# Photogrammetry: DTM Extraction & Editing


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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 (e.g., SRTM 2003 and eSRTM 2014)
- LIDAR

# Photogrammetry

- The science of making reliable measurements by the use of photographs and especially aerial photographs.

- Challenges and solutions:
  - Geometric distortions (transformation)
  - Relief displacement (ortho-rectification)
  - Obscured targets (true-orthorectification)

# Distortion

- Distortion: shift in the position of an image on a photograph that alters the perspective characteristics of the image.

- Displacement: shift in the position of an image on a photograph that does not alter the perspective characteristics of the photo

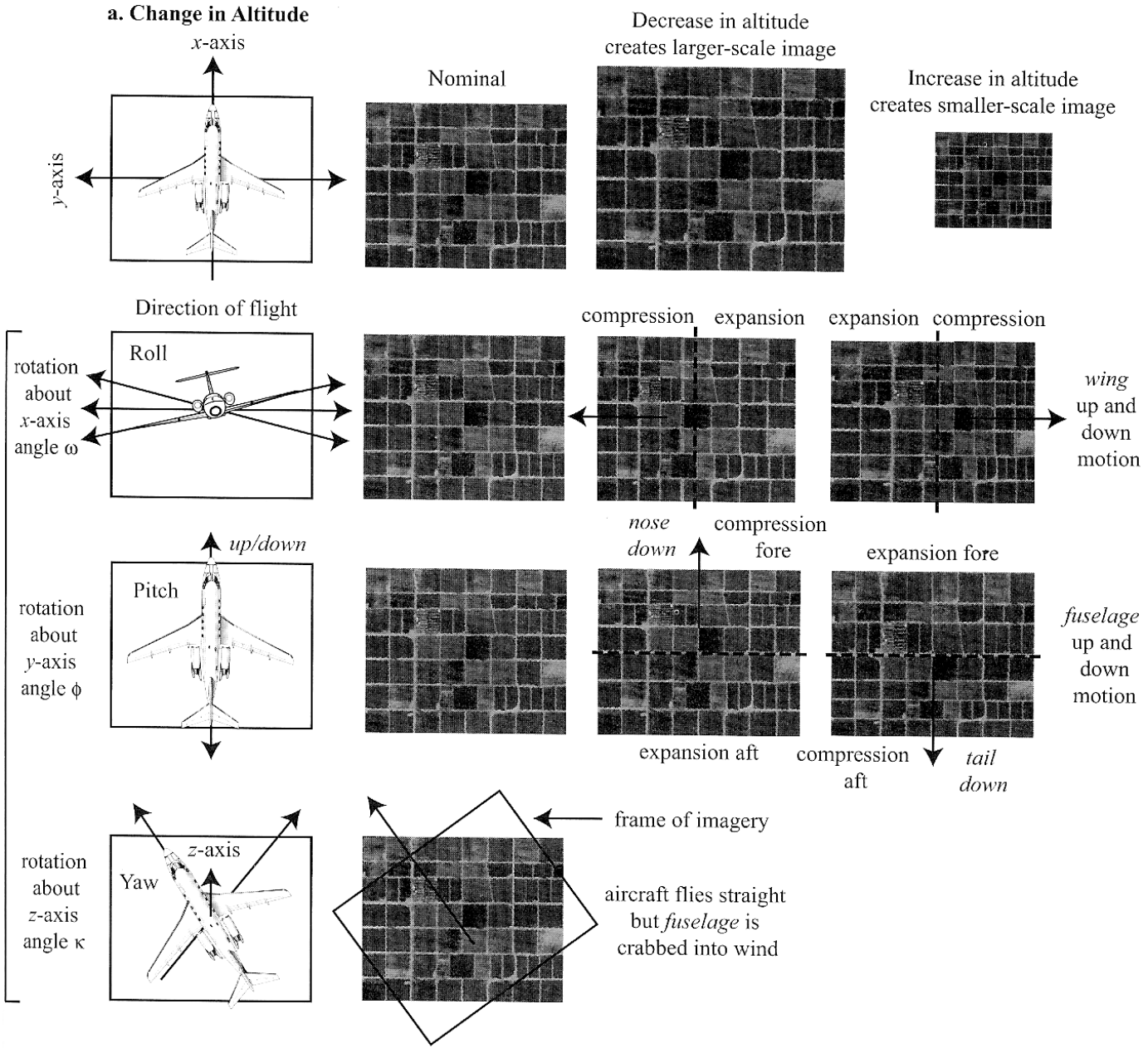
# Types of Distortion

- Film and print Shrinkage
- Atmospheric Reaction of light rays (refraction)
- Image motion
- Lens Distortion

The effects of film shrinkage, atmospheric refraction are usually negligible in most cases.

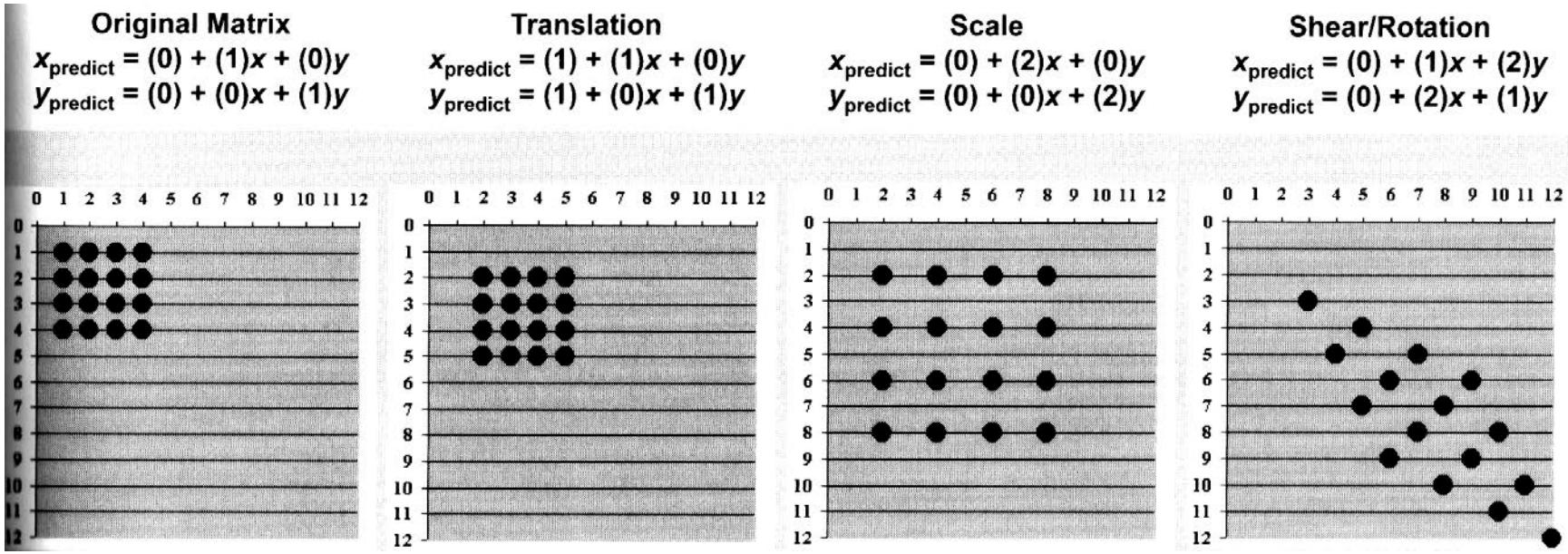
# Geometric Distortions

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


a. Change in Altitude
x-axis
y-axis
Nominal
Decrease in altitude
creates larger-scale image
Increase in altitude
creates smaller-scale image
Direction of flight
Roll
rotation
about
x-axis
angle ω
compression
expansion
expansion
compression
wing
up and
down
motion
up/down
Pitch
rotation
about
y-axis
angle ϕ
nose
down
compression
fore
expansion fore
fuselage
up and
down
motion
expansion aft
compression
aft
tail
down
z-axis
Yaw
rotation
about
z-axis
angle κ
frame of imagery
aircraft flies straight
but fuselage is
crabbed into wind

