

# Photogrammetry: DTM Extraction & Editing



How can one determine the x, y, and z of a location?  
**Approaches to DTM Extraction**

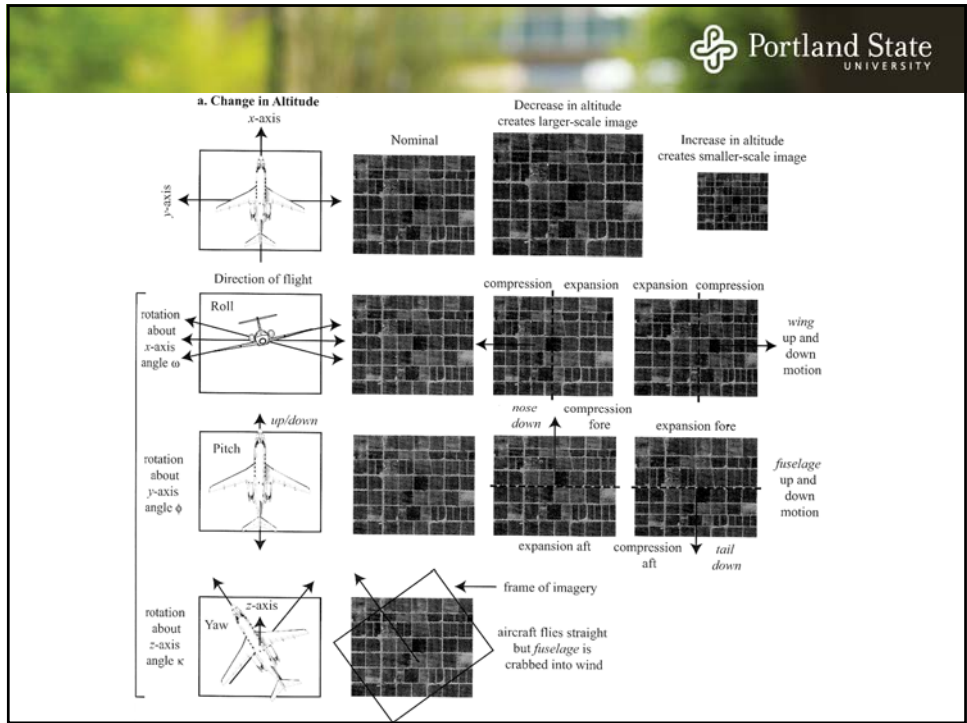
- Ground surveying
- Digitized topographic maps
- Traditional photogrammetry
  - Hardcopy vs. softcopy approach
- Radar
- LIDAR

## Photogrammetry

- The science of making reliable measurements by the use of photographs and especially aerial photographs.
- Challenges:
  - Geometric distortions
  - Relief displacement
  - Obscured targets

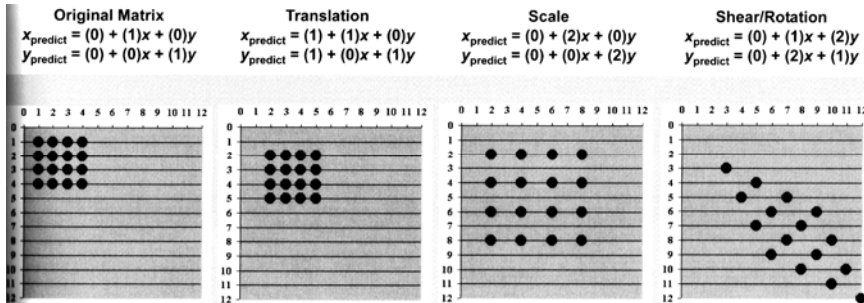
## Geometric Distortions

- External errors
  - Altitude changes
  - Attitude changes (roll, pitch, and yaw)
- Internal errors
  - e.g., lens distortion, earth rotation



