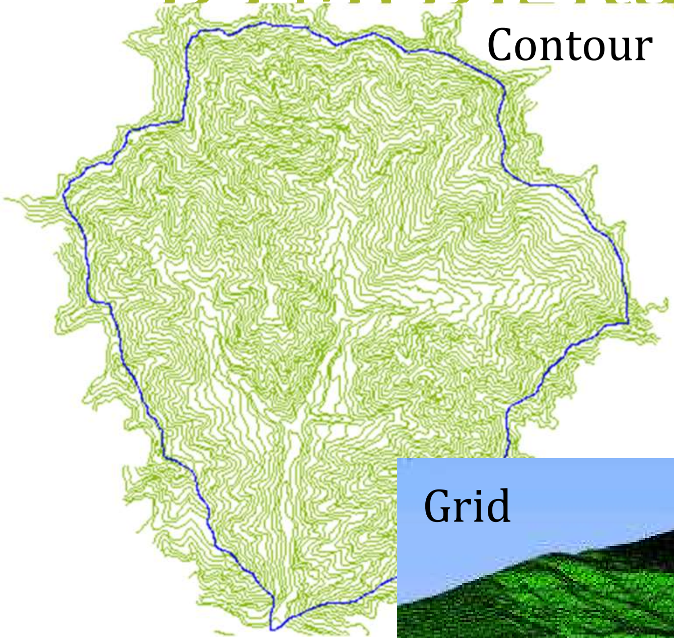
DTM(Digital Terrain Model)

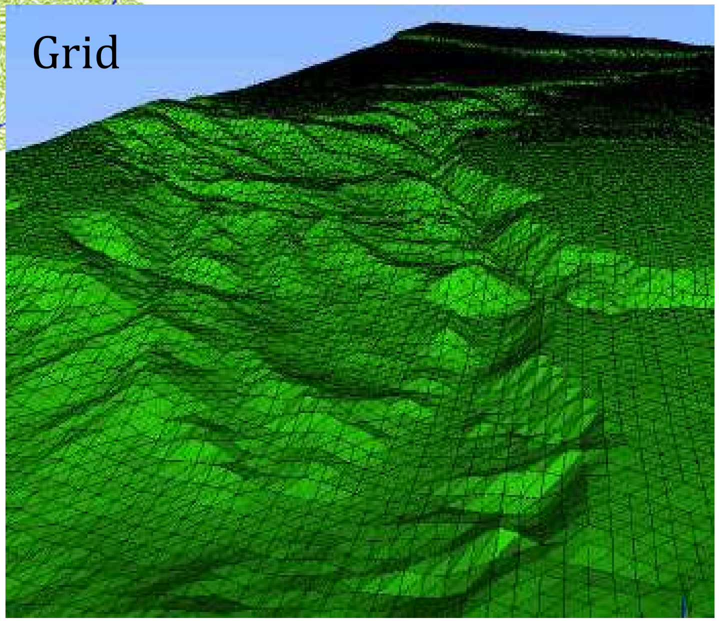
- DTM model is stored usually as a rectangular equal-spaced grid, with space (resolution) of between 50 and 500 meters mostly presented in cartesian coordinate system – i.e. x, y, z .

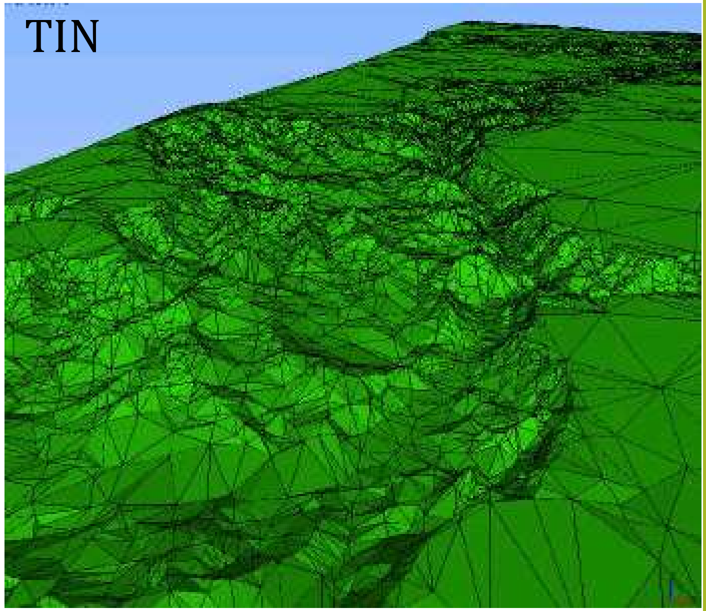
- For several applications a higher resolution is required (as high as 1 meter spacing).

