

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
- Photogrammetry
 - Hardcopy vs. softcopy approach
 - Structure from Motion (SfM/PhoDAR)
- 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

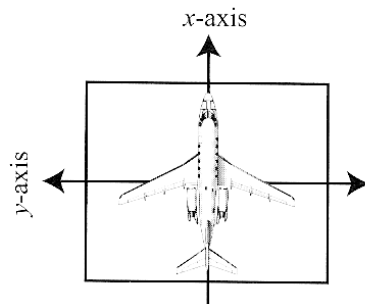
The effects of film shrinkage, atmospheric refraction are usually negligible in most cases.

Geometric Distortions

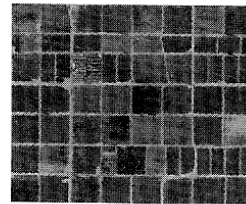
Systematic errors

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

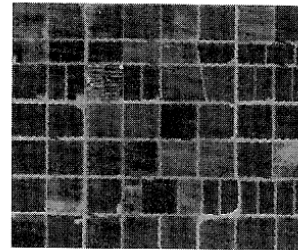
a. Change in Altitude



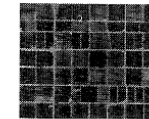
Nominal



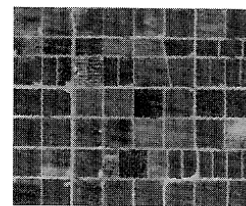
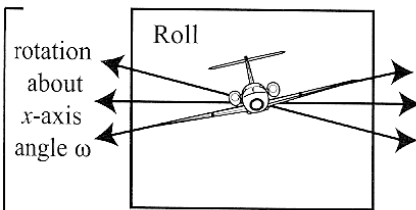
Decrease in altitude
creates larger-scale image



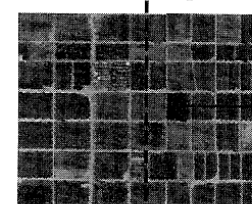
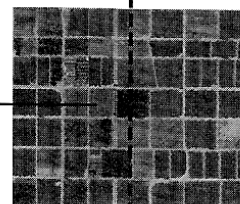
Increase in altitude
creates smaller-scale image



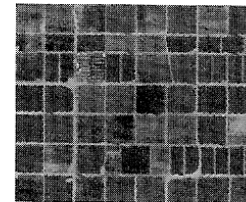
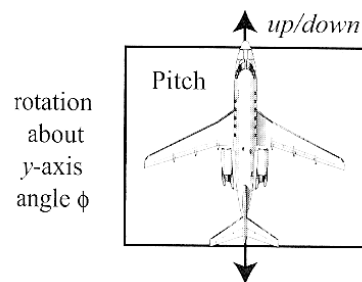
Direction of flight



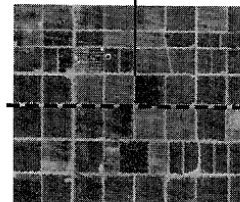
compression expansion expansion compression



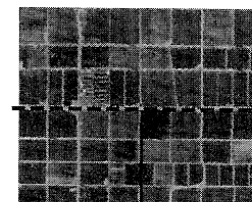
wing
up and
down
motion



nose
down compression
fore



expansion fore

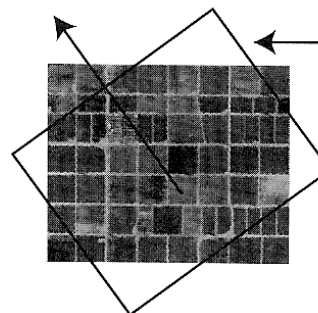
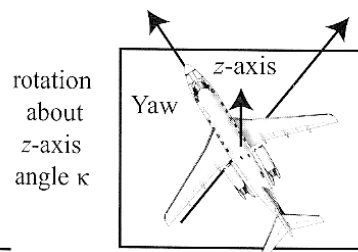