## Methods of Correcting Geometric Distortion

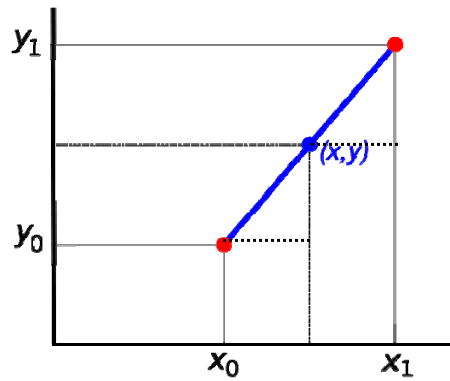
- Affine Transformation (aka linear or first-order transformation)
- Higher order polynomial transformation



How to tell if triangles are similar

- AAA are congruent
- SSS in same proportion
- SAS (proportional sides next to congruent angle)

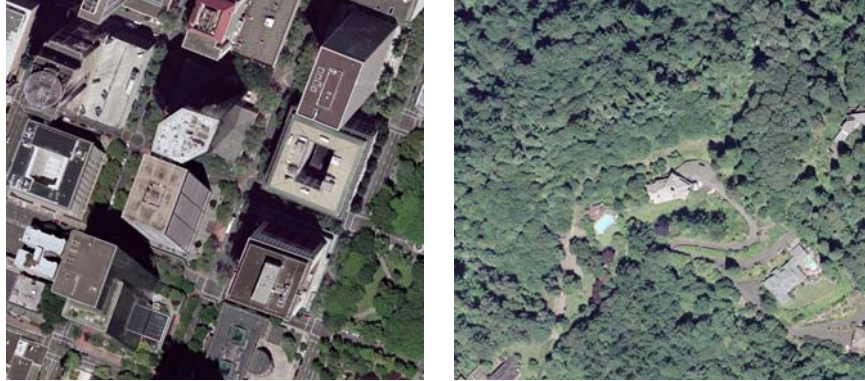
Known:  $x_0, y_0, x_1, y_1,$  and  $x$   
Find:  $y$



$$\frac{y - y_0}{y_1 - y_0} = \frac{x - x_0}{x_1 - x_0}$$

$$y = y_0 + (x - x_0) \frac{y_1 - y_0}{x_1 - x_0}$$

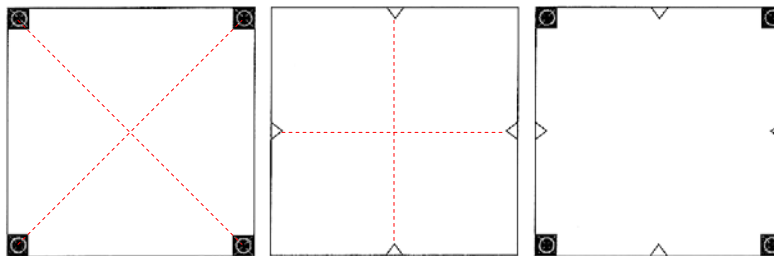
# Relief Displacement



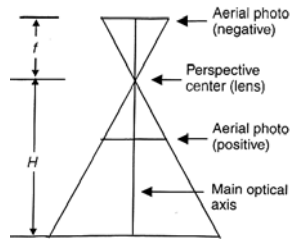
RD changes the measured distances and angles on photos.

# Basic Aerial Photography Geometry

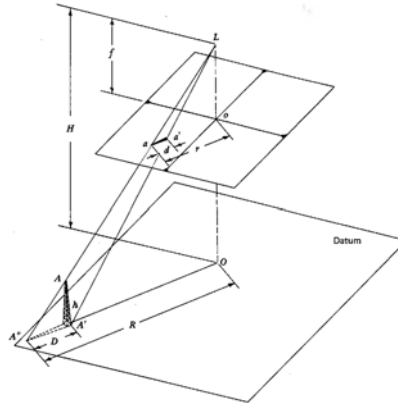
- Fiducial marks
- Principal point



## Geometric Components of Relief Displacement



$$\frac{1}{S} = \frac{f}{H}$$



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

$$h = \frac{dH}{r}$$

$d$  = relief displacement  
 $h$  = object height  
 $r$  = radial distance between location and PP on photo  
 $H$  = flying height

## Correcting for Relief Displacement: Orthorectification

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

$d$  = relief displacement  
 $h$  = object height  
 $r$  = radial distance between location and PP on photo  
 $H$  = flying height

# Image Parallax

- the apparent displacement or the difference in apparent direction of an object as seen from two different points not on a straight line with the object.