- DTM can be stored in a GIS databases in several ways:
  - a set of contour vectors ;
  - a rectangular grid of equal-spaced corner/point heights ; or,
  - an irregularly spaced set of points connected as triangles (TIN - Triangular Irregular Network)

DTM(Digital Terrain Model)

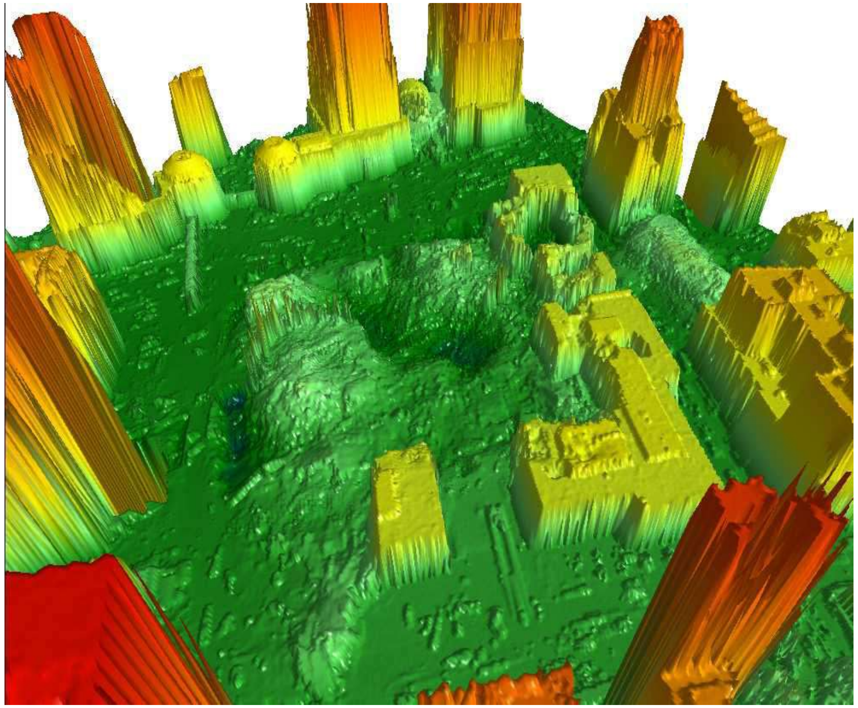


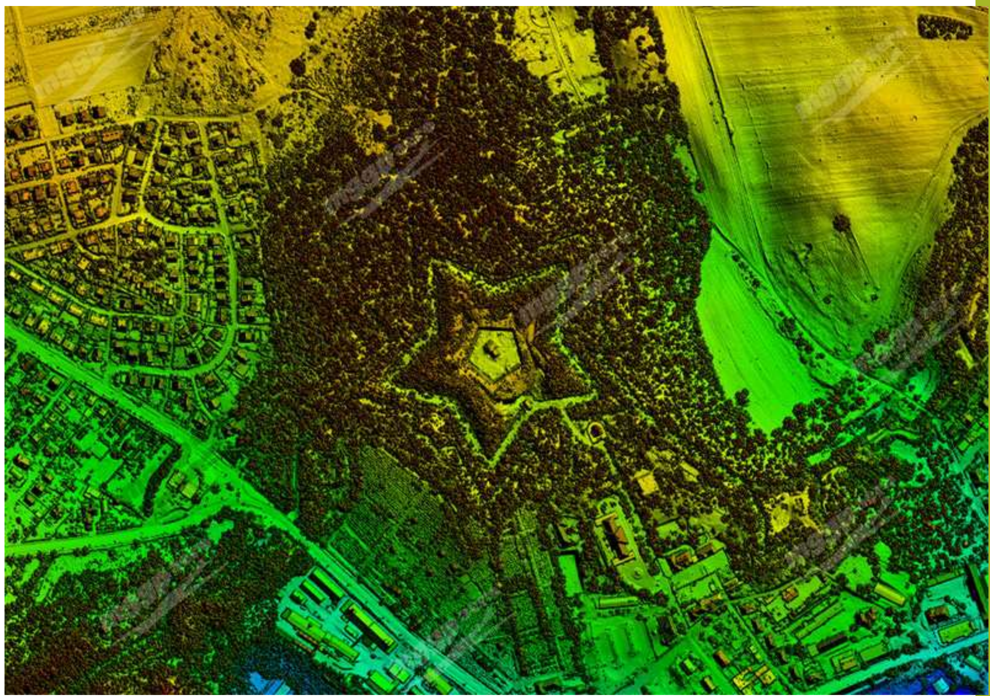




DSM (Digital Surface Model)

- DSM describes the terrestrial surface, including the objects covering it like buildings, vegetation etc.





