Stereoscopic Models and Measurements

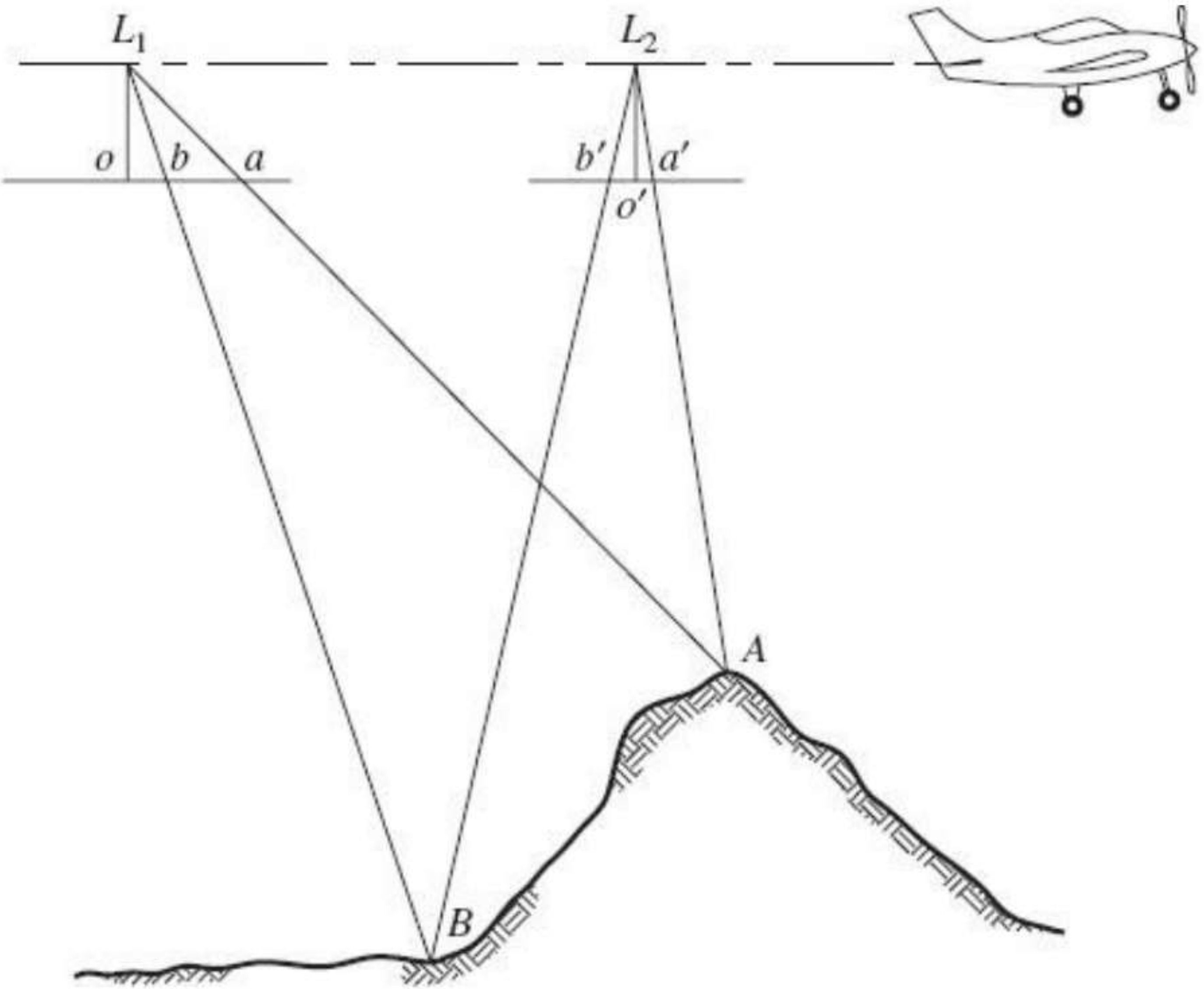
Parallax

Stereo vision

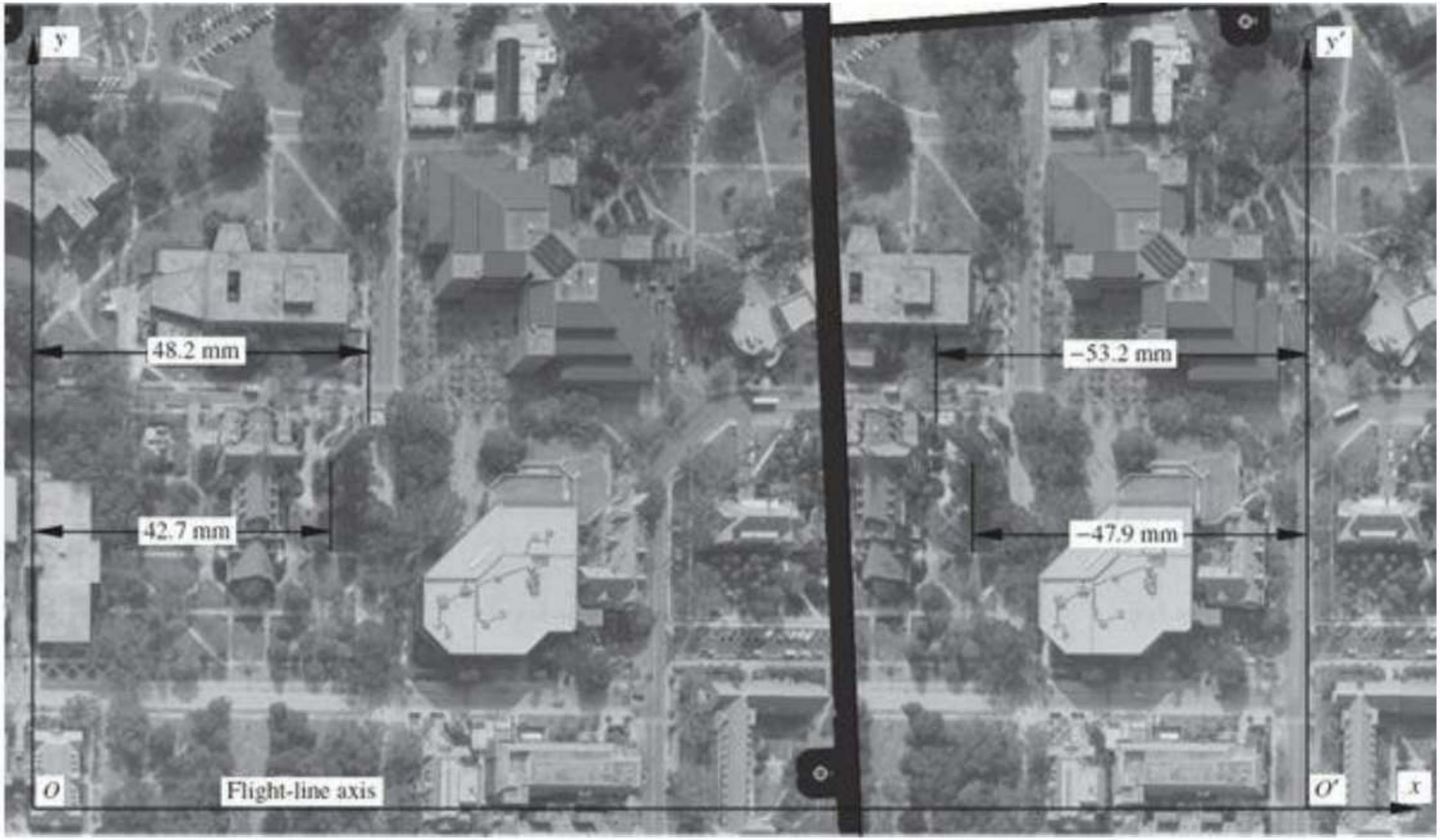
Stereo models

Stereoscopic Parallax

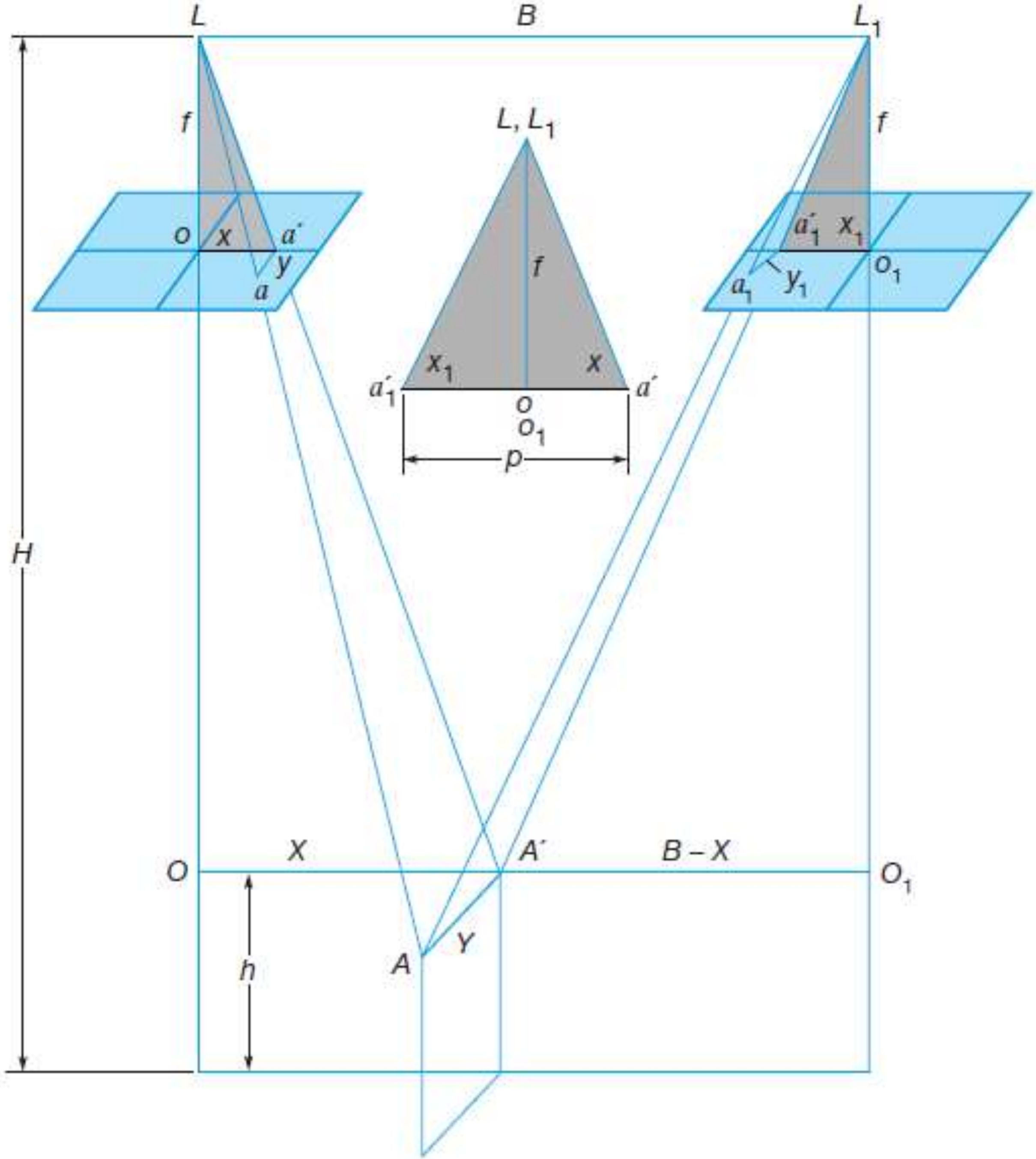
- The apparent displacement of the position of an object wrt a frame of reference due to a shift in the point of observation, try it.
- The shift is along the line of movement.
- The closer the object to the frame, the larger the shift, so parallax is a function of height.



Stereoscopic parallax of vertical aerial photographs.



y
48.2 mm
42.7 mm
O
Flight-line axis
y′
−53.2 mm
−47.9 mm
O′
x



$$\frac{f}{H-h} = \frac{P}{B}$$

Parallax equations

What is (x) ?

Parallax (p) = $x - x_1$

$$H\text{-}h = \frac{Bf}{p}$$

get the flying height or point elevation

$$X = \frac{B}{p}x \qquad Y = \frac{B}{p}y$$

get ground coordinates

Example (1)

A pair of overlapping vertical photographs was taken from a flying height of 1233 m above sea level with a 152.4-mm-focal-length camera. The air base was 390 m. With the photos properly oriented, flight-line coordinates for points a and b were measured as $x_a = 53.4$ mm, $y_a = 50.8$ mm, $x_a' = -38.3$ mm, $y_a' = 50.9$ mm, $x_b = 88.9$ mm, $y_b = -46.7$ mm, $x_b' = -7.1$ mm, $y_b' = -46.7$ mm. Calculate the elevations of points A and B and the horizontal length of line AB.

Answer

Example (2)