fuselage
up and
down
motion

expansion aft

compression
aft

tail
down

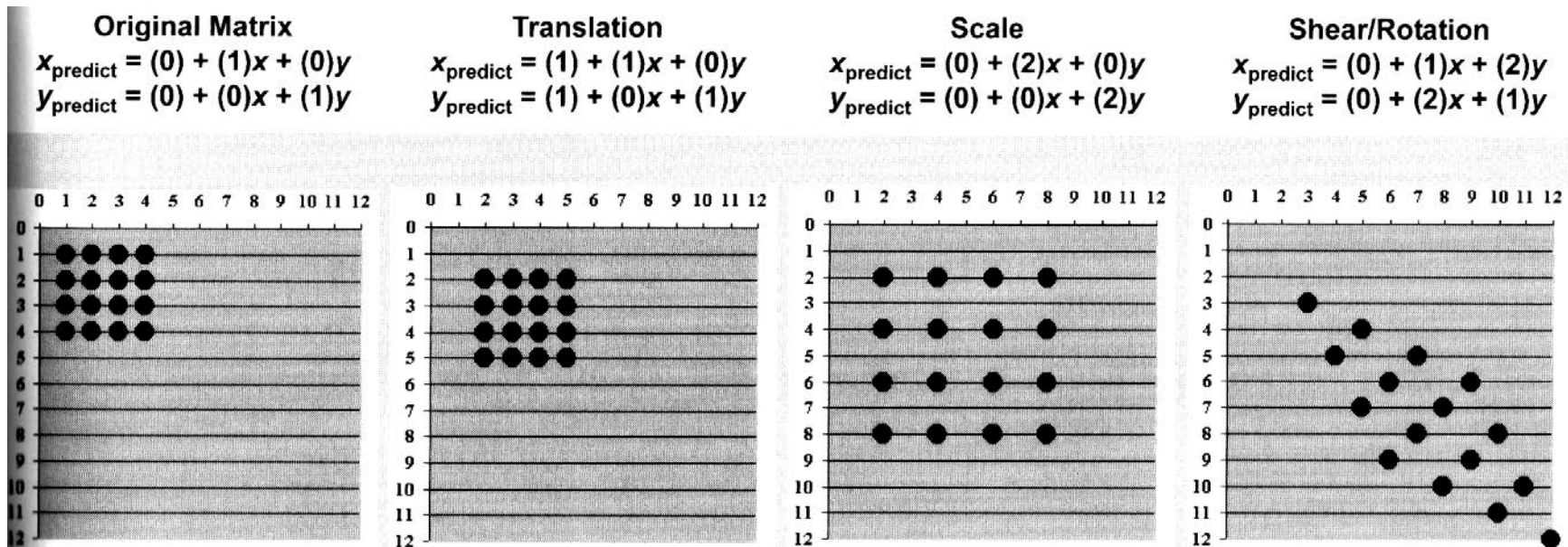


frame of imagery

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



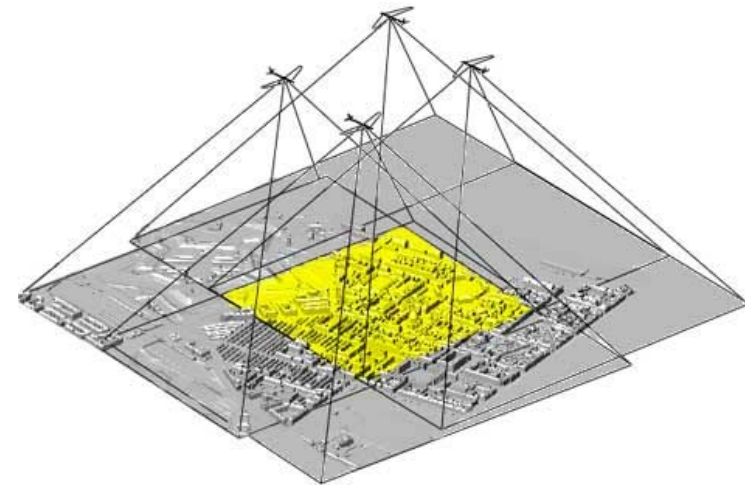
Orthophoto & Ortho-rectification

Orthophotos - orthographic photographs

- Photographs that do not have distortions nor displacements.

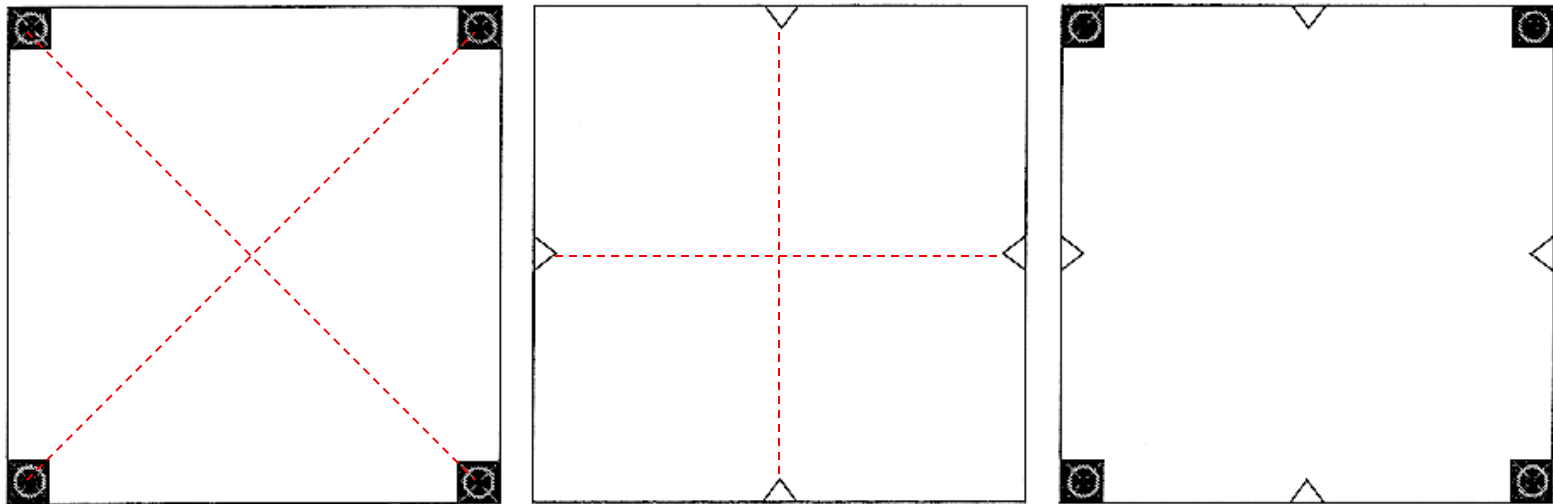
True orthophotos:

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

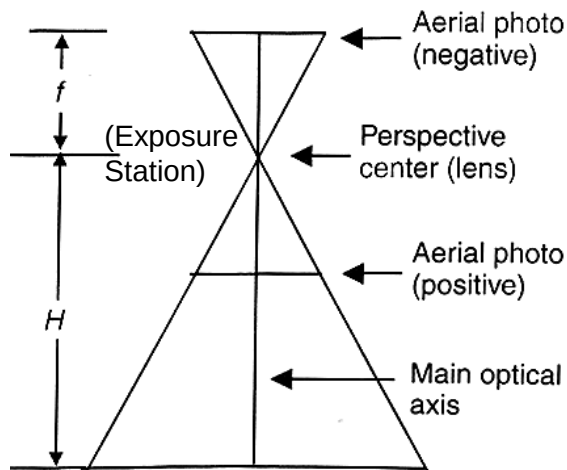


Basic Aerial Photography Geometry

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



Geometric Components of Relief Displacement

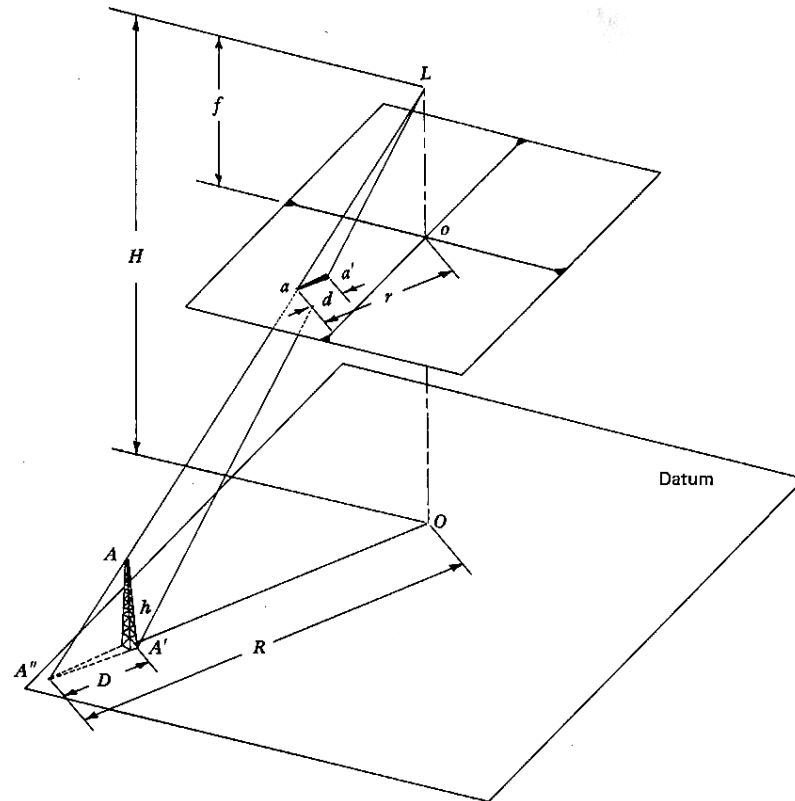


$$\frac{1}{S} = \frac{f}{H}$$

1/S: photo scale

f: focal length of camera

H: flying height



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

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

d = relief displacement

h = object height