Digital photogrammetric softwares

Application	License	Platform	Standalone / Plugin	Automatic modelling	Scalability	Type of photogrammetry	Data source	Inception	Vendor / Creator
123D Catch	Proprietary[1]	Android, iOS, Microsoft Windows, Web-based	Standalone	Yes	Yes, multiple images	Close-range	Images[3]	2011[citation needed]	Autodesk
Autodesk Remake	Unknown	Microsoft Windows	Standalone	Yes	Yes, multiple images	Close-range	Images	2015	Autodesk
Geomatica	Proprietary	Microsoft Windows	Standalone	Yes	Yes, multiple images	Aerial, Satellite	Images	1982	PCI Geomatics
ImageModeler	Unknown	Unknown	Standalone	No	Yes, multiple images	Close-range	Images	2009	Autodesk
ImageStation	Proprietary	Microsoft Windows	Standalone	Yes	Yes, multiple images	Aerial, Satellite, UAS	Images	1980	Hexagon Geospatial
IMAGINE Photogrammetry	Proprietary	Microsoft Windows	Standalone	Semi-automatic	Yes, multiple images	Aerial, Satellite, UAS	Images	2009	Hexagon Geospatial
INPHO	Unknown	Microsoft Windows	Standalone	Yes	Yes, multiple images	Aerial, Satellite, UAS	Images	1980	Trimble
PhotoModeler	Proprietary	Microsoft Windows	Standalone	Semi-automatic	Yes, multiple images	Close-range	Images	1994	Eos Systems - PhotoModeler
PhotoModeler Scanner	Proprietary	Microsoft Windows	Standalone	Yes	Yes, multiple images	Close-range	Images	2008	Eos Systems - PhotoModeler
PhotoModeler UAS	Proprietary	Microsoft Windows	Standalone	Yes	Yes, multiple images	Close-range, UAS	Images	2016	Eos Systems - PhotoModeler
PhotoScan	Unknown	Linux, OS X, Microsoft Windows	Standalone	Yes	Yes, multiple images	Aerial, UAS	Images	2010	Agisoft
Pix4Dmapper Discovery	Unknown	Microsoft Windows, Web-based	Standalone	Yes	Yes, multiple images	Aerial, Close-range, UAS	Images	2011	Pix4D SA
Pix4Dmapper Pro	Proprietary	Microsoft Windows, cloud computing, OS X, Linux	Standalone	Yes	Yes, multiple images	Aerial, Close-range, UAS	Images, videos	2011	Pix4D SA
Pix4Dmodel	Proprietary	Microsoft Windows, MacOS, Cloud	Standalone	Yes	Yes, multiple images	Aerial, Close-range, UAS	Images	2011	Pix4D SA
SOCET SET	Proprietary	Microsoft Windows	Standalone	No	Yes, multiple images	Aerial, Close-range, Satellite	Images		BAE Systems

Feature extraction….

- The process of transforming data into information is known as "Information Extraction". This process is called "Feature extraction"- isolation of components within multi spectral data that are most useful in portraying the essential elements of an image. This can be of four types:
- 1. Interactive
- 2. Semi-automatic
- 3. Fully automatic
- 4. Autonomous

Need for automatic feature extraction….

- Monitoring land use changes in settlement areas is important for urban planning. There is a great need for timely maps for urban and regional planning applications. Land use in urban areas changes continuously mainly due to the construction of new buildings, roads and other man made objects.
- In order to use the huge amount of information available from high-resolution satellite and aerial images more efficiently, it will be necessary to find methods that detect objects like streets, houses, vegetation and other cartographic features in a fully automatic manner. Since manual extraction of buildings from imagery is a very slow process, automated methods have been proposed to improve the speed and utility for urban map's production process.

Feature extraction- an object oriented approach…

- **The basis of this type of classification lies on the principle that any particular scene consists of individual *entities* or *segments* or *objects* having particular properties like form and shape, size and color.**

- **Each object, in some way or the other is related to its neighboring objects by relations like 'inside it', 'outside it', 'below it', 'next to it' and so on.**

- **Thus, this cognition process of comparing the objects and their relationships with the available knowledge is made use of in object oriented classification to classify image.**

- **As against MXL classifier which has a pixel based approach towards classification, OOC has a context based approach for classification.**

- **It is a hybrid classifier as it deals with the spatial as well as spectral data of an image.**

Segmentation….

- It is an optimization procedure which locally minimizes the average heterogeneity of image objects for a given resolution. It can be applied on the pixel level or an image object level domain.

- The size of each image object is controlled by the **SCALE** parameter which determines the maximum allowed heterogeneity for the resulting image objects.