An overlapping pair of vertical photographs taken with a 152.4-mm-focal-length camera has an air base of 548 m. The elevation of control point A is 283 m above sea level, and the parallax of point A92.4 mm. What is the flying height above sea level for this stereopair?

Answer

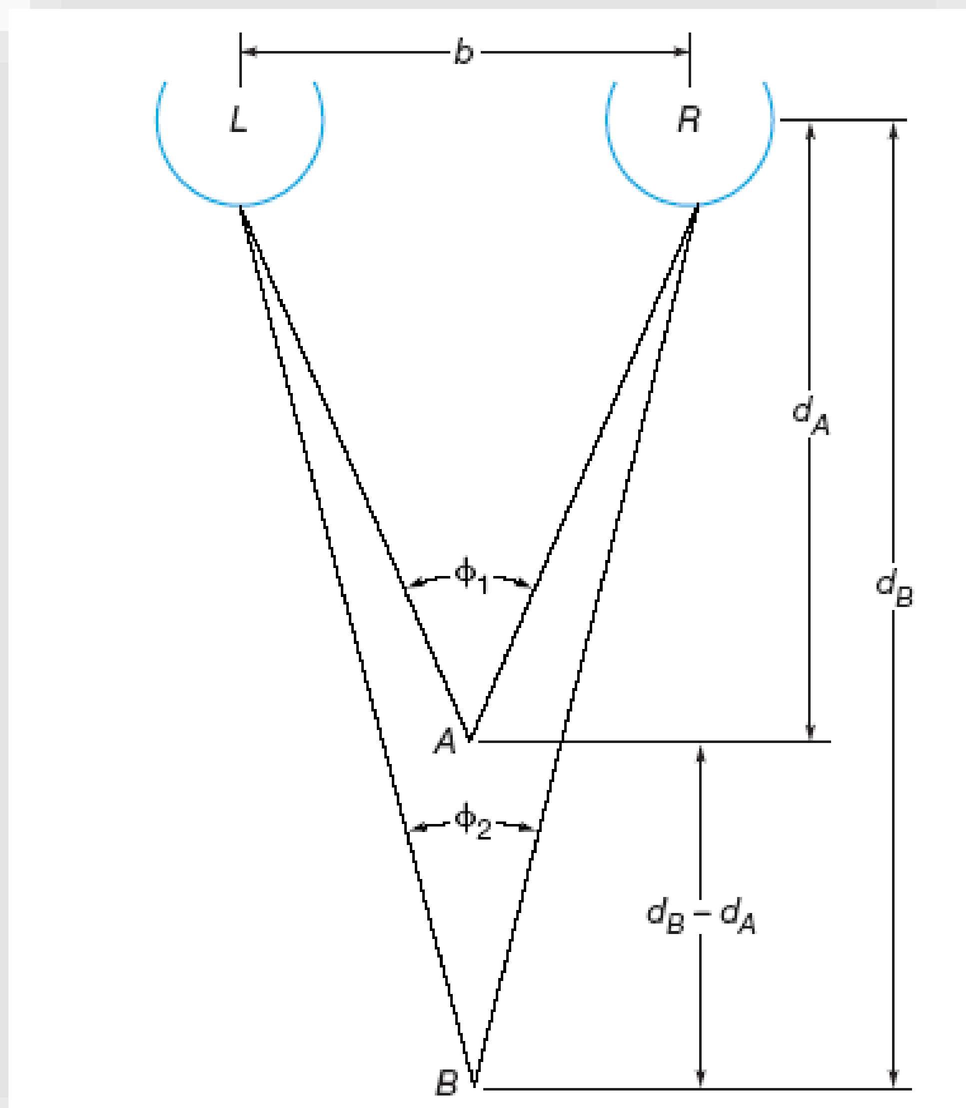
$$H = h + \frac{Bf}{p}$$

$$= (1622 - 263)\frac{86.3}{152.4}$$

$$= 77\bar{0} \text{ m}$$

Stereoscopic Viewing

- The two eyes are separated by 63 to 68mm (eye base), and each views an object from a slightly different direction. The angle formed by the two viewing rays at an object



Stereoscopic Viewing

- The eye converges on the object or area viewed. This is achieved by changing the direction of the eye balls with the muscles. The eyes then focus on the object by changing the shape of the lens.
- The image distance of the eyes is fixed (about 23mm) while the focal length is varies as the shape of the lens changes, to satisfy the lens equation.
- The instantaneous field of view of the eye, where it has a complete sharpness of vision is only 1o to 2°, while the total field of view covered by scanning movements, is about 170° (panoramic).
- is the parallactic angle 'Y (

Stereoscopic Viewing

- The theory of stereoscopic viewing and parallactic angles
- Conditions for viewing a stereo model:
  - See the same point from two locations
  - Separately
  - At, or almost at, the same time.