$$p_a = X_a - x'_a$$

$p_a$  = parallax of point A

$x_a$  = x coord of a on left photo

$x'_a$  = x coord of a' on right photo

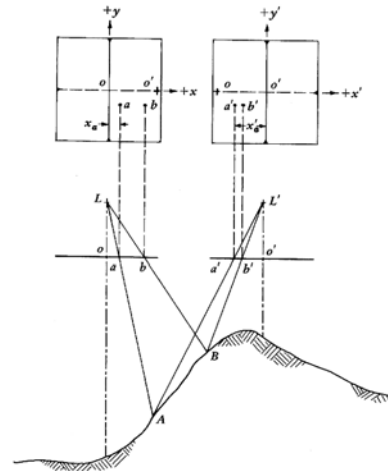
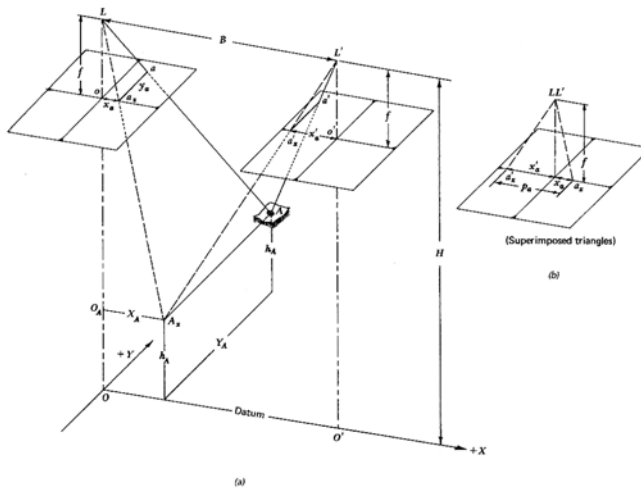


Figure 3.15 Parallax displacements on overlapping vertical photographs.

# Calculating Object Height & Location from Parallax



Parallax Equations:

$$h_A = H - \frac{B \times f}{p_a}$$

$$X_A = B \frac{x_a}{p_a}$$

$$Y_A = B \frac{y_a}{p_a}$$

$p_a$  = parallax of A

$x_a$  = x coord of A on left photo

$X_A$  = ground coord of A

$h_A$  = height of A

$B$  = air base

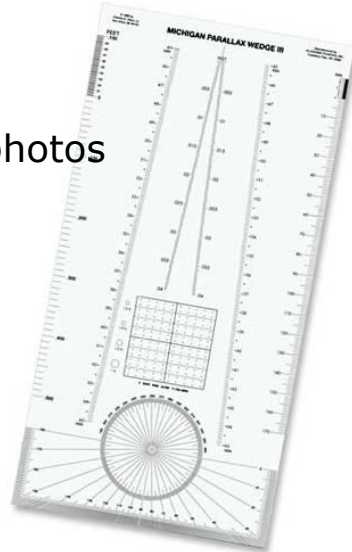
$H$  = flying height

Figure 3.17 Parallax relationships on overlapping vertical photographs: (a) adjacent photographs forming a stereopair; (b) superimposition of right photograph onto left.

## Measuring Parallax

Based on a stereopair of photos

- Floating half marks
- Parallax wedge

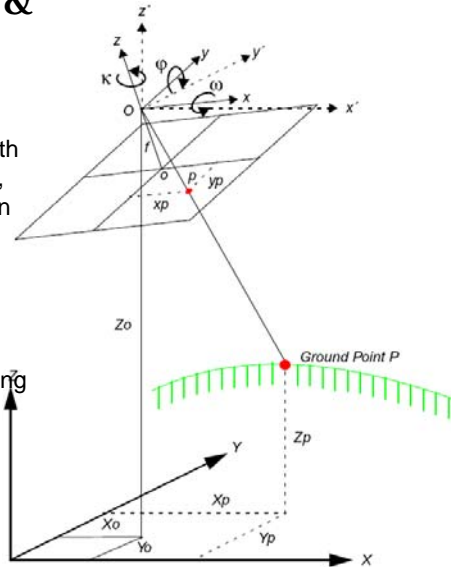


## Digital Photogrammetry: Softcopy Photogrammetric Systems

- Scanned stereopair photos
- Interior and exterior orientations
  - Camera & photo parameters
  - Flight parameters
  - GCPs
- Image matching
  - Tie points
  - Algorithms
- Generate DEM and orthophotos