- Thus, the scale should be chosen such that image objects of the biggest possible scale which still distinguish different image regions (As large as possible and as fine as necessary.)

Rule formation….

✓**Processes are the fundamental tool for editing and sequencing development functions.**

✓**The Process Tree window is the central place where rule sets are organized.**

✓**A single process represents an individual operation of an image analysis routine. Thus, it is the main working tool for developing rule sets.**

✓**A single process is the elementary unit of a rule set providing a solution to a specific image analysis problem.**

✓**Every single process has to be edited to define an algorithm to be executed on an image object domain.**

✓**Combine single processes in a sequence by building a rule set. We can organize a process sequence with parent and child processes which are executed in a defined order.**

✓**The two main functions of algorithms are generating or modifying image objects and classifying image objects.**

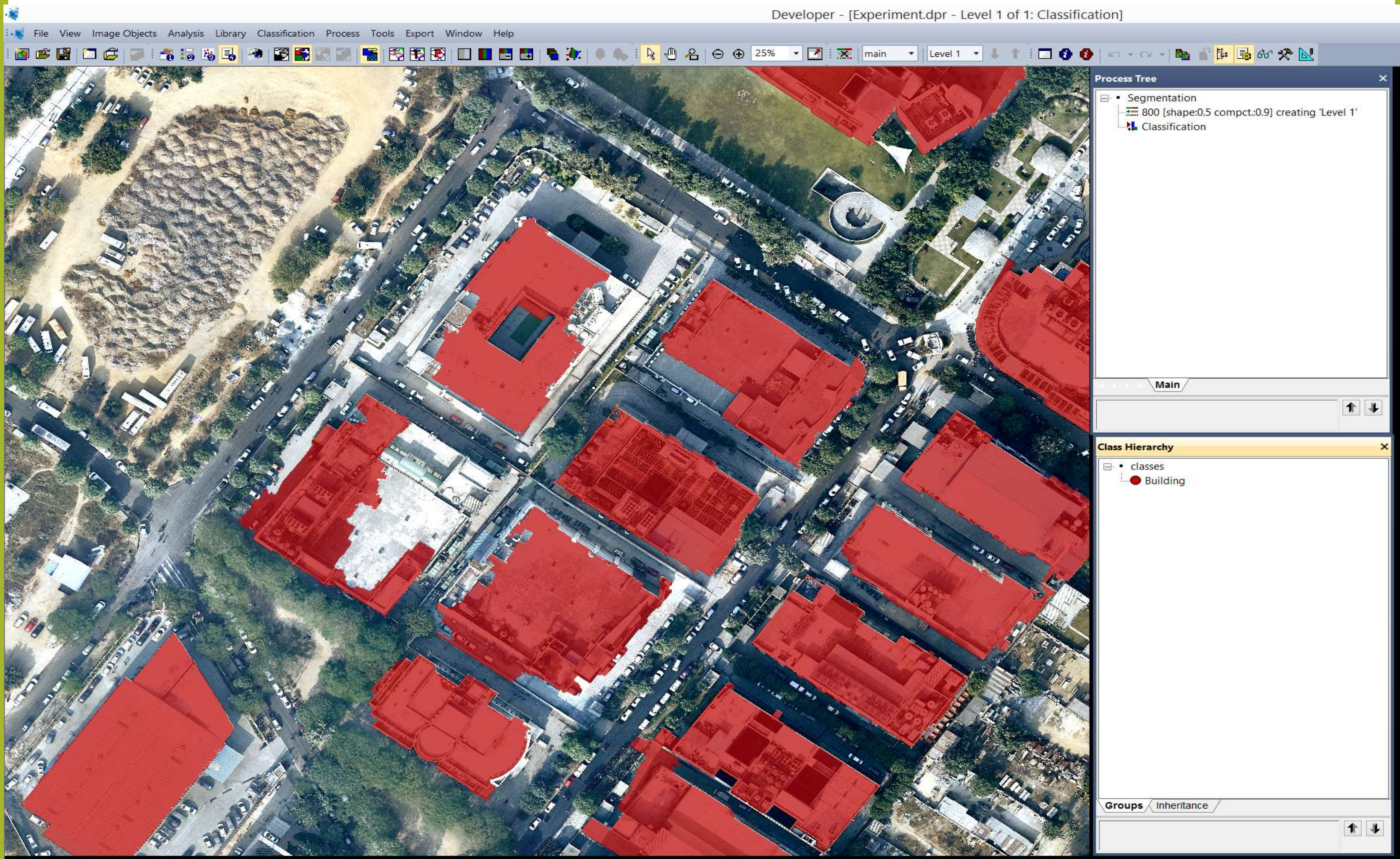
Vectorization….