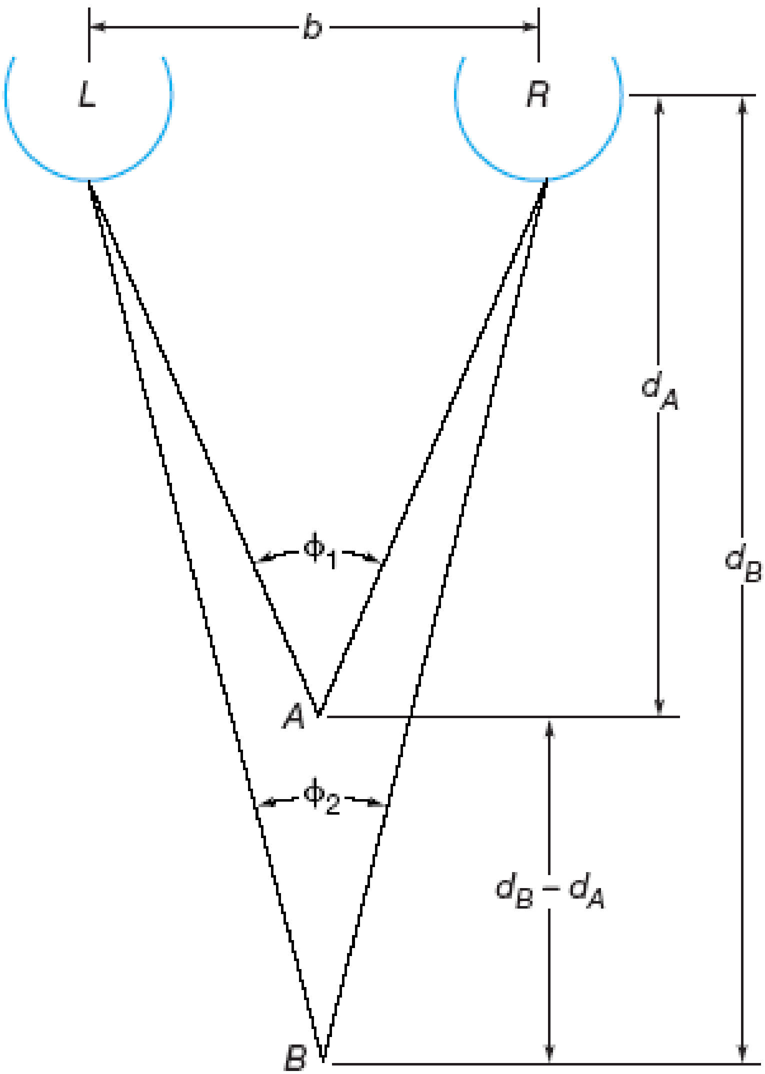
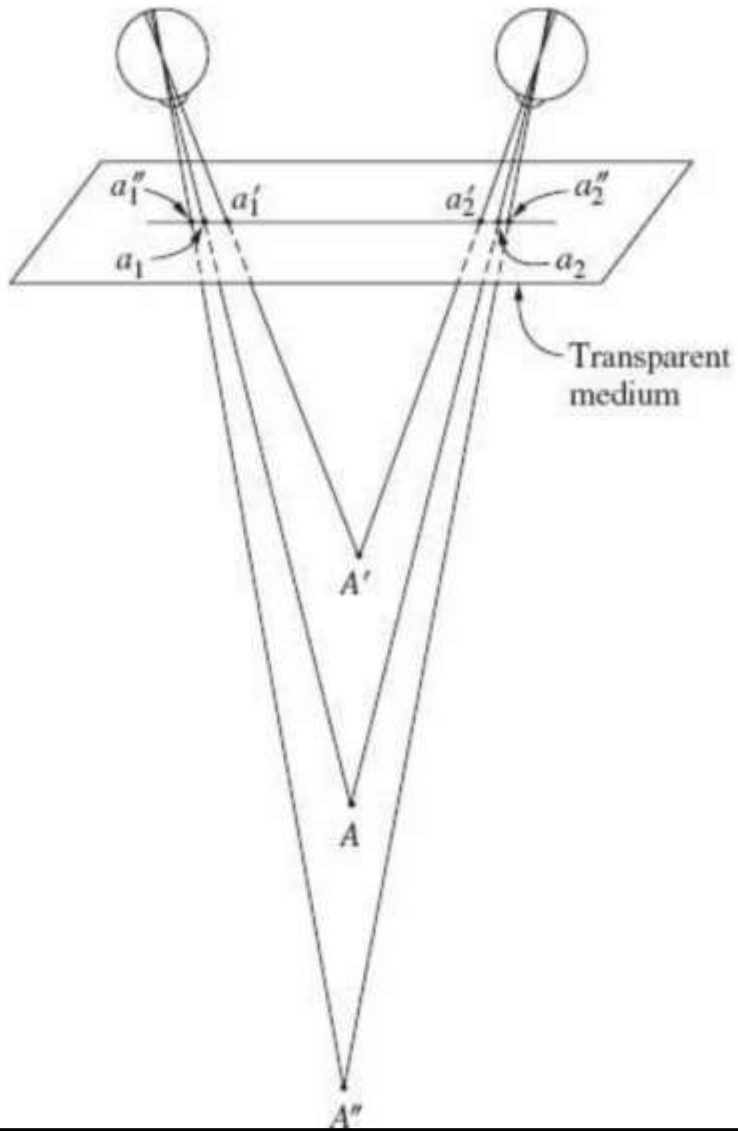
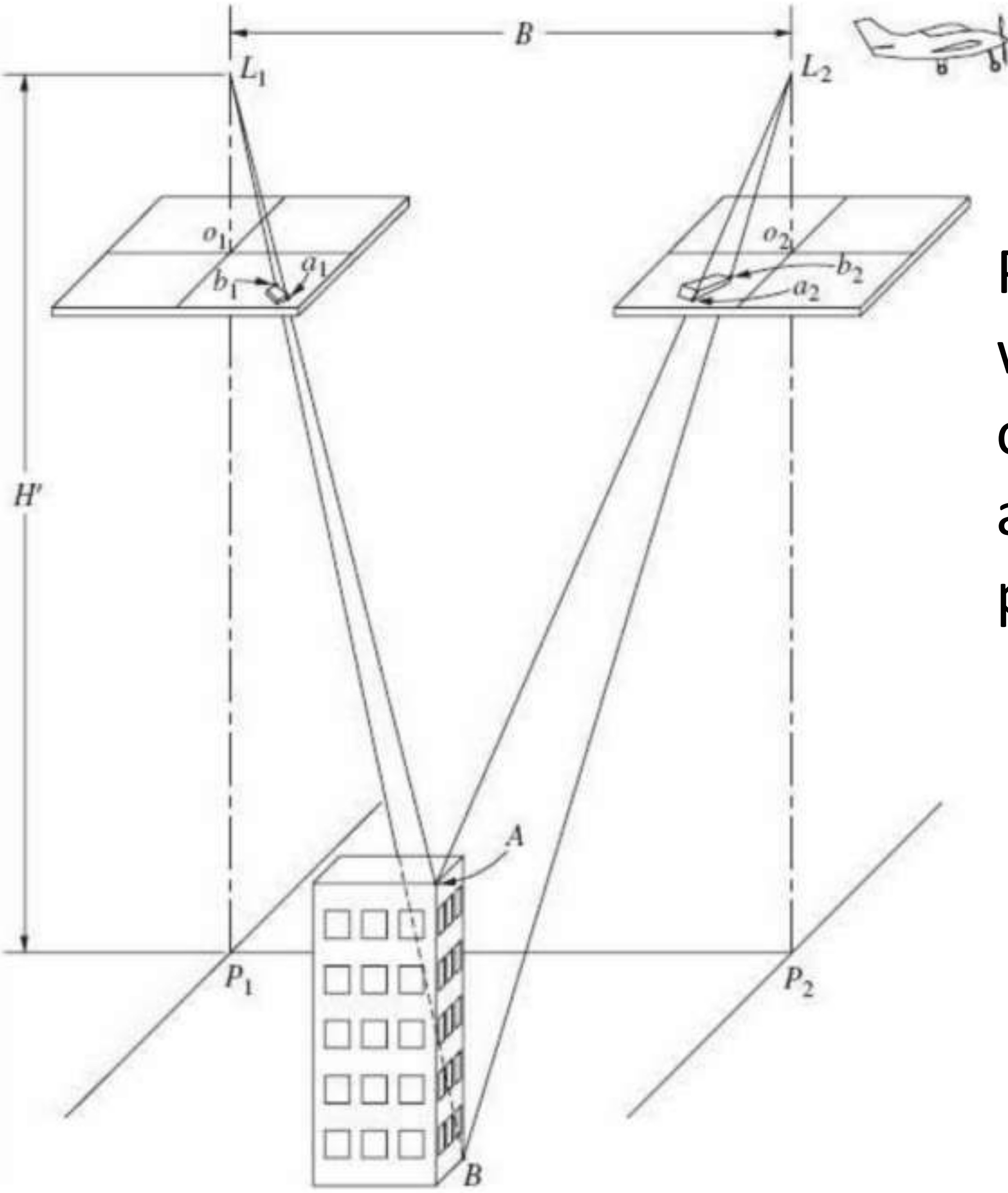