# Methods of Correcting Geometric Distortion

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



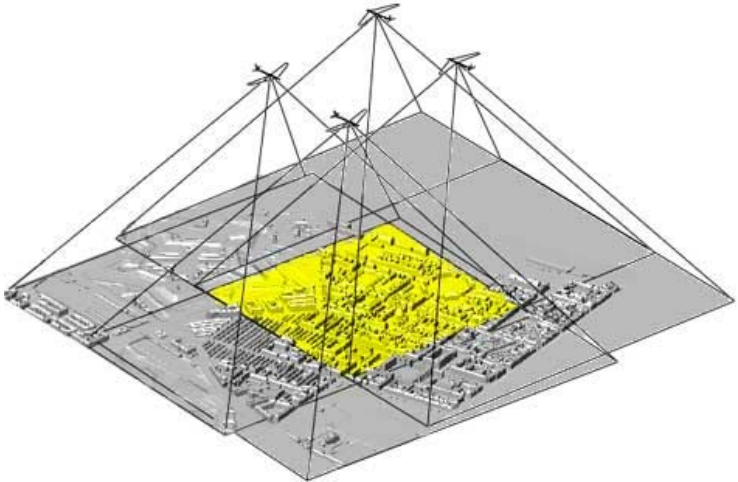
# Orthophoto & Ortho-rectification

Orthophotos - orthographic photographs

- Photographs that do not have distortions nor displacements.

True orthophotos:

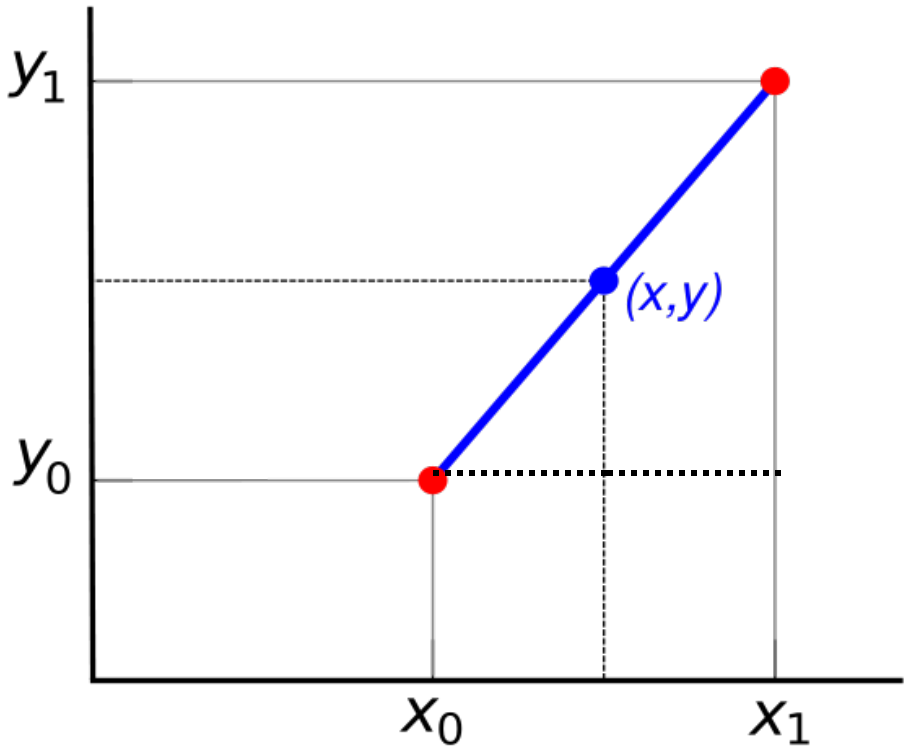
http://www.sharpgis.net/page/True-Orthophoto-Generation.aspx



How to tell if triangles are similar

- AAA are congruent (i.e., coincident)
- SSS in same proportion
- SAS (proportional sides next to congruent angle)

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

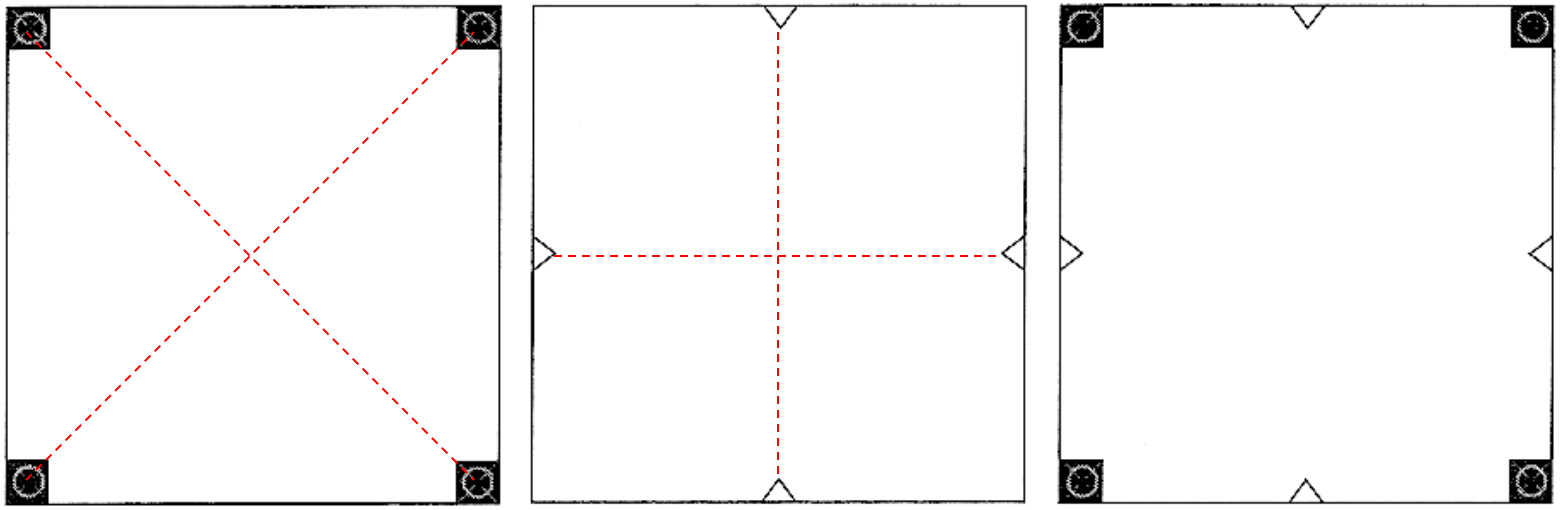



$$\frac{y - y_0}{y_1 - y_0} = \frac{x - x_0}{x_1 - x_0}$$

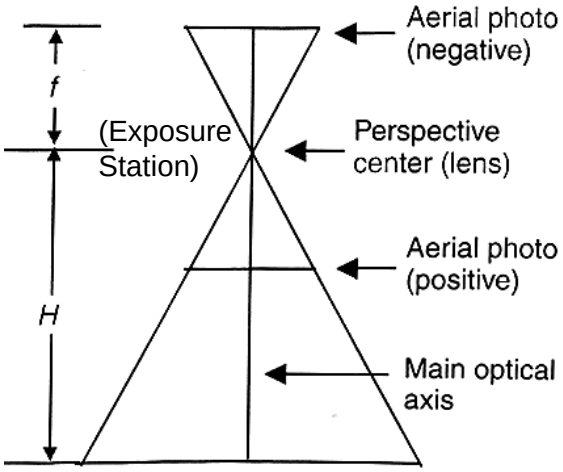
$$y = y_0 + (x - x_0)\frac{y_1 - y_0}{x_1 - x_0}$$