- Within Definiens Developer vector structures are not only used for import and export, but also for advanced classification.

- After segmentation and rule based classification, vectorization functionality allows the production of polygons and skeletons for each object. Definiens Developer supports the import and export of thematic data in shape format.

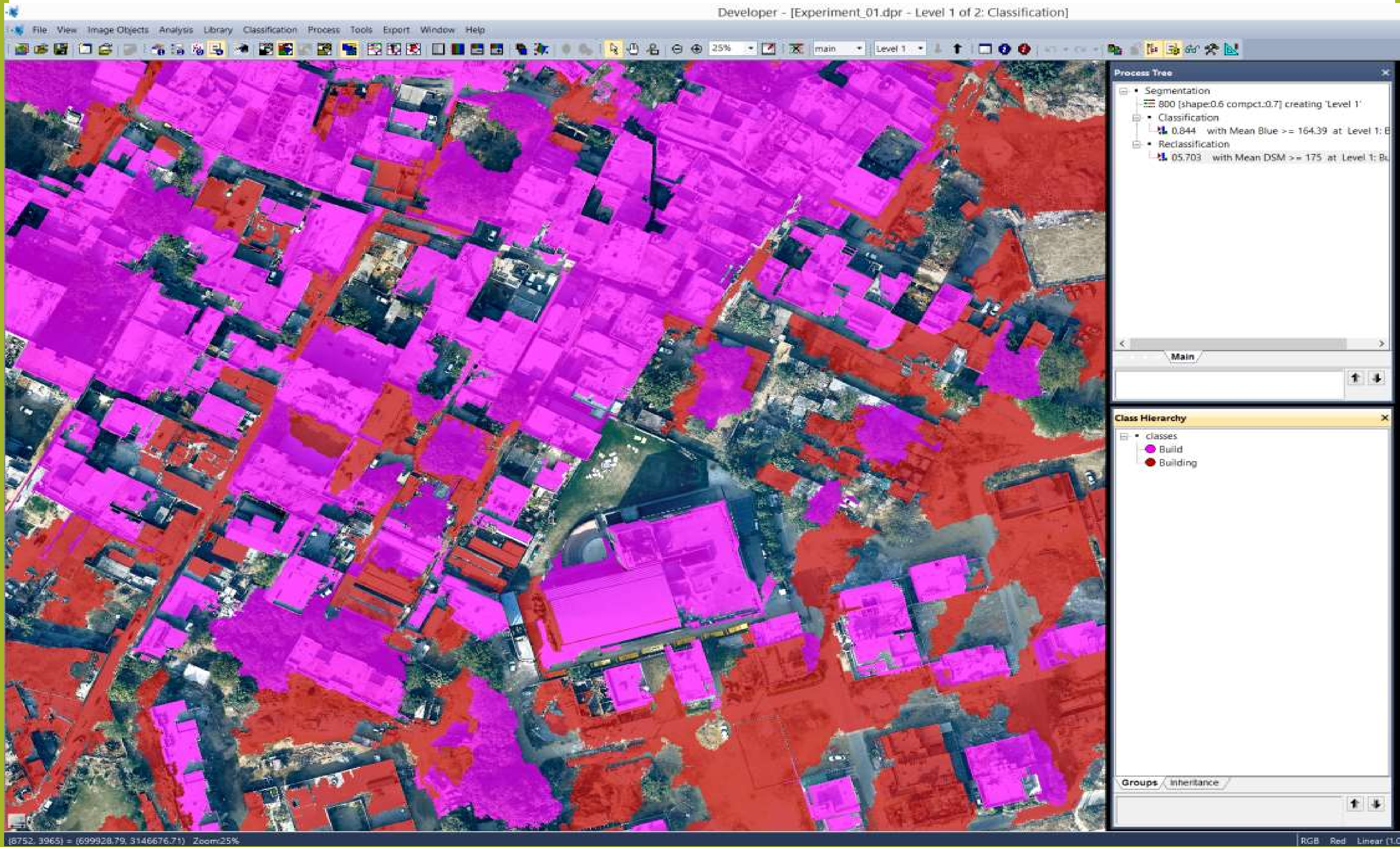
Building Extraction

Here the constructed (Buildings) has been identified on the basis of their height (175m) by using the DSM as an ancillary data to get the height information of the buildings.