Figure 27–11 Parallactic angles in stereoscopic viewing.

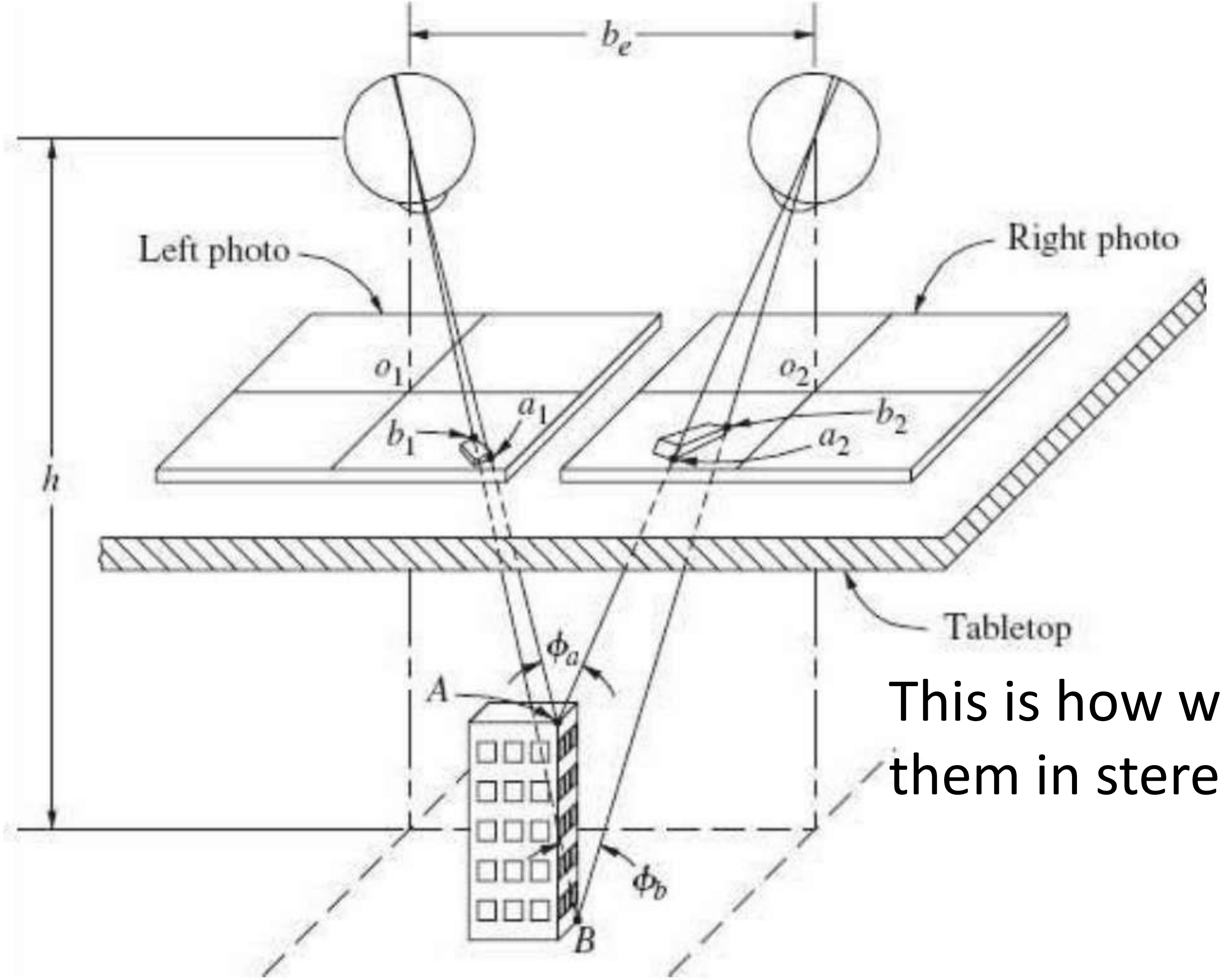
Stereoscopic Viewing



How do we fool our brain to see stereo (3D) from two photos that were taken from the same object form two different positions at the same time?