# Basic Aerial Photography Geometry

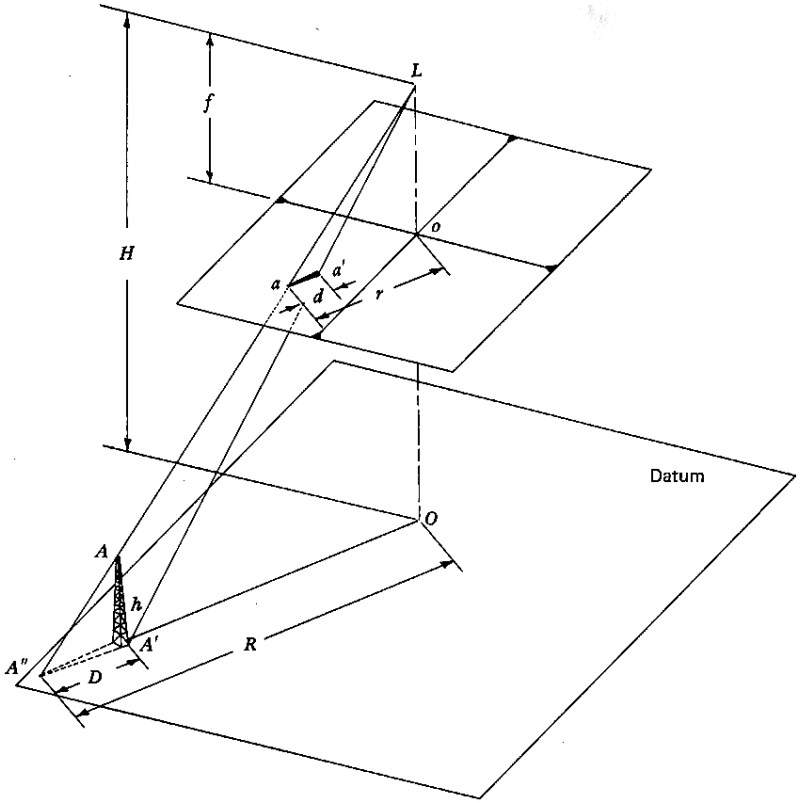
- Fiducial marks
- Principal point
- 9” x 9” (or 228.6mm x 228.6mm)



# Geometric Components of Relief Displacement




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




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

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

1/S: photo scale
f: focal length of camera
H: flying height

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

# Calculating Relief Displacement

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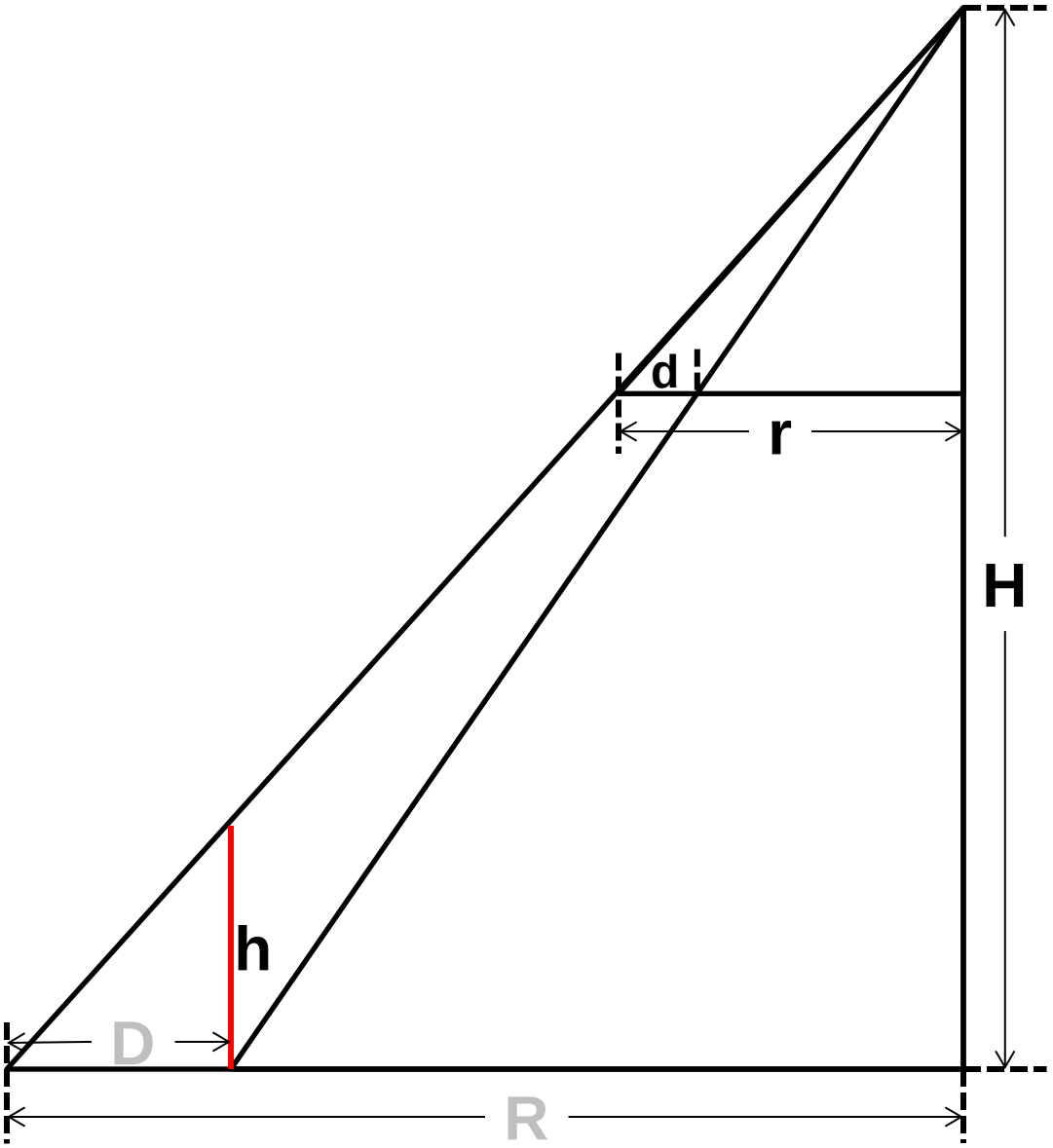
d = relief displacement