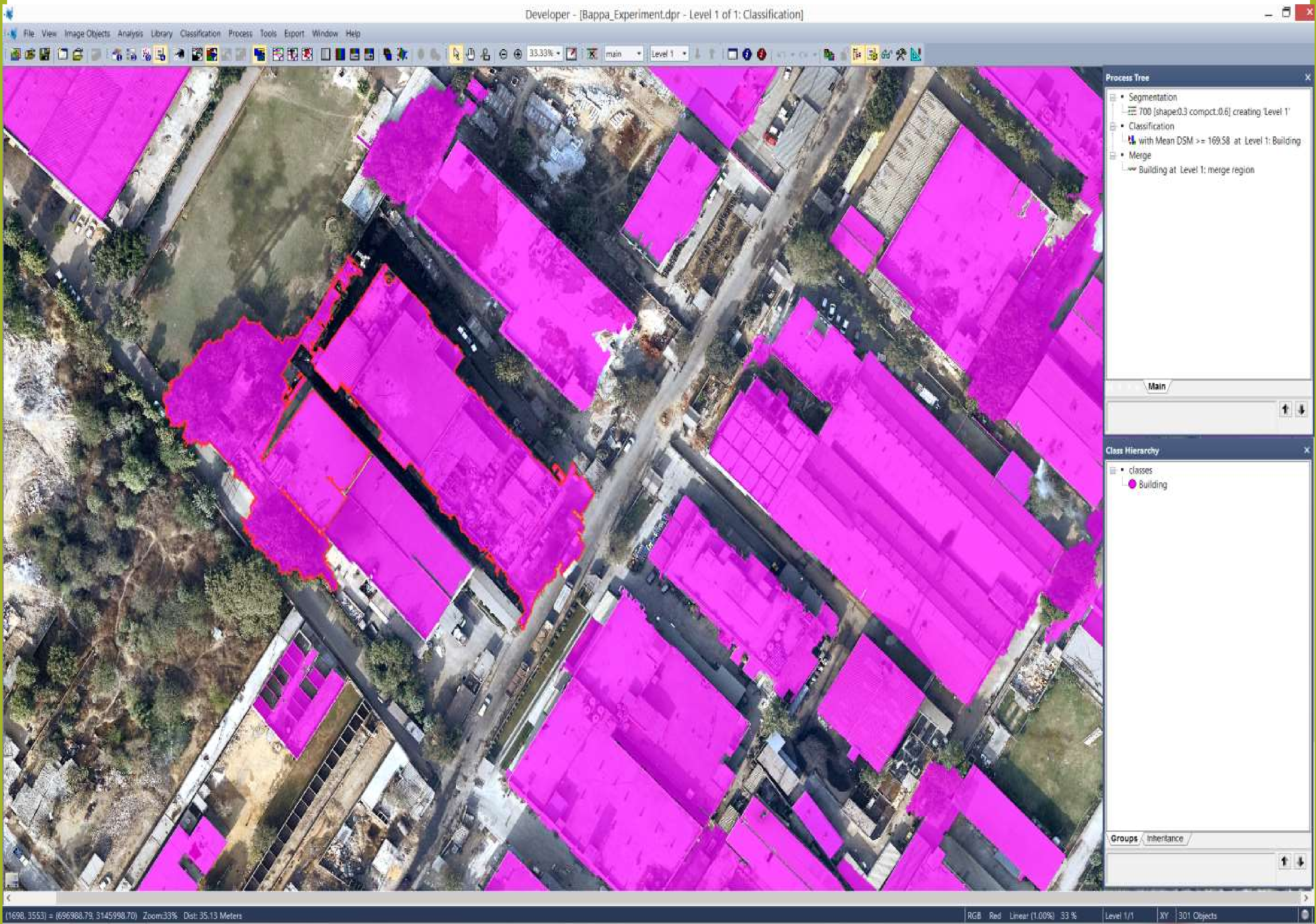


Building Extraction Cont…….