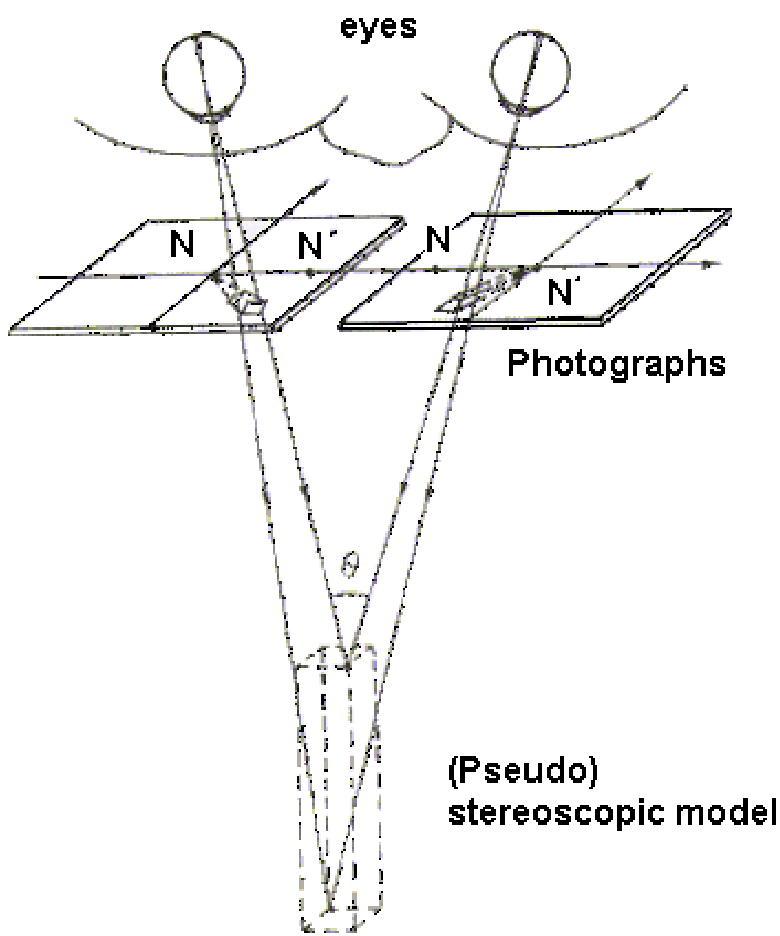


Photos are taken, in which the same object (building) appears in two photos



This is how we see them in stereo

Stereo Model



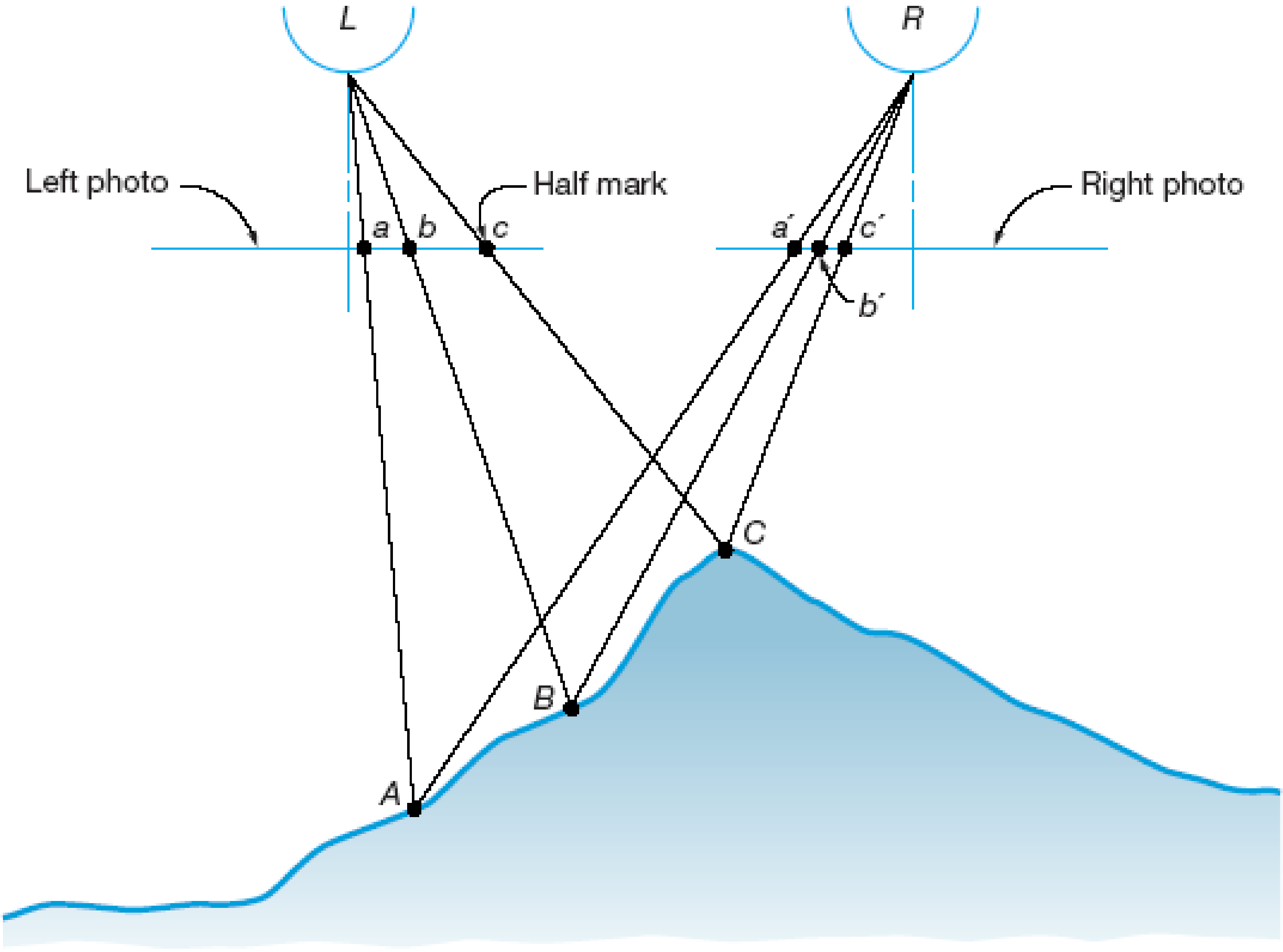
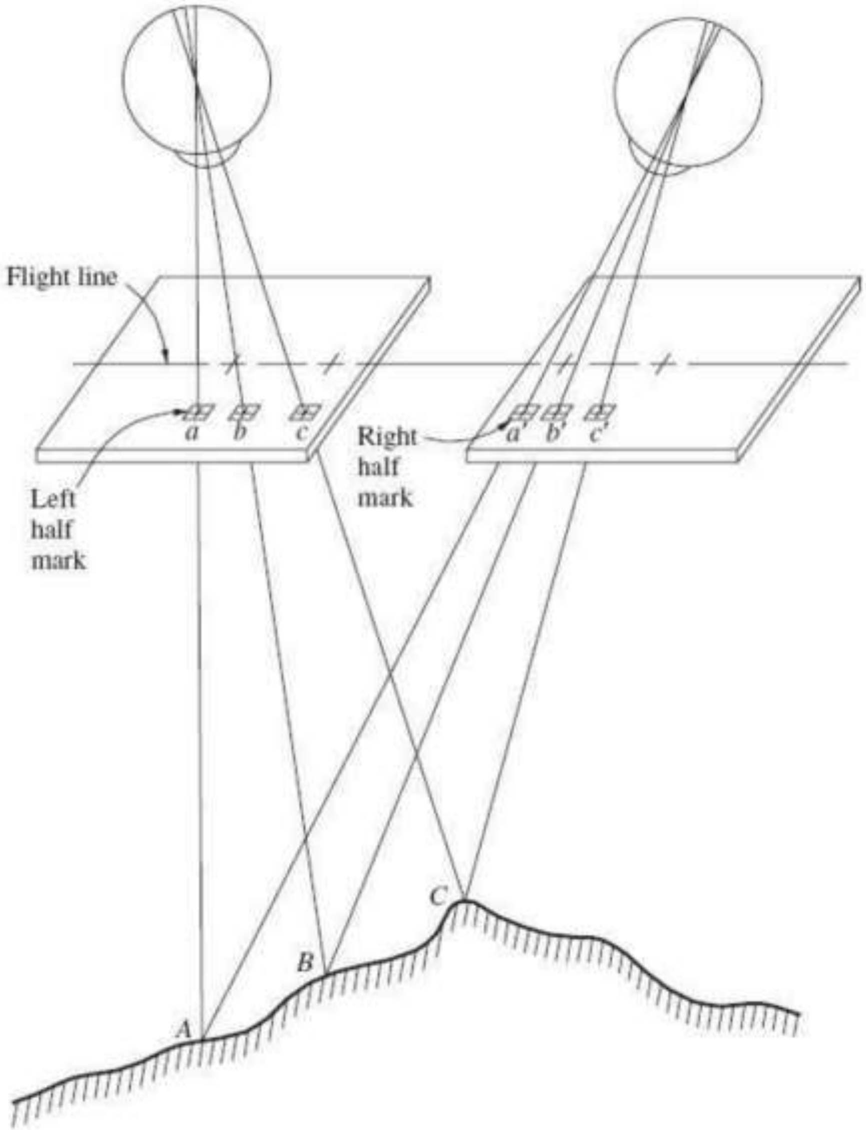


Figure 27–13 Principle of the floating mark.