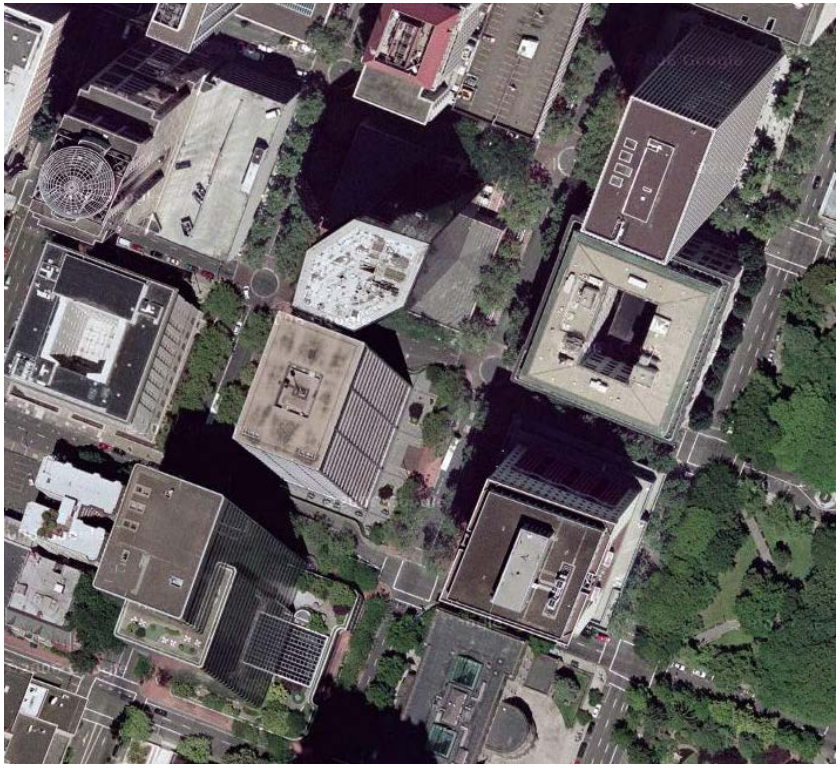
h = object height

r = radial distance between location and PP on photo

H = flying height



# Relief Displacement



RD changes the measured distances and angles on photos.

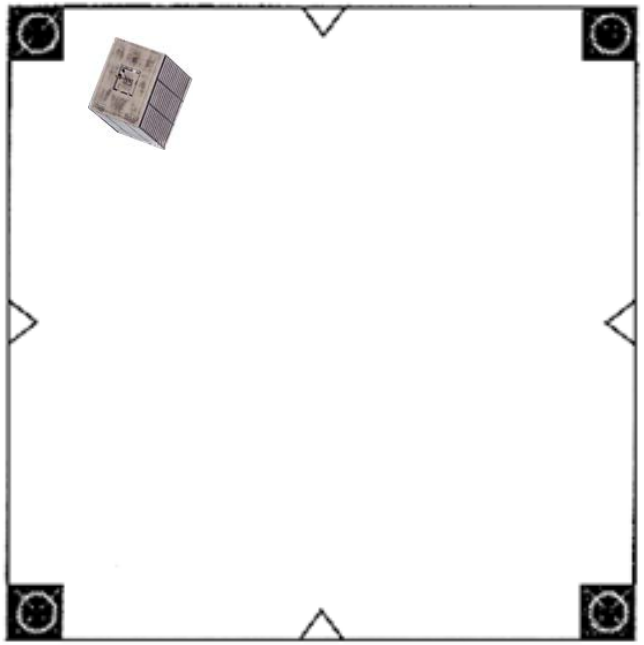
# Correcting for Relief Displacement: Orthorectification

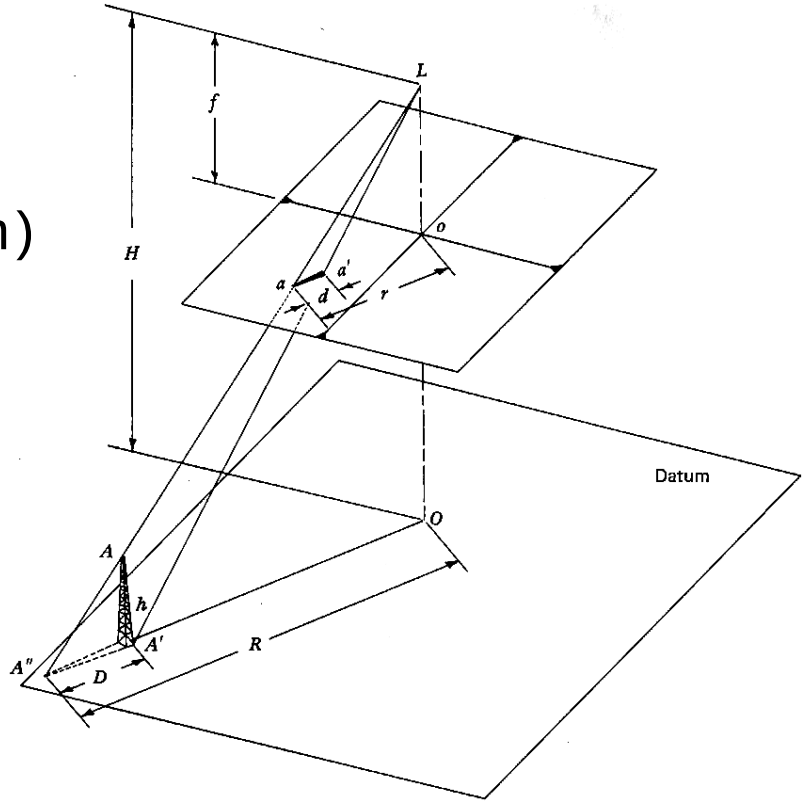
$$d = \frac{rh}{H}$$

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

# Exercise

- Given a photo with known flight height (e.g., 1220 m)
- Demonstrate the steps to measure the height of a building on the photo.