r = radial distance between location and PP on photo

H = flying height

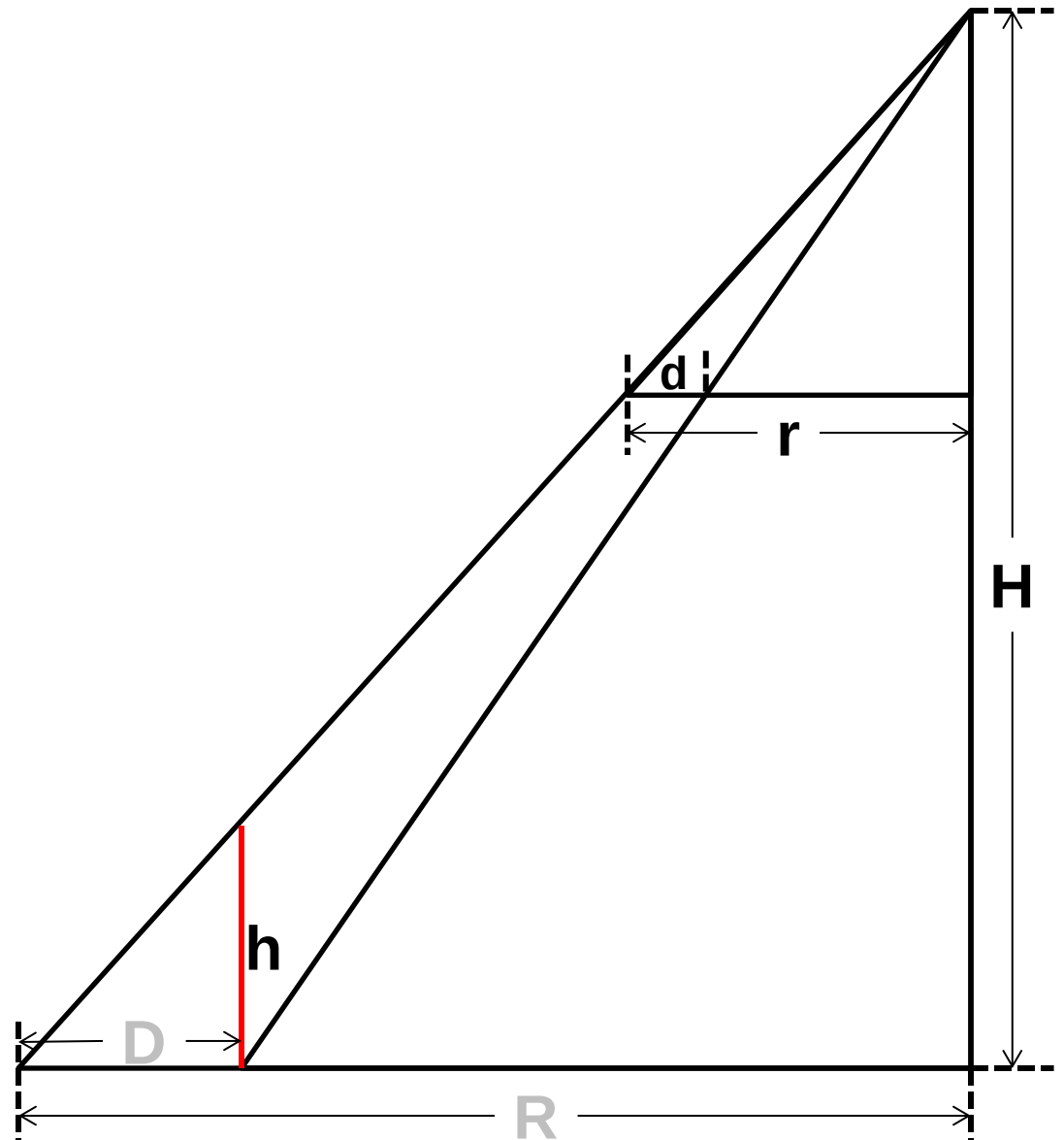
Calculating Relief Displacement

d = relief displacement

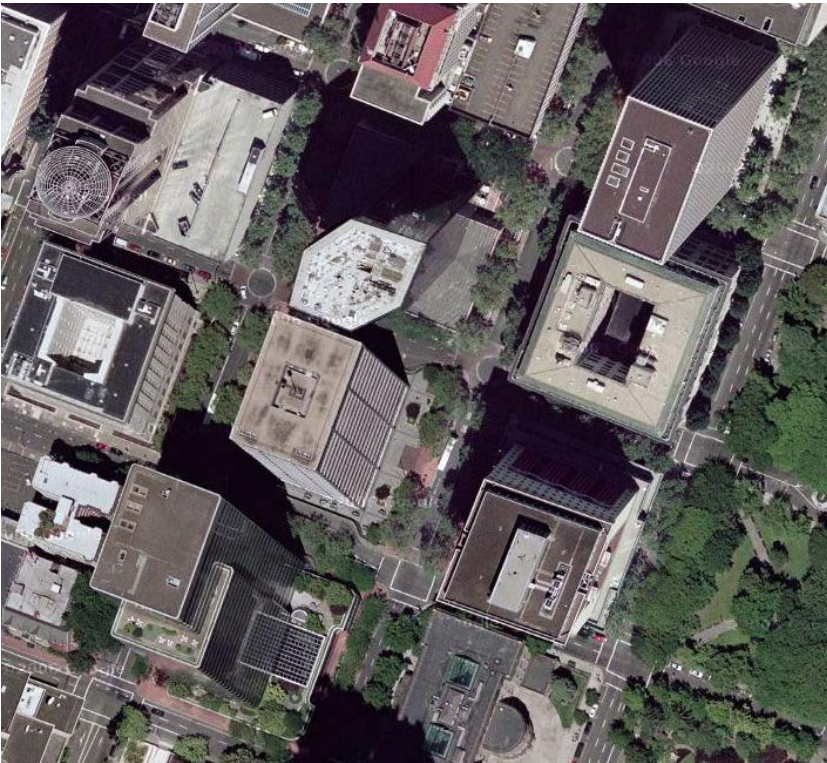
h = object height

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

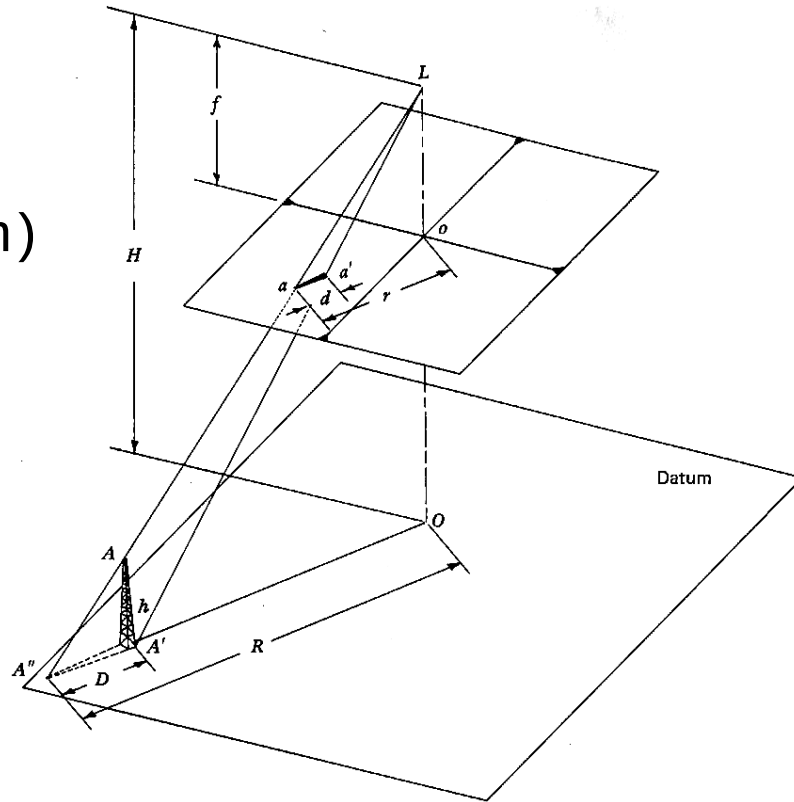
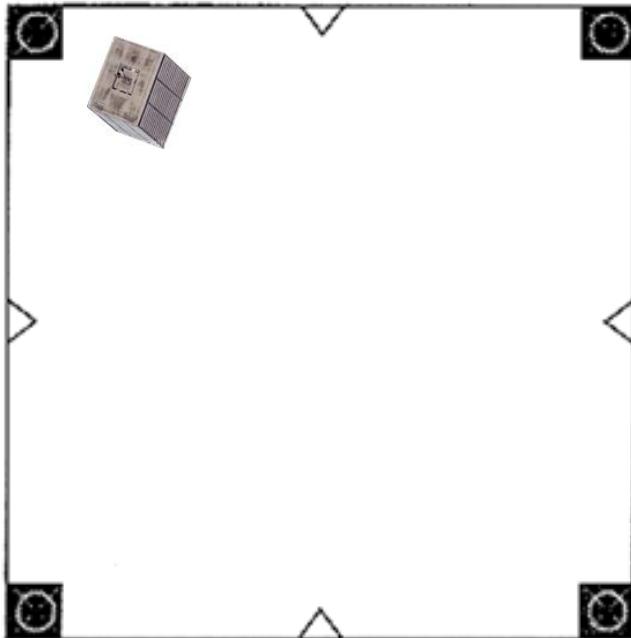
h = object height

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

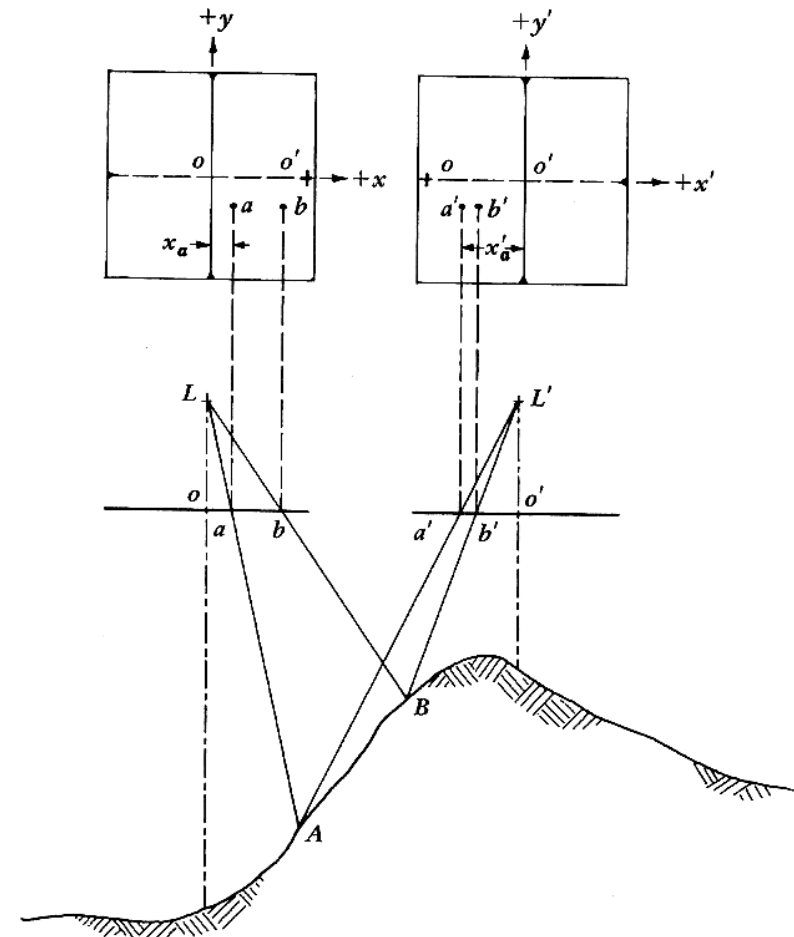


Figure 3.15 Parallax displacements on overlapping vertical photographs.