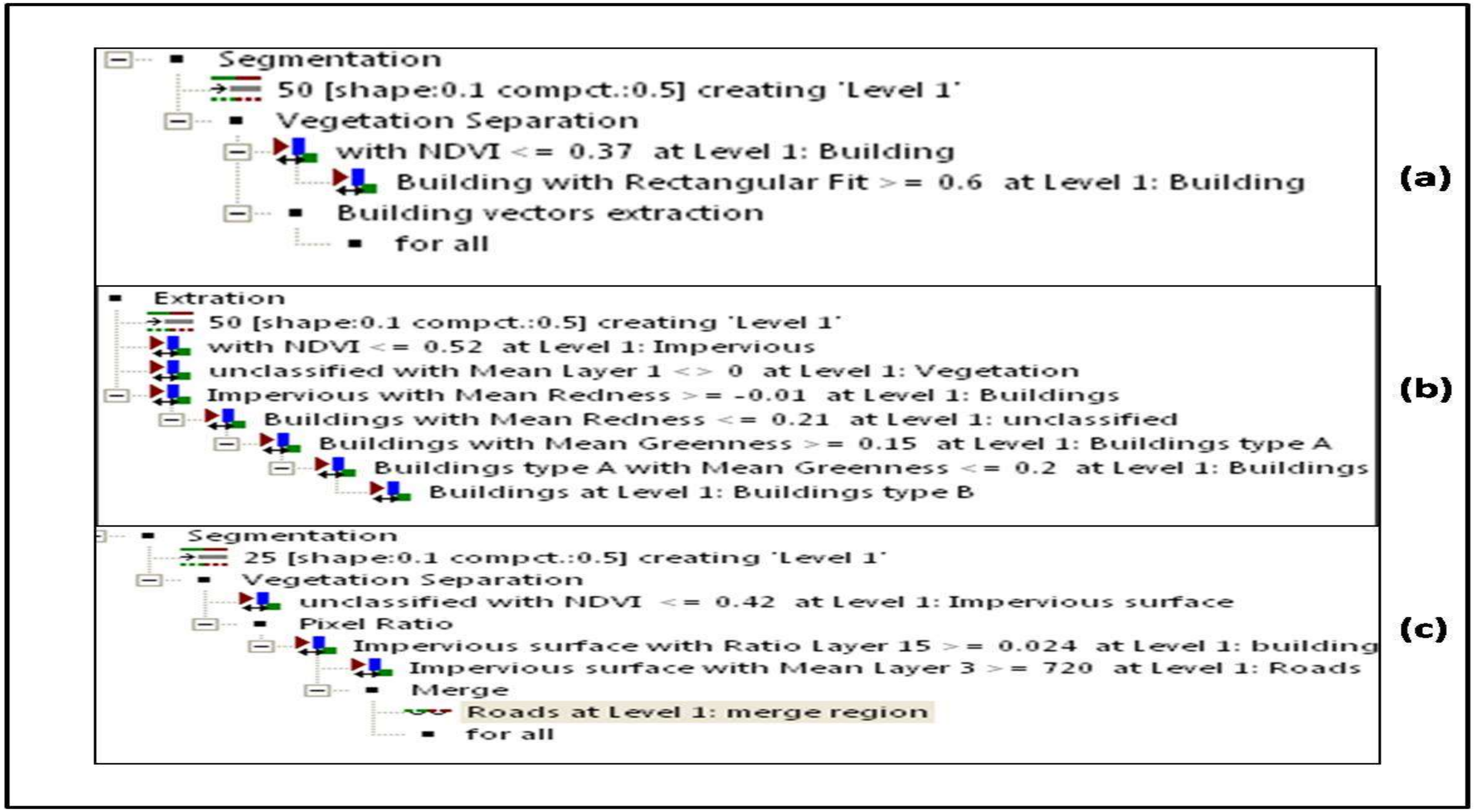
This image is showing that two difference heights(164.39m & 175m) has been used to discriminate the constructed (Buildings) area.



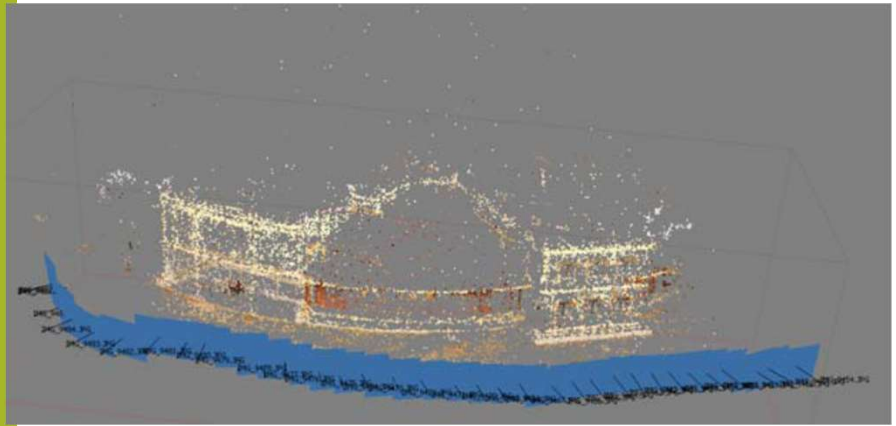
Building Extraction Cont…….