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

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

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

# 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 coor of a on left photo
$x'_a$ = x coor of a' on right photo

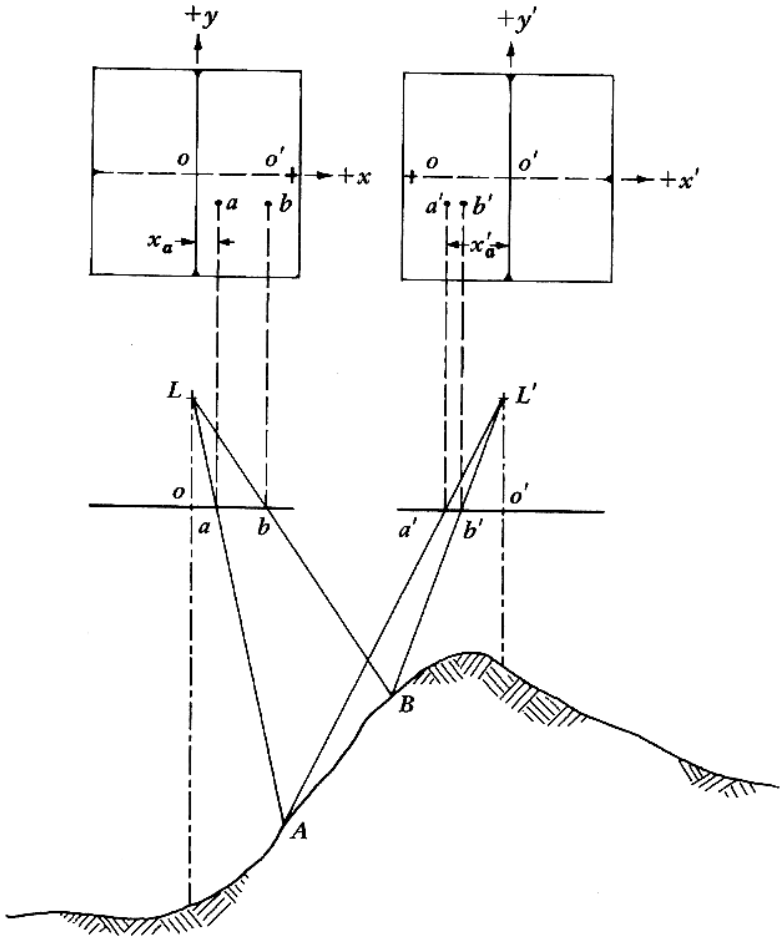



**Figure 3.15** Parallax displacements on overlapping vertical photographs.

**Figure 189: Exposure Stations Along a Flight Path**

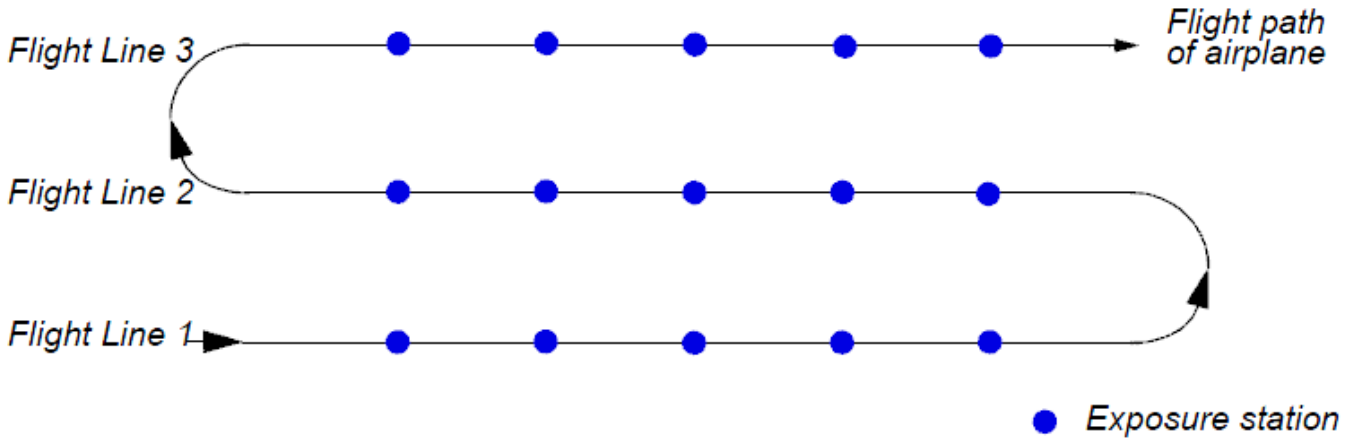
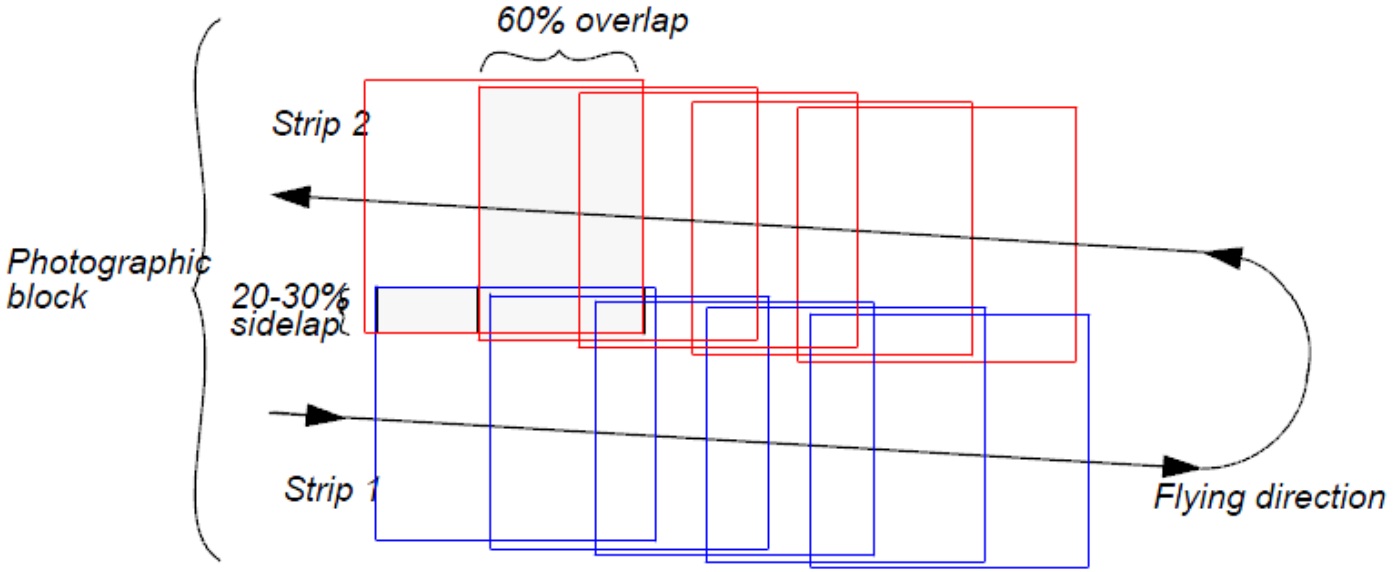
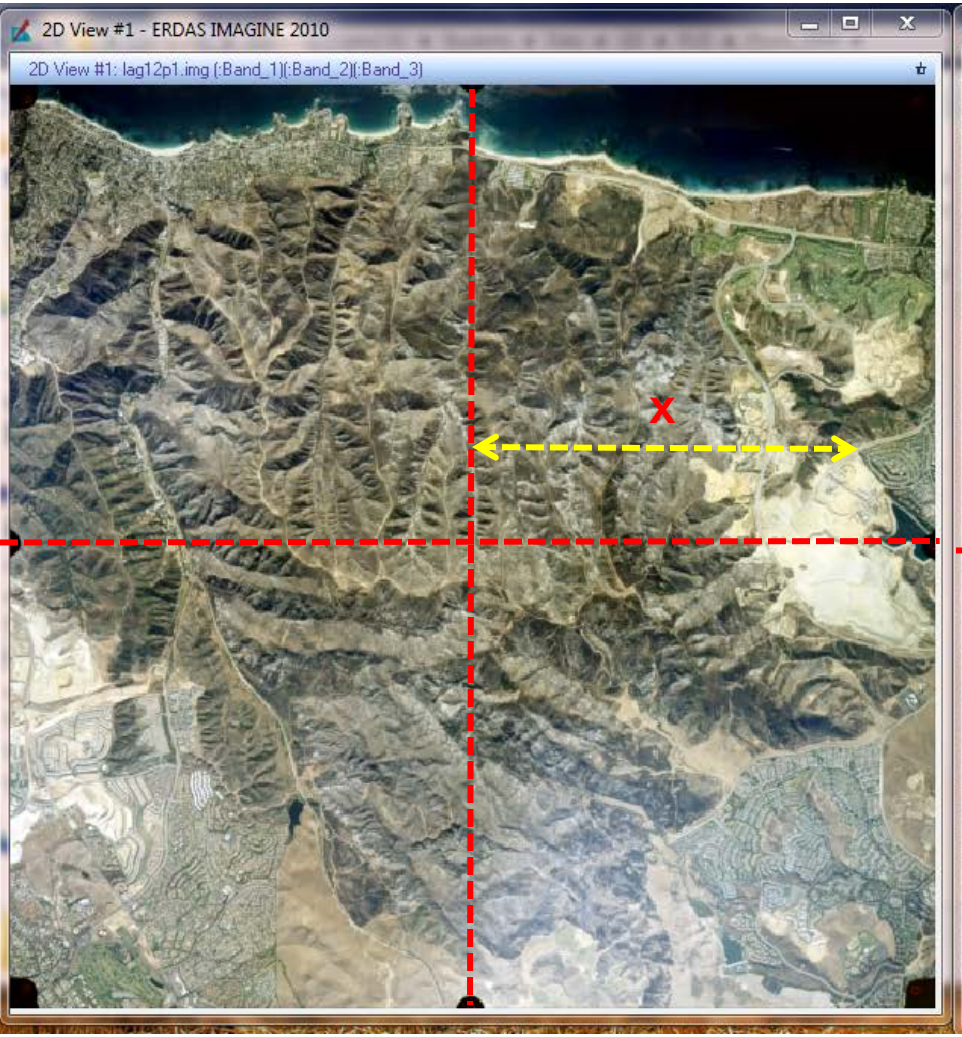
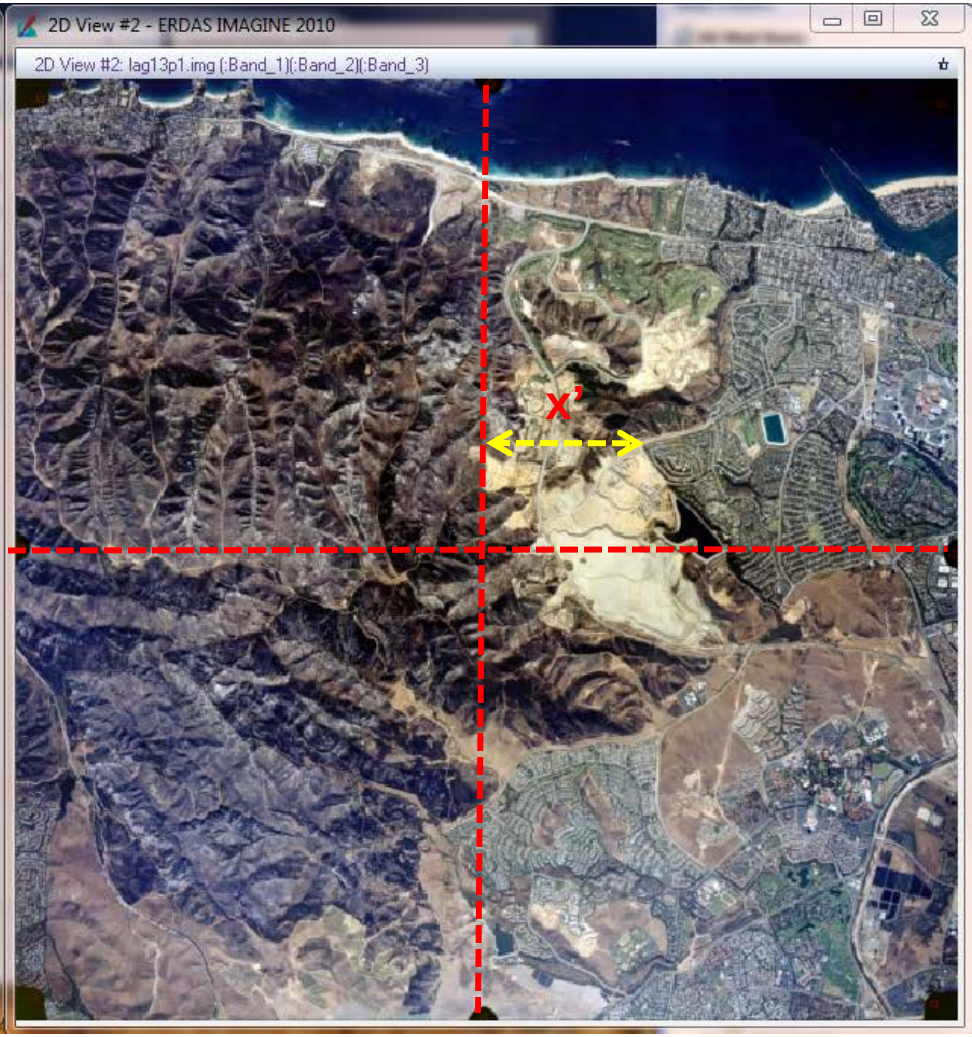