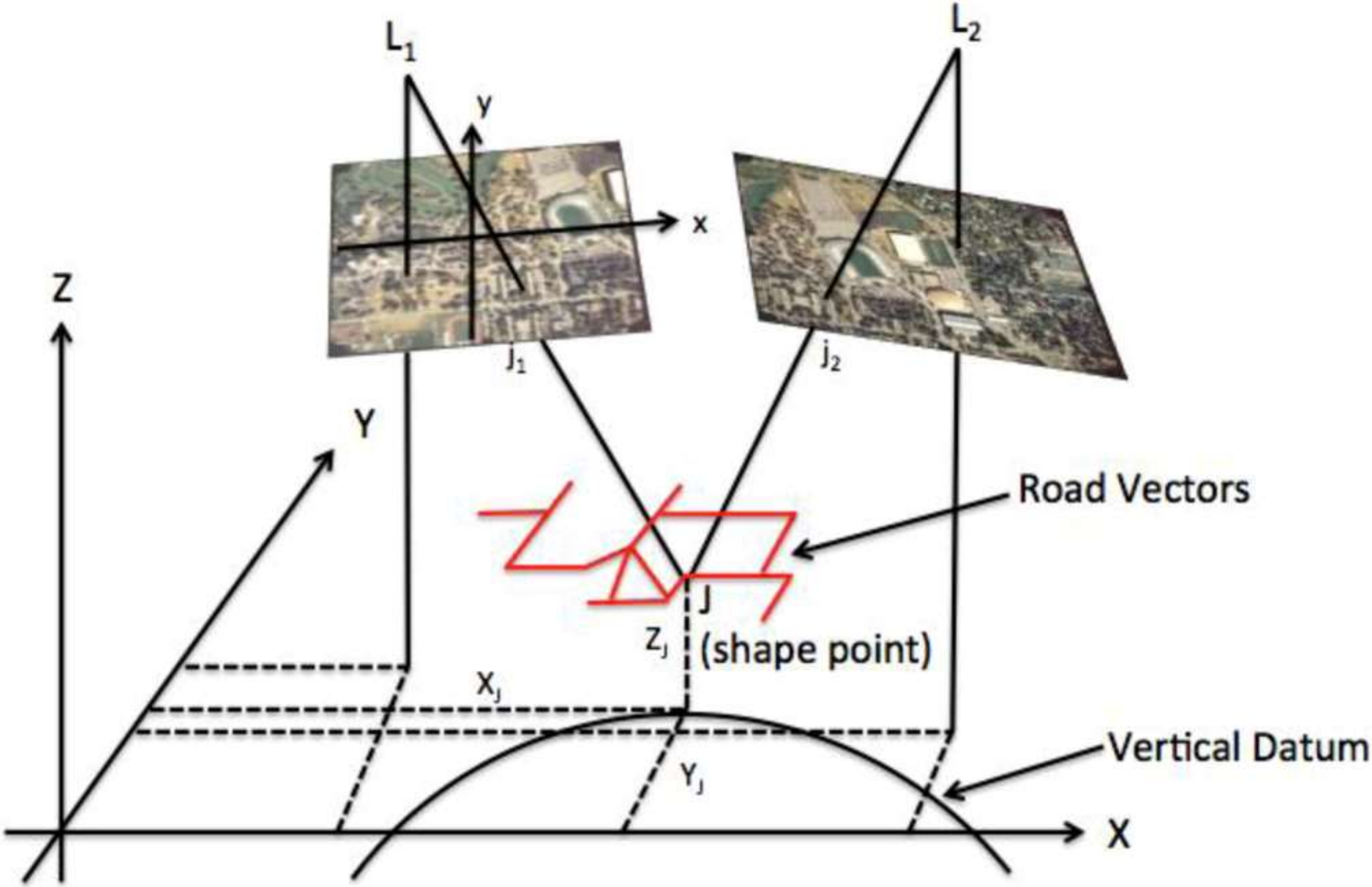
The principle of the floating mark.

Stereoscopic Vision Demo

Photogrammetric Workstations

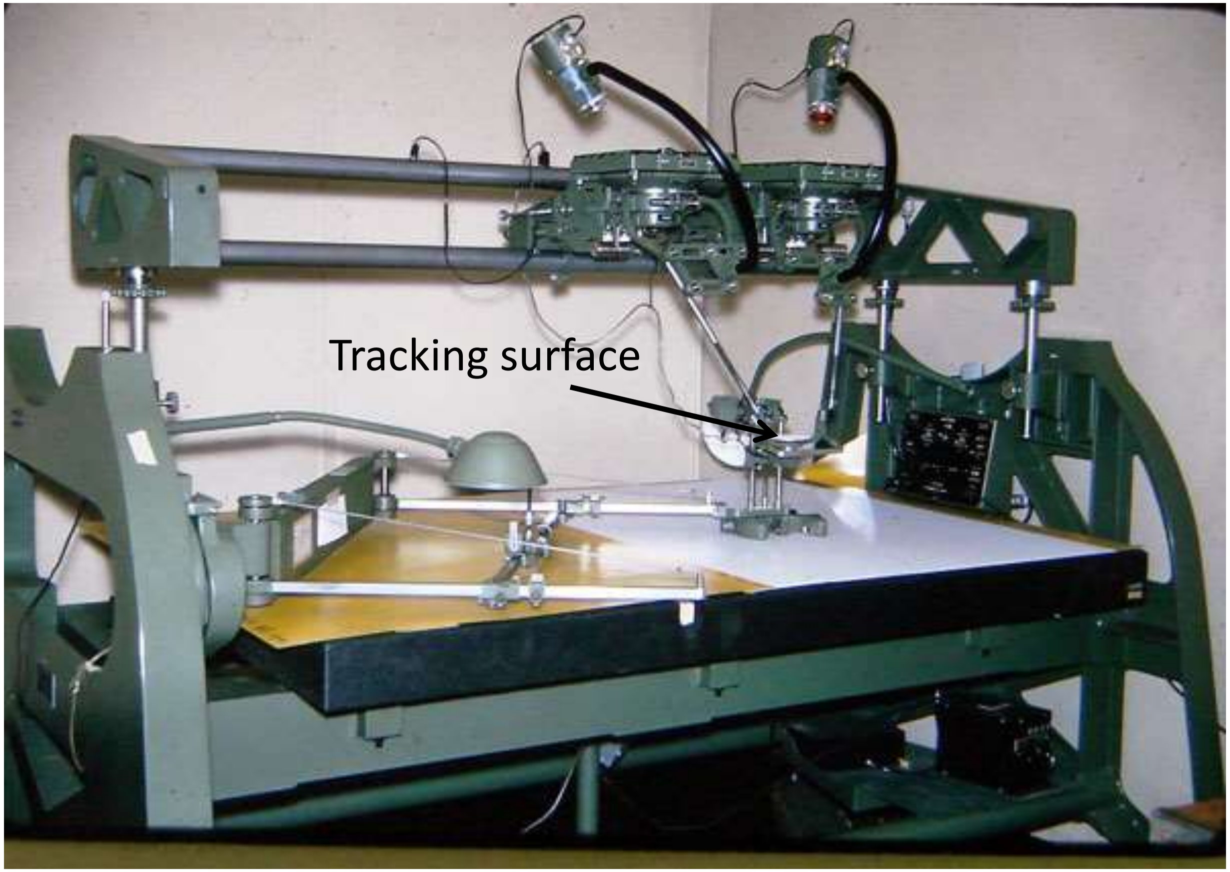
- A softcopy photogrammetric system is the current choice in professional photogrammetric firms for mapping, and surveying-like products at accepted engineering accuracies.
- Images are captured by digital cameras onboard of airplanes dedicated to photogrammetric applications.
- Drone imagery and LIDAR data are used as supplementary data to assist in visualization and automated DEM generation
- In this process, photos are oriented and measurements are performed on a computer screen by applying equations on a pair, a strip, or a block of photographs.
- Regardless of the method of orientation, each pair of photos are displayed at one time, a stereo model is generated, and then 3D measurements and digitization is performed.