Figure 189: Exposure Stations Along a Flight Path

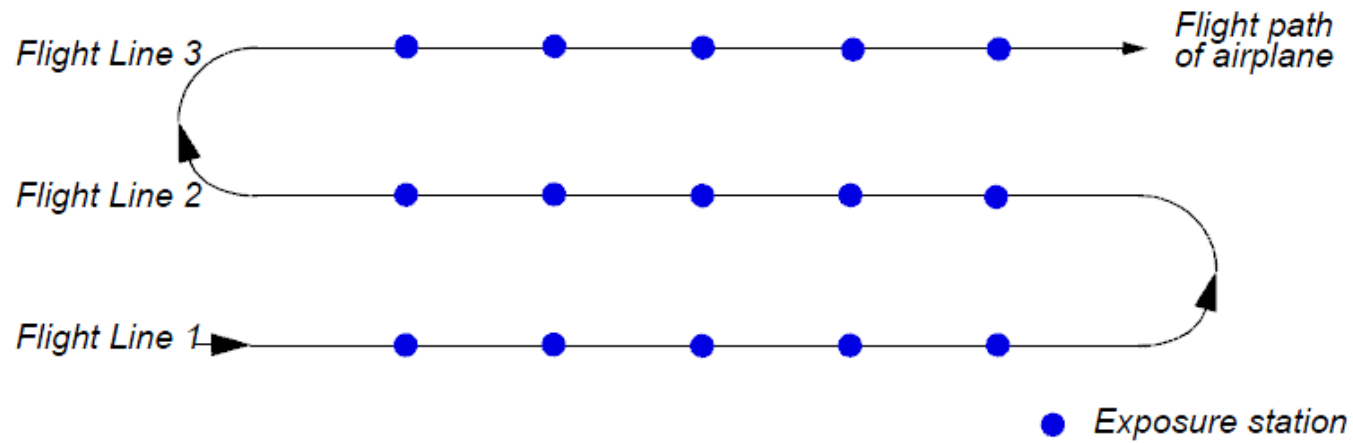
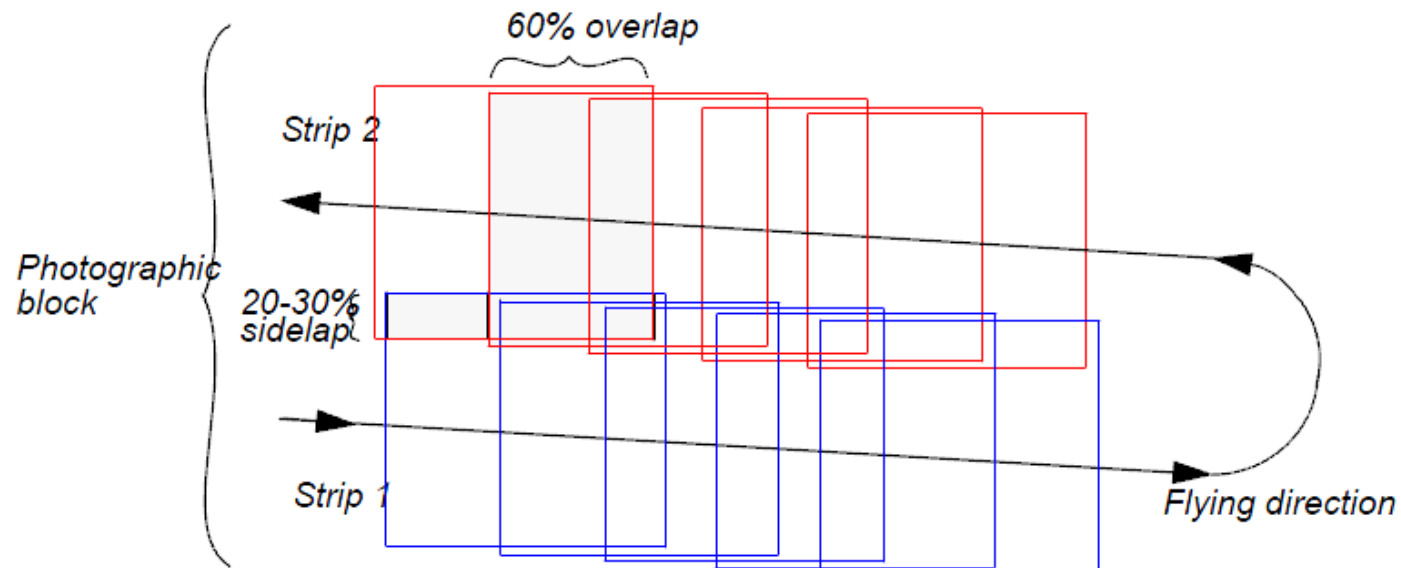
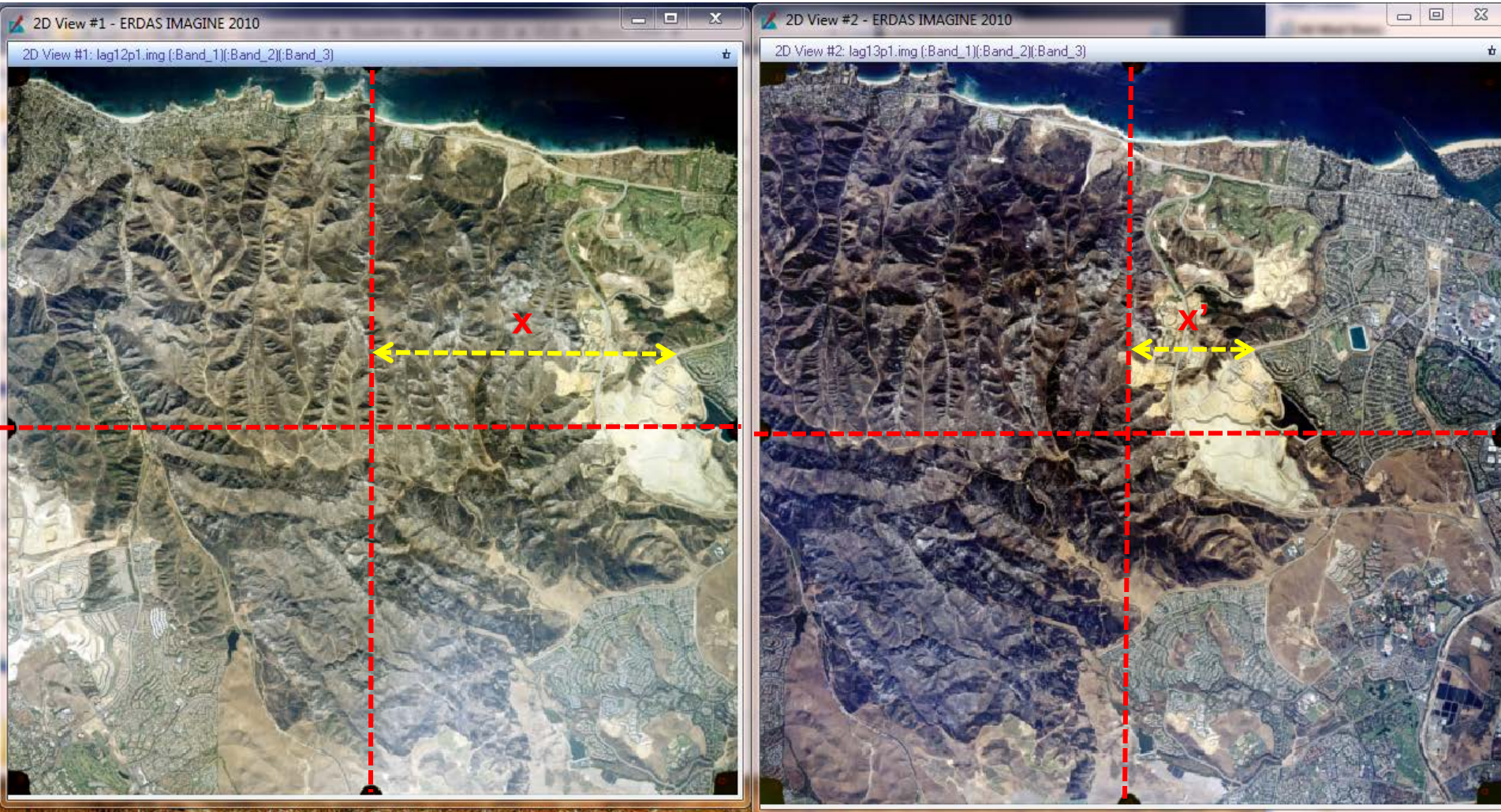