**Figure 190: A Regular Rectangular Block of Aerial Photos**

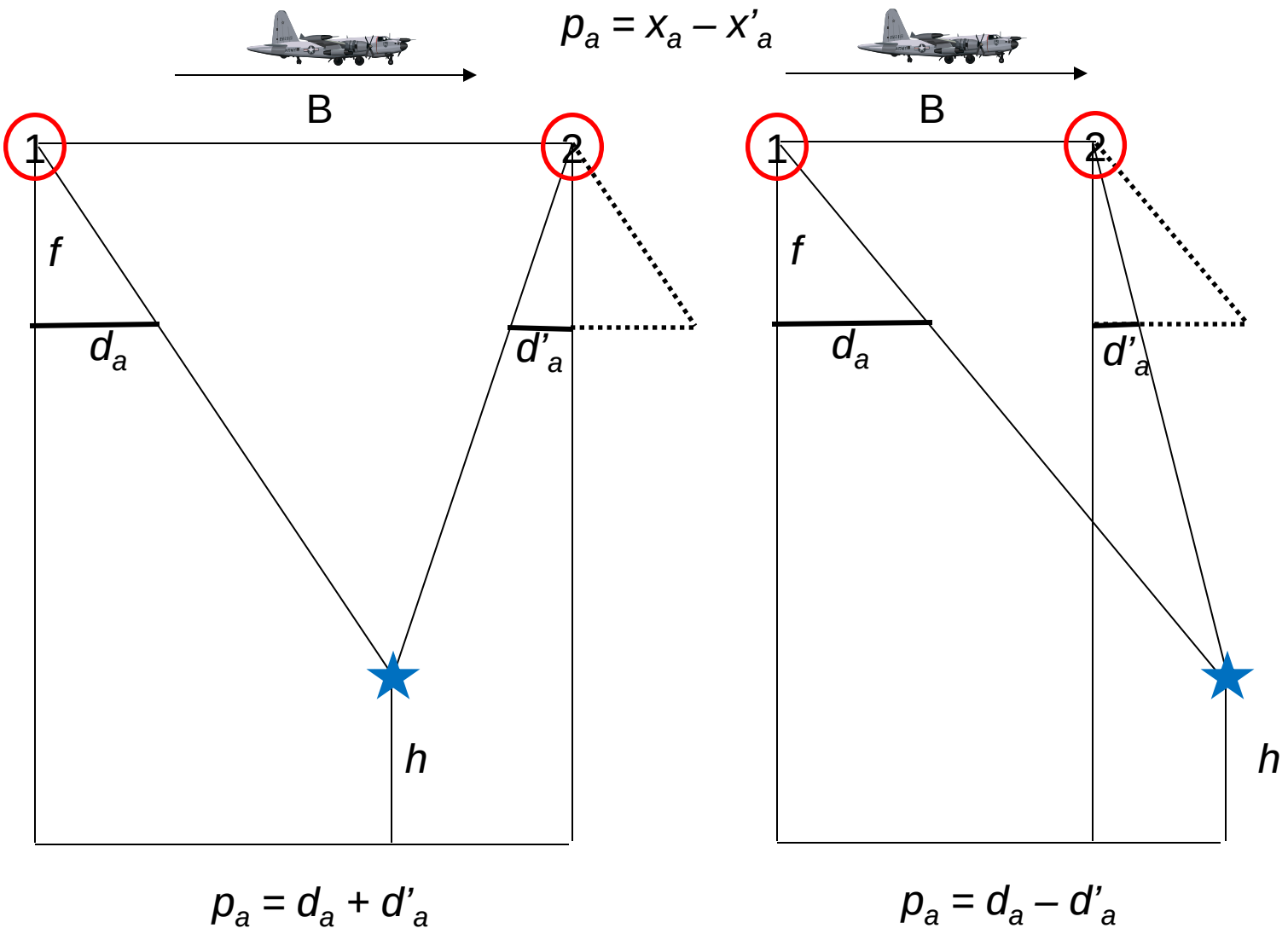



2D View #1 - ERDAS IMAGINE 2010
2D View #1: lag12p1.img (:Band_1)(:Band_2)(:Band_3)
x