Stereo Models



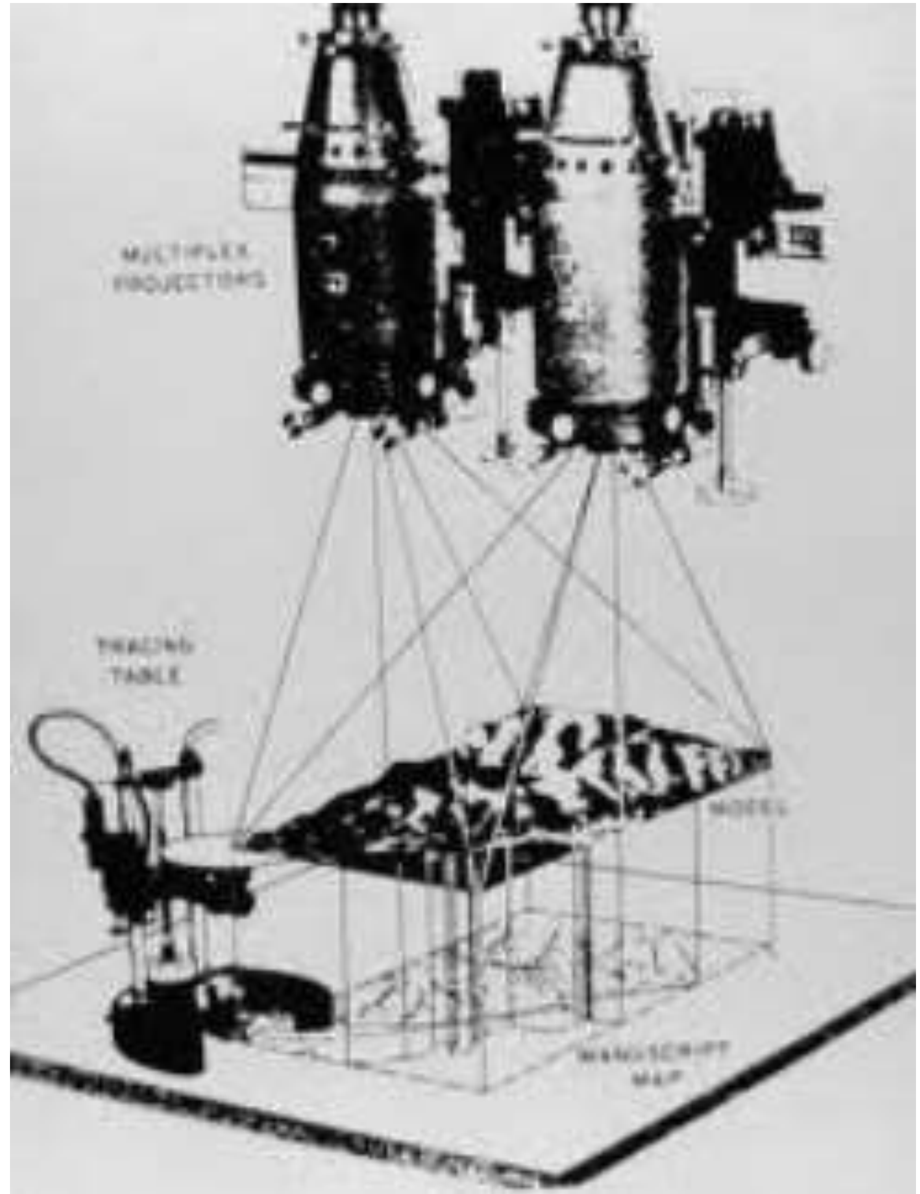
Measurement of Stereo Model

In that historical plotter, after the images are mounted, oriented, light is projected through them, the model is tracked on the white small screen: X, Y, and Z

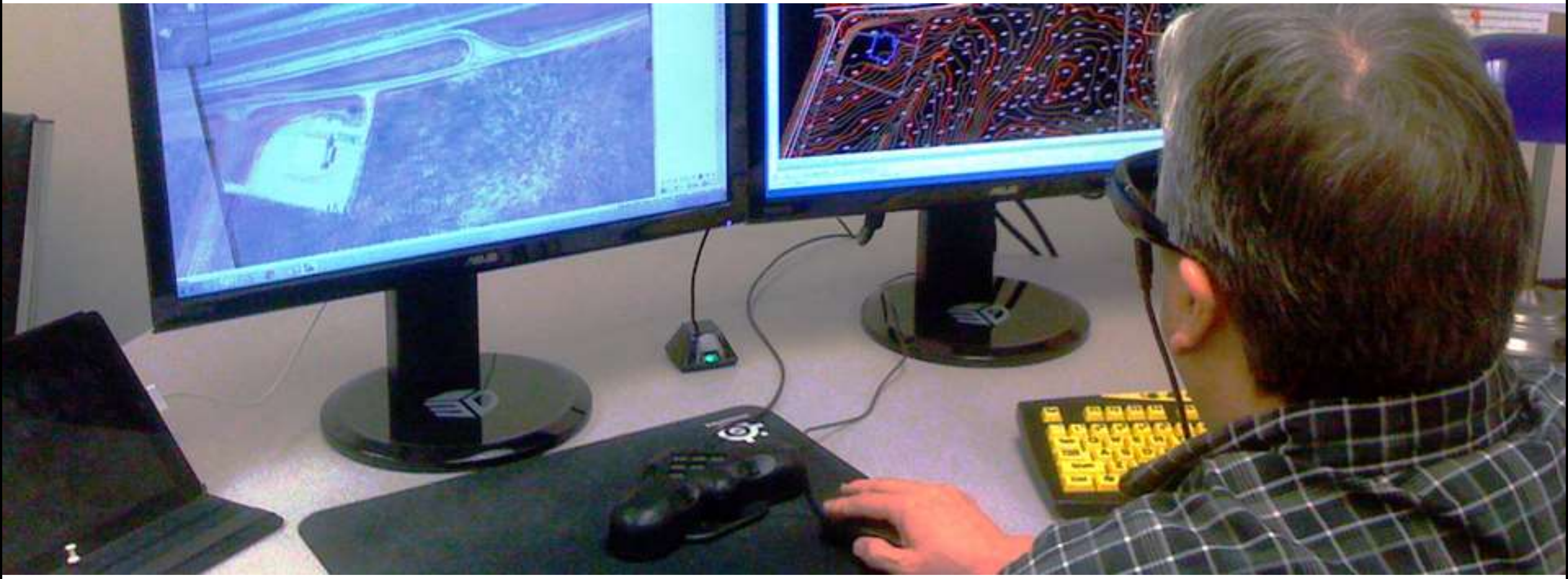


The pseudo model shown in the image to the right, was tracked and coordinates recorded. This is done today by

- mathematically solve for the location and orientation of the images
- for each point on the model, the equations to solve for where the rays from the corresponding points in images should have met. Therefore, every point in the model is assigned horizontal and vertical coordinates.




GPSi



Topographic mapping in photogrammetry

Introduction of Transformation of Image to Ground Coordinates

Software Demo

- Triangulation with E-foto

Orientation of stereo images

In this section, an introduction of several methods used to orient the photographs, establish a stereo model, and measure photo coordinates are briefly introduced. Students are NOT expected to understand, at this point, the procedures in depth. The information is presented to explain what the software in labs is performing. The topics may be re-visited in depth later.

- The goal is to compute ground coordinates from measured photo coordinates.

The transformation can be done in many ways, but the interior orientation has to be done for each photo first for film camera to ensure accurate measured photo coordinates. This is one of your first tasks in labs.

A- Interior Orientation

- The purpose of the interior orientation is to determine precise camera parameters to ensure precise image coordinate measurements
- A camera calibration is performed to determine precise values for several camera parameters (elements of interior orientation).
- Examples of the interior orientation elements are the calibrated focal length of the camera and radial lens distortion (distortion in image position along radial lines from the center)