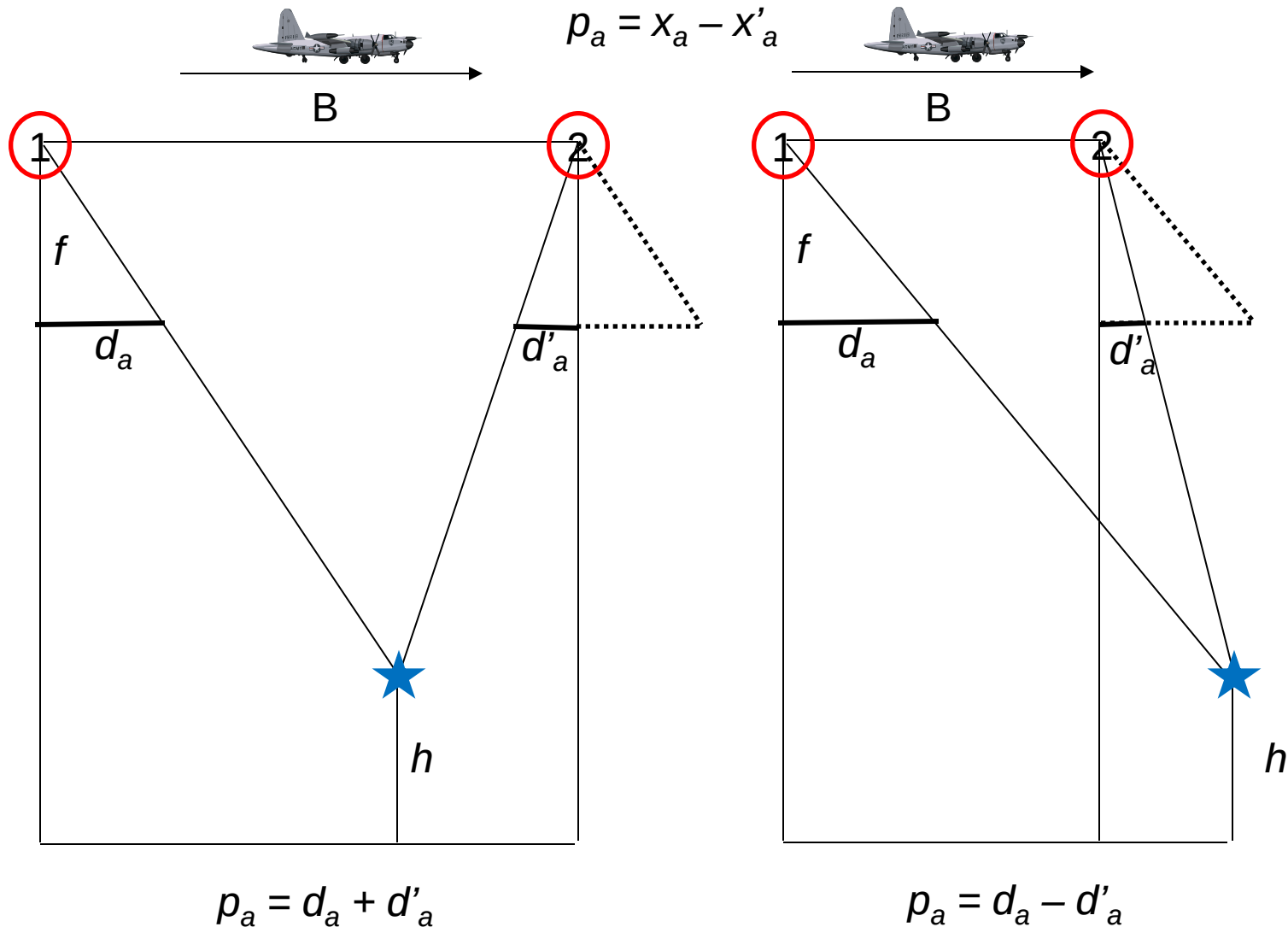
Figure 190: A Regular Rectangular Block of Aerial Photos