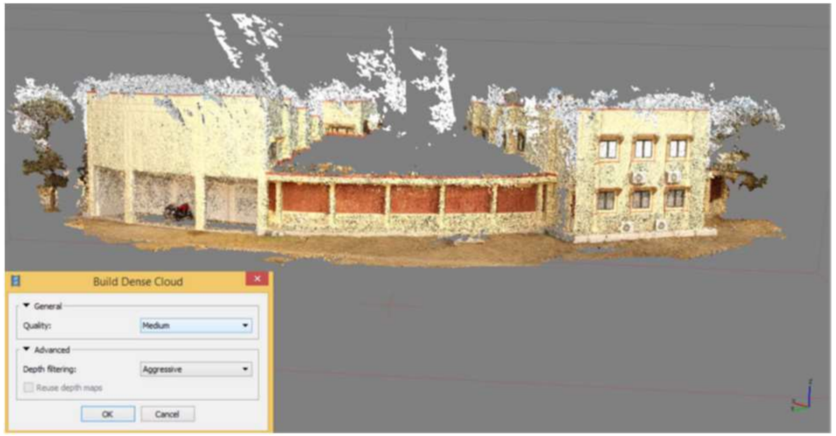
Cont….



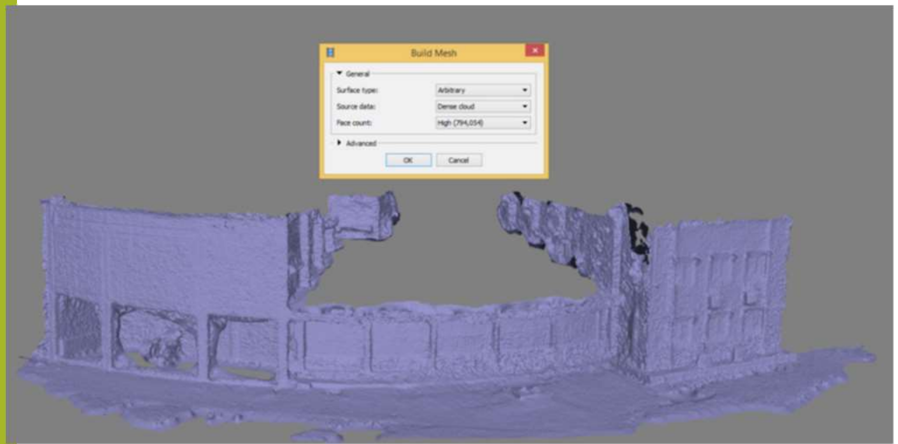
Segmentation
50 [shape:0.1 compct.:0.5] creating 'Level 1'
Vegetation Separation
with NDVI <= 0.37 at Level 1: Building
Building with Rectangular Fit >= 0.6 at Level 1: Building
Building vectors extraction
for all
(a)
Extration
50 [shape:0.1 compct.:0.5] creating 'Level 1'
with NDVI <= 0.52 at Level 1: Impervious
unclassified with Mean Layer 1 <> 0 at Level 1: Vegetation
Impervious with Mean Redness >= -0.01 at Level 1: Buildings
Buildings with Mean Redness <= 0.21 at Level 1: unclassified
Buildings with Mean Greenness >= 0.15 at Level 1: Buildings type A
Buildings type A with Mean Greenness <= 0.2 at Level 1: Buildings
Buildings at Level 1: Buildings type B
(b)
Segmentation
25 [shape:0.1 compct.:0.5] creating 'Level 1'
Vegetation Separation
unclassified with NDVI <= 0.42 at Level 1: Impervious surface
Pixel Ratio
Impervious surface with Ratio Layer 15 >= 0.024 at Level 1: building
Impervious surface with Mean Layer 3 >= 720 at Level 1: Roads
Merge
Roads at Level 1: merge region
for all
(c)



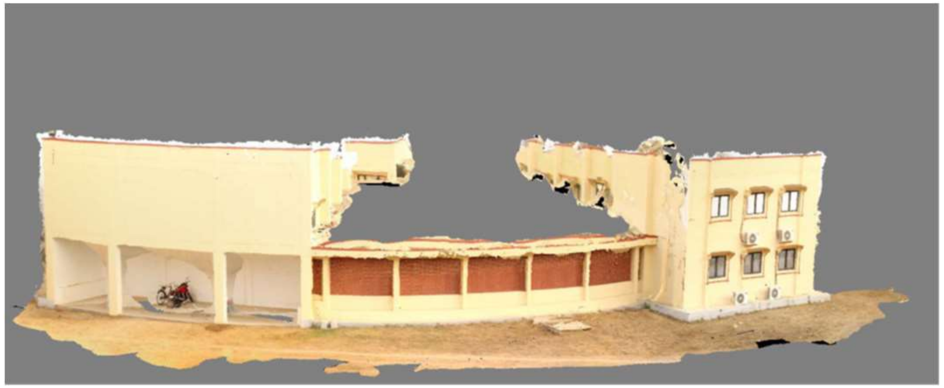
smart point



Dense Cloud



Mesh Building



Textured Model

Thank You for your Patience