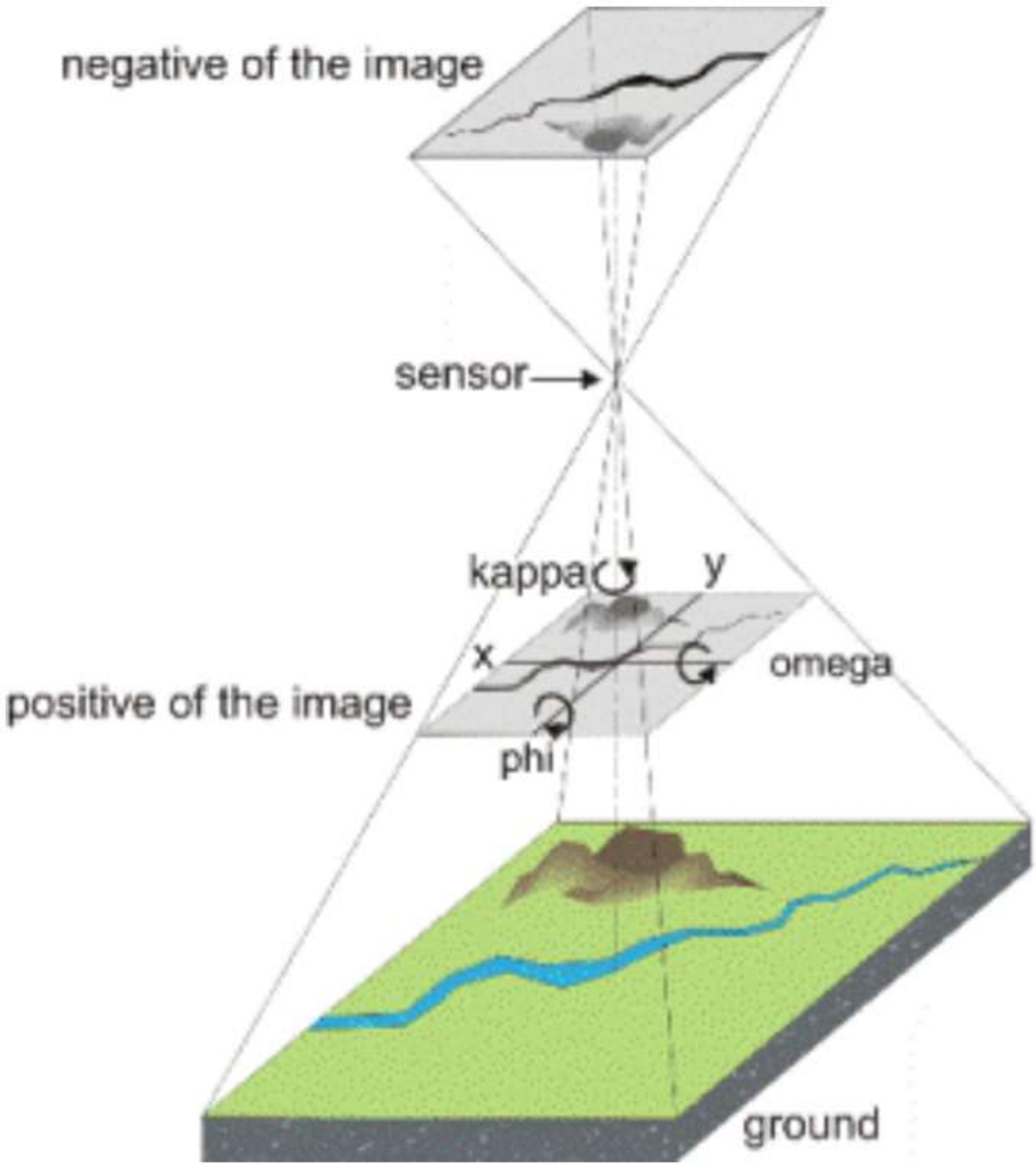
B- Exterior Orientation

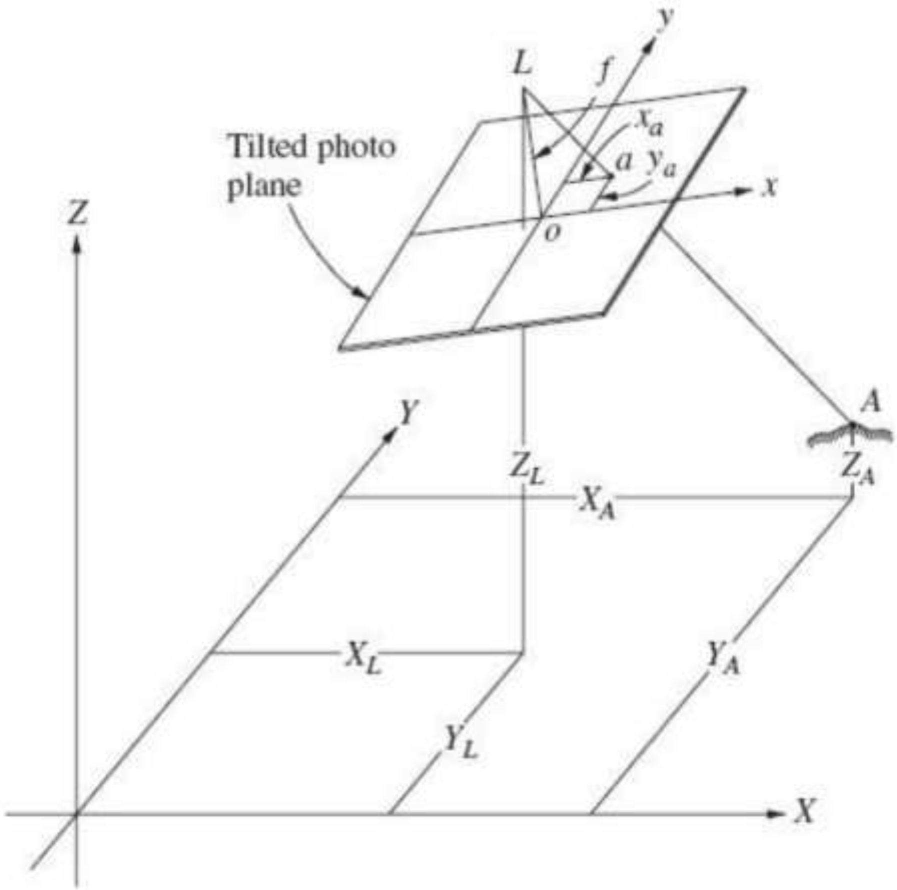
- Exterior orientation (EO) is the determination of the position and orientation of the camera when the image was taken. Once the EO is done, the solution for the ground coordinates is the done by the same way, as will be explained
- After the interior orientation is performed, we need to re-establish the geometry of photographs in space when they were taken, and calculate ground coordinates. For each photo, we need to know 6 exterior orientation parameters: three coordinates of the PP, and 3 angles of tilt of the photo in space. This is called: exterior orientation”. This can be done in analytical photogrammetry in many ways:

B-1- Exterior Orientation By Space resection

1- First analytical method to relate photo and ground coordinates, is to orient each photograph separately. This is done for a single photo by space resection using the collinearity condition. One way used by lab software.

Once we know the 6 parameters for each photo, we can solve for the location of points on the ground by solving for the intersection of rays of light in the sketch below.

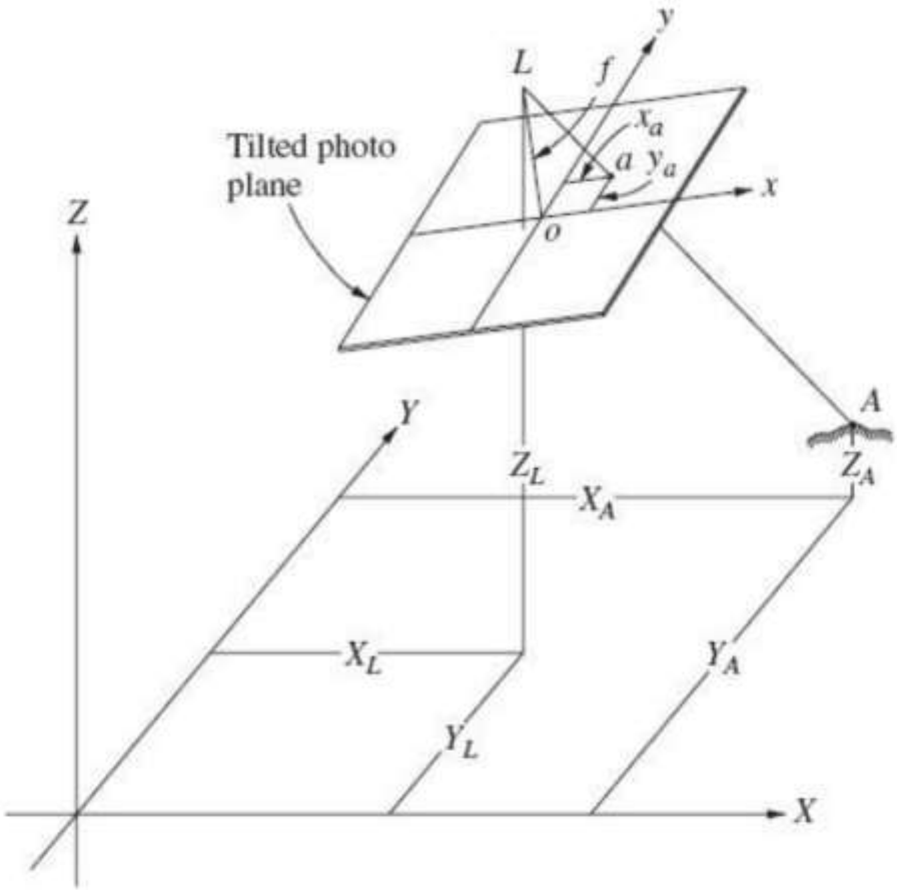

negative of the image
sensor
kappa
y
x
omega
positive of the image
phi
ground



The *collinearity* condition.

$$x_a = x_o - f\left[\frac{m_{11}(X_A - X_L) + m_{12}(Y_A - Y_L) + m_{13}(Z_A - Z_L)}{m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L)}\right]$$

$$y_a = y_o - f\left[\frac{m_{21}(X_A - X_L) + m_{22}(Y_A - Y_L) + m_{23}(Z_A - Z_L)}{m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L)}\right]$$



The *collinearity* condition.