$$p_a = x_a - x'_a$$

Image Parallax

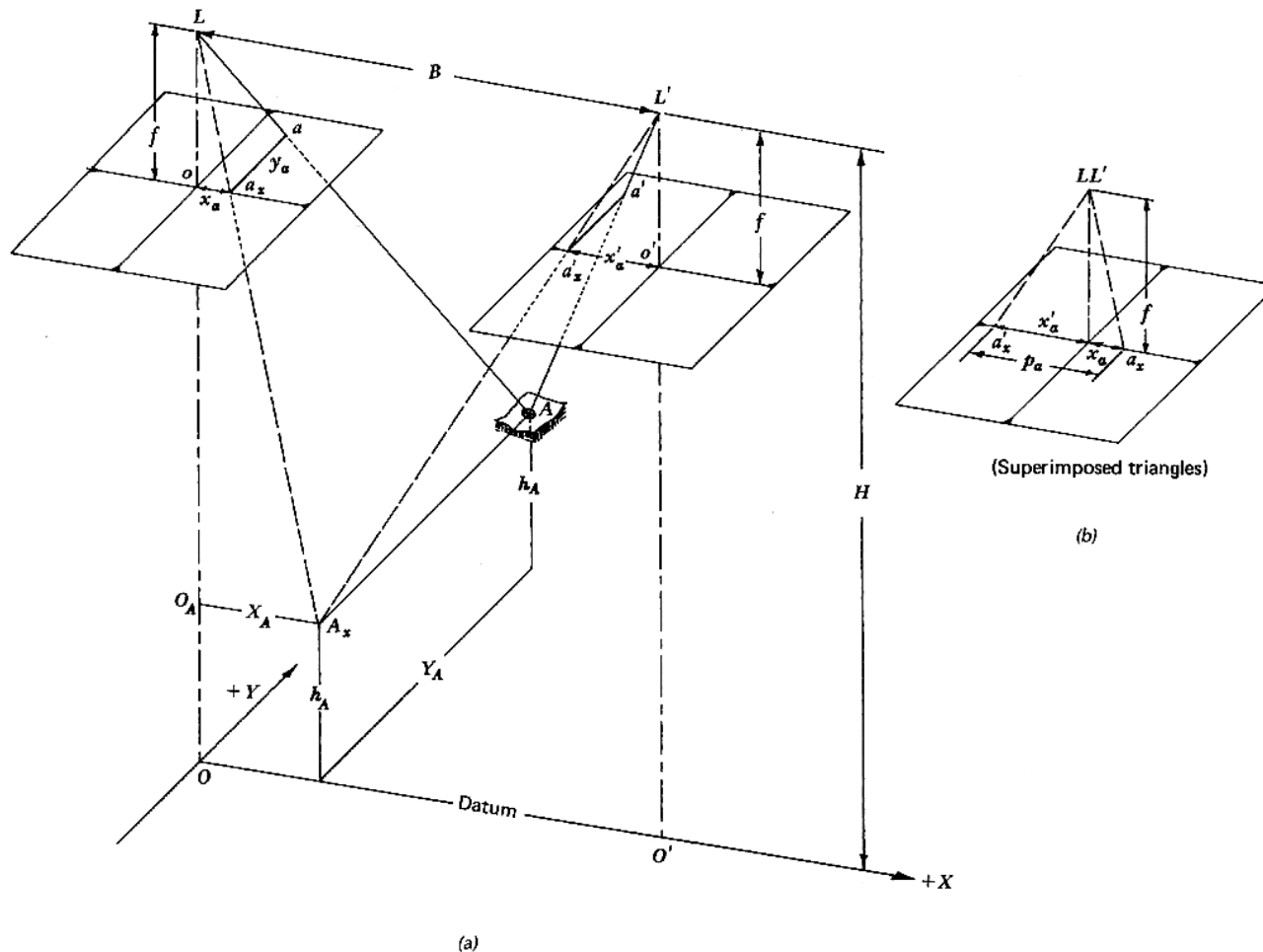


★ Ground Target

① Perspective center 1

② Perspective center 2

Calculating Object Height & Location from Parallax



Parallax Equations:

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

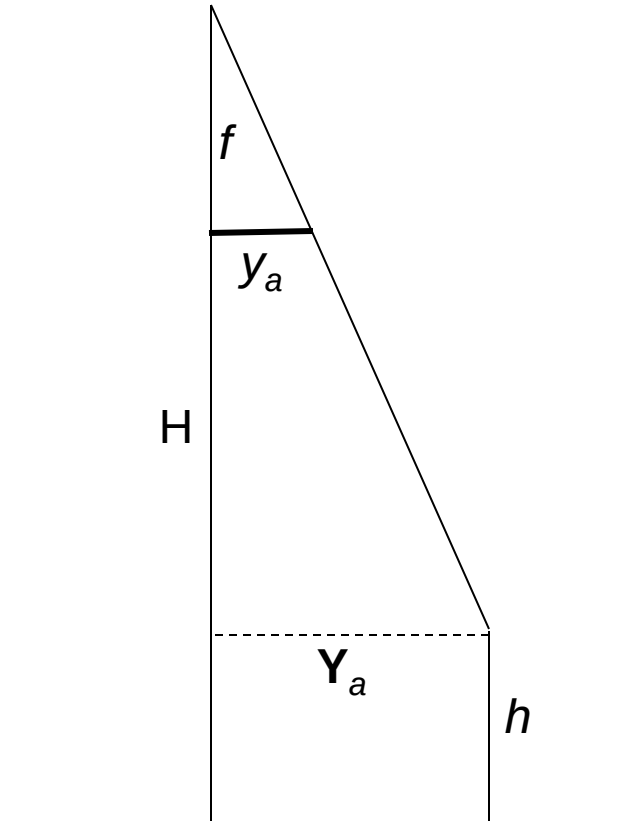
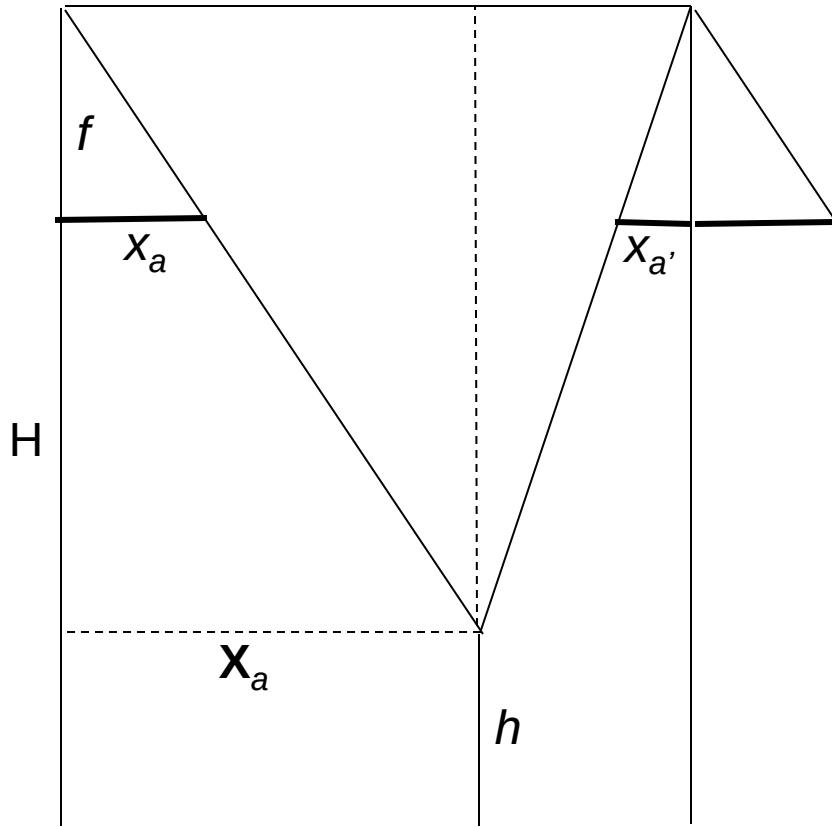
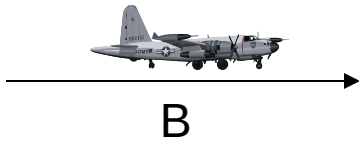
$$X_A = B \frac{x_a}{p_a}$$

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

p_a = parallax of A
 x_a = x coor of A on left photo
 X_A = ground coor 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.