## Collinearity Condition & Equations

- If collinearity condition is achieved on both photos in a stereopair then the ground X, Y, Z can be computed from x and y within the image coordinate system on both photos.
- Six exterior orientation parameters
- Collinearity equations can be derived using GCPs.
- Inertial Measurement Unit (IMU)



## Leica Photogrammetry Suite (LPS)

- Leica Geosystems
- Based on ERDAS Imagine
- LPS (Version 9.0)
  - Project Manager
  - LPS Automatic Terrain Extraction (ATE)
  - Project Manager & ATE were called OrthoBASE in Version 8.X
  - LPS Terrain Editor
- Imagine VirtualGIS

## LPS Block Files (.blk)

- A block must be created to to performing any photogrammetric tasks in LPS
- A block contains information including:
  - Projection, spheroid, and datum information
  - Imagery used within a project
  - Camera or sensor model information associated with the imagery
  - GCPs and their measured image positions
  - geometric relationships between the imagery in a project and the ground

## Coordinate Systems in Digital Photogrammetry

- Pixel coordinates (rc)
- Image coordinates (xy)
- Image space coordinates (xyz)
- Ground space coordinates (XYZ)

## Interior Orientation

- Interior orientation defines the internal geometry of a camera or sensor as it existed at the time of data capture.
- It defines image space coordinates based on pixel and image coordinates and camera parameters (e.g.,  $f$  and lens distortion model).

## Exterior Orientation

- Exterior orientation defines the position and angular orientation associated with the camera to achieve collinearity condition.
- It defines ground space coordinates based on image space coordinates and flight information (e.g., flying altitude and attitude).

## What DPI should I use?

Dots per inch (DPI)

e.g., 200 DPI = 200 dots/inch  
= 200 dots/2.54 cm  
= 2.54/200 cm/dot  
= 0.0127 cm/dot  
= 127 microns/dot

e.g., scan a 1:4000 photo at 200 DPI  
127 microns/dot (map) = 127 x 4000 microns/dot (ground)  
= 508000 microns/dot  
= 50.8 cm/dot = 0.5 meters/dot

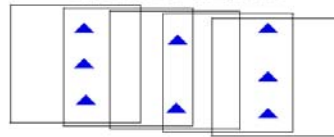
## Redundancy (DF) of Forming Collinearity Eqs.

Degree of Freedom (DF) =  
# Observation Eqs - # Unknown

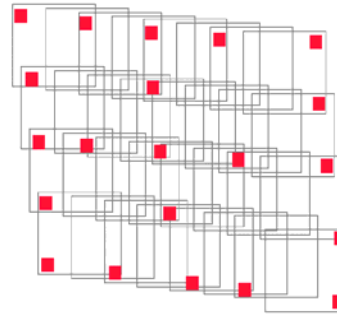
- 1 GCP provides 2 obser. eqs. on one image
- 1 tie point provides 2 obser. eqs. on one image
- 1 photo has 6 unknown ( $X, Y, Z, \omega, \rho, \kappa$ )
- 1 tie point has 3 unknown ( $X, Y, Z$ )

# GCPs: How many do you need?

Figure 8-12: GCP Configuration



- 3 for single frame.
- 2 on every third image of a strip
- 1 on every third image of a block



## Photogrammetry vs. Conventional Geometric Correction

Photogrammetry	Transformation
Bundle block adjustment (Relies on image models, GCPs, and block triangulation)	Single photo adjustment (Relies on GCPs and polynomial equations)
A minimum of 3 GCPs to achieve high accuracy. GCPs can be shared by the entire block of photos.	More GCPs are required to achieve satisfactory accuracy. GCPS are not shared.
Minimize errors for the entire block of photos. Ideal for photo-mosaicking.	Minimize errors within a single photo.
Allow the correction of relief displacement and the generation of DEM when stereopairs are used.	Unable to do orthorectification