2D View #2 - ERDAS IMAGINE 2010
2D View #2: lag13p1.img (:Band_1)(:Band_2)(:Band_3)
x'

$$p_a = x_a - x'_a$$

# Image Parallax




★ Ground Target  (1) Perspective center 1  (2) Perspective center 2

# Calculating Object Height & Location from Parallax

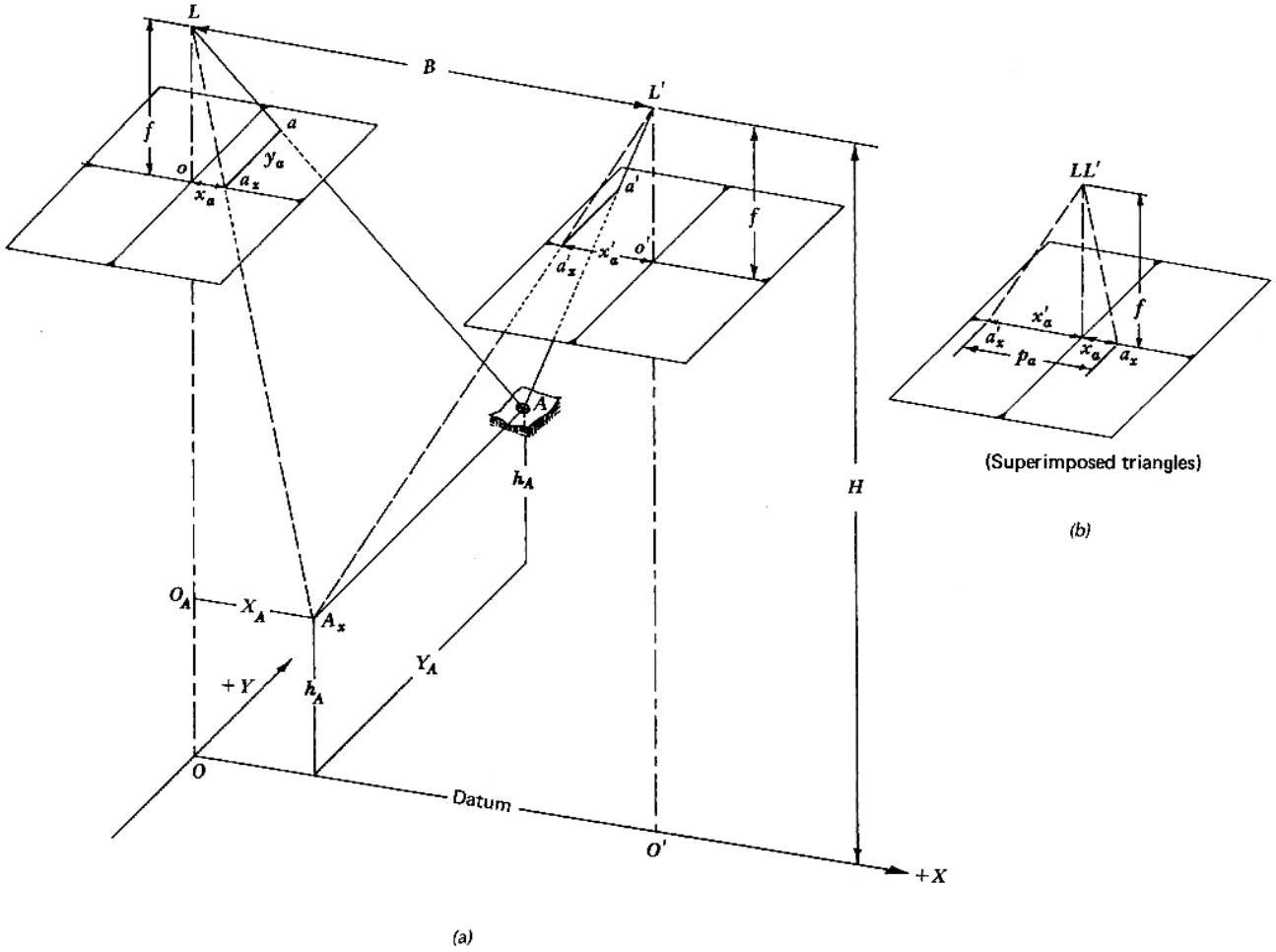



**Figure 3.17** Parallax relationships on overlapping vertical photographs: (*a*) adjacent photographs forming a stereopair; (*b*) superimposition of right photograph onto left.

Parallax Equations:

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

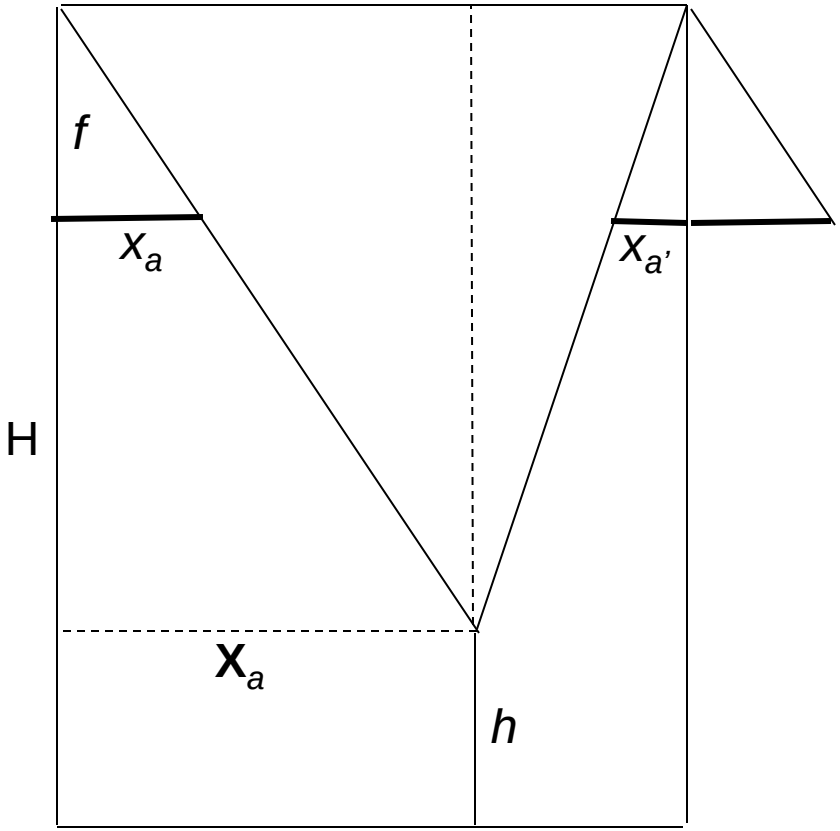
$$X_A = B\frac{x_a}{p_a}$$

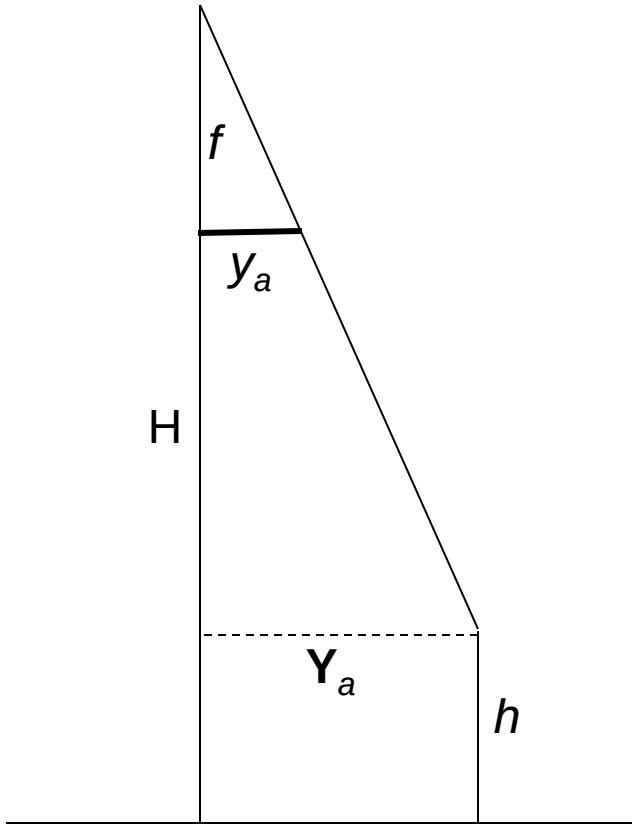
$$Y_A = B\frac{y_a}{p_a}$$

$p_a$ = parallax of A
$x_a$ = x coor of A on left photo
$X_A$ = ground coor of A
$h_A$ = height of A
B = air base
H = flying height