Values of X_a , Y_a , and h ?



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

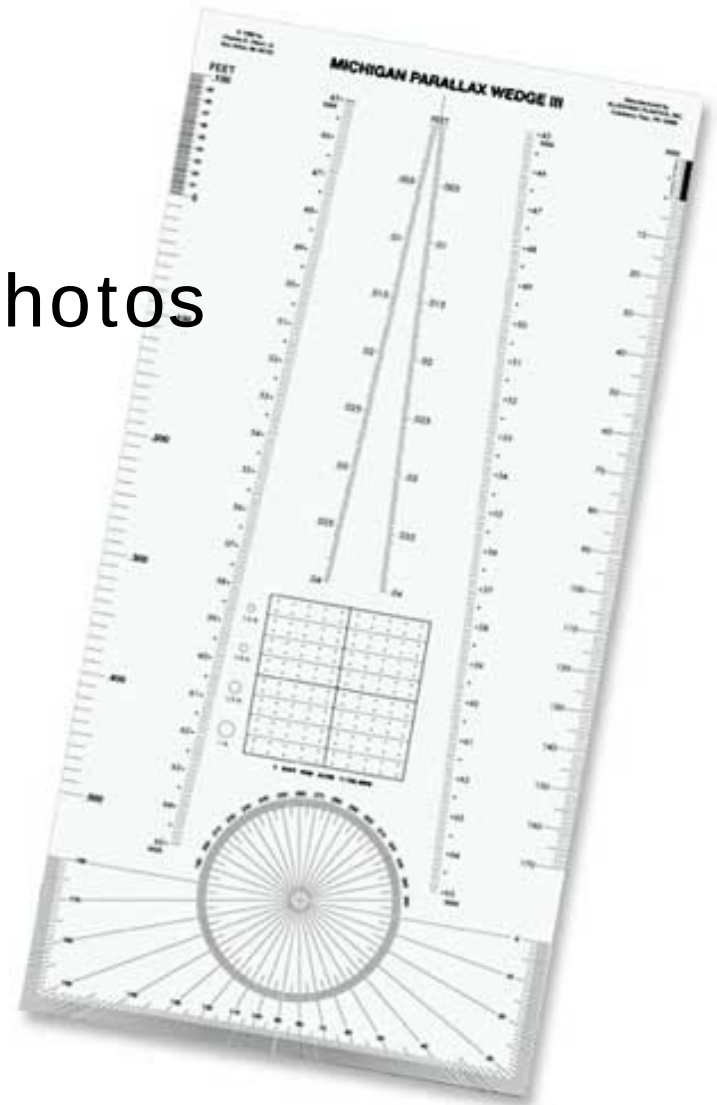
$$\frac{X_a}{H - h} = \frac{x_a}{f}$$

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

Measuring Parallax

Based on a stereopair of photos

- Floating half marks
- Parallax wedge



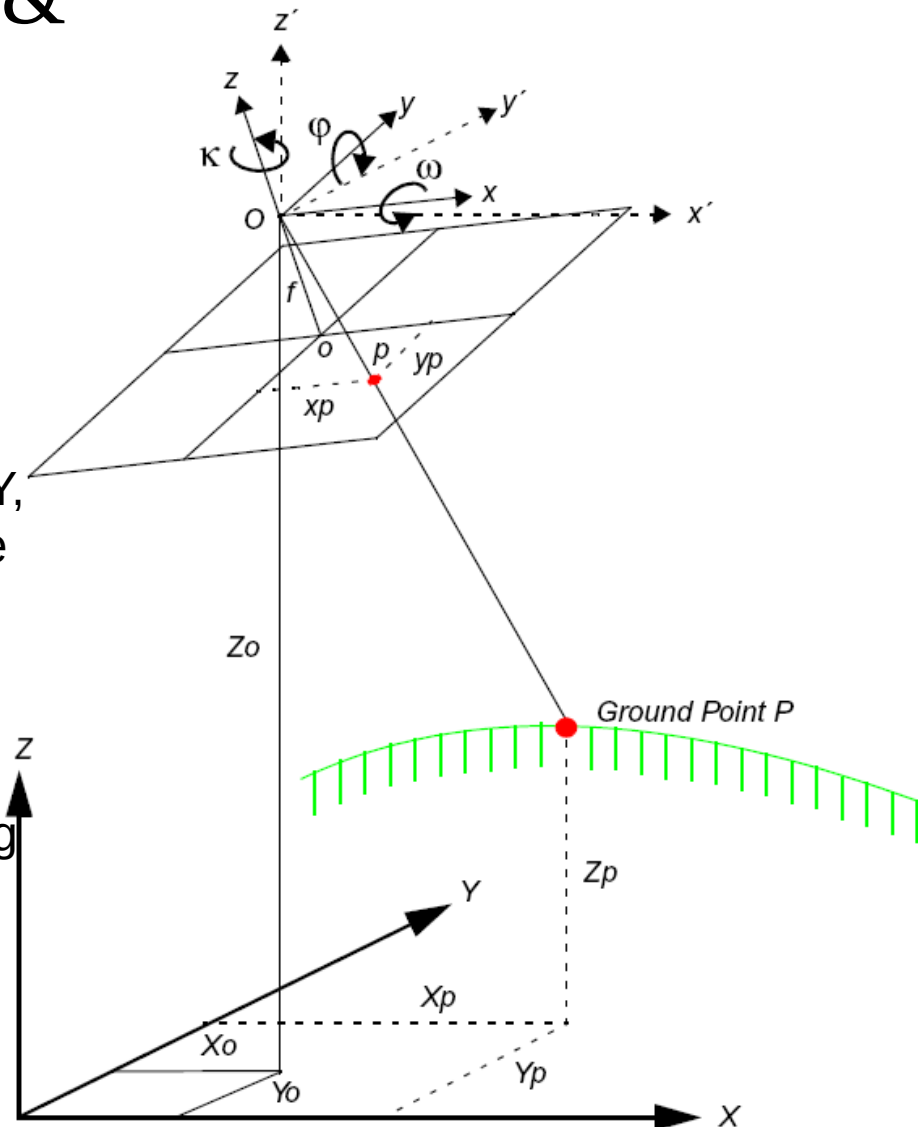
Digital Photogrammetry:

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

<http://www.youtube.com/watch?v=i7ierVkXYa8>