# Values of $\mathbf{X}_a$, $\mathbf{Y}_a$, and $h$?

B



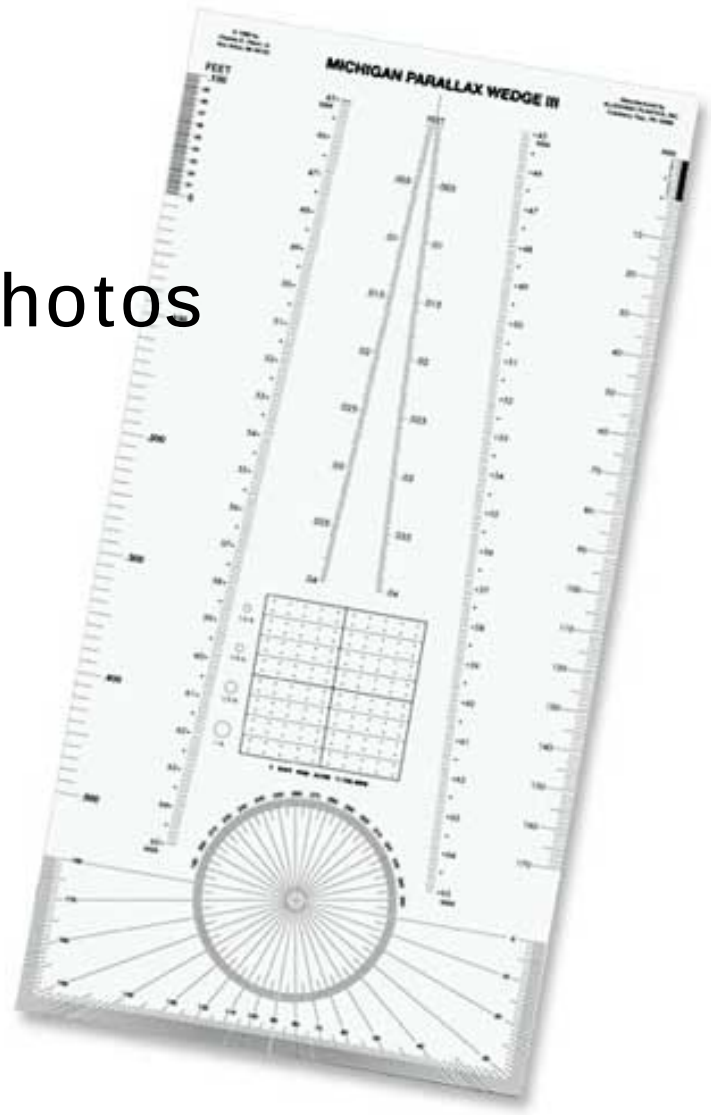

$$\frac{f}{x_a + x_{a'}} = \frac{H - h}{B} \qquad \frac{X_a}{H - h} = \frac{x_a}{f}$$

$$\frac{Y_a}{H - h} = \frac{y_a}{f}$$

# Measuring Parallax

Based on a stereopair of photos

- Floating half marks
- Parallax wedge

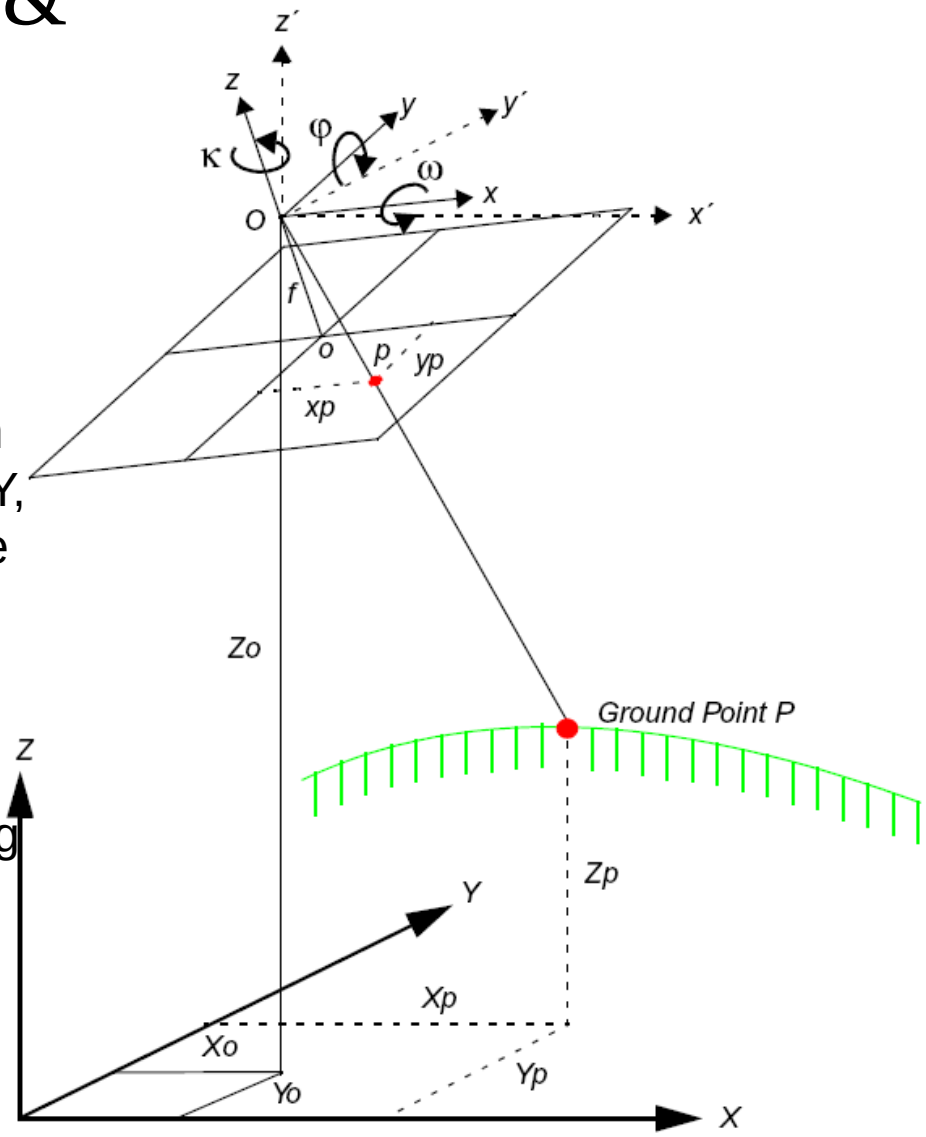


# Digital Photogrammetry:
## Softcopy Photogrammetric Systems

- 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

- Alignment of exposure station (O), object location on the photo (p), and object location on the ground (P).
- 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)



# Photogrammetry / Structure From Motion Software

- VisualSFM (open source) (web)
- Agisoft PhotoScan (web)
  - Standard educational edition $59
  - Professional educational edition $549
- PhotoModeler (web)
  - PhotoModeler $1145
  - PhotoModeler Scanner $2495
  - PhotoModeler Motion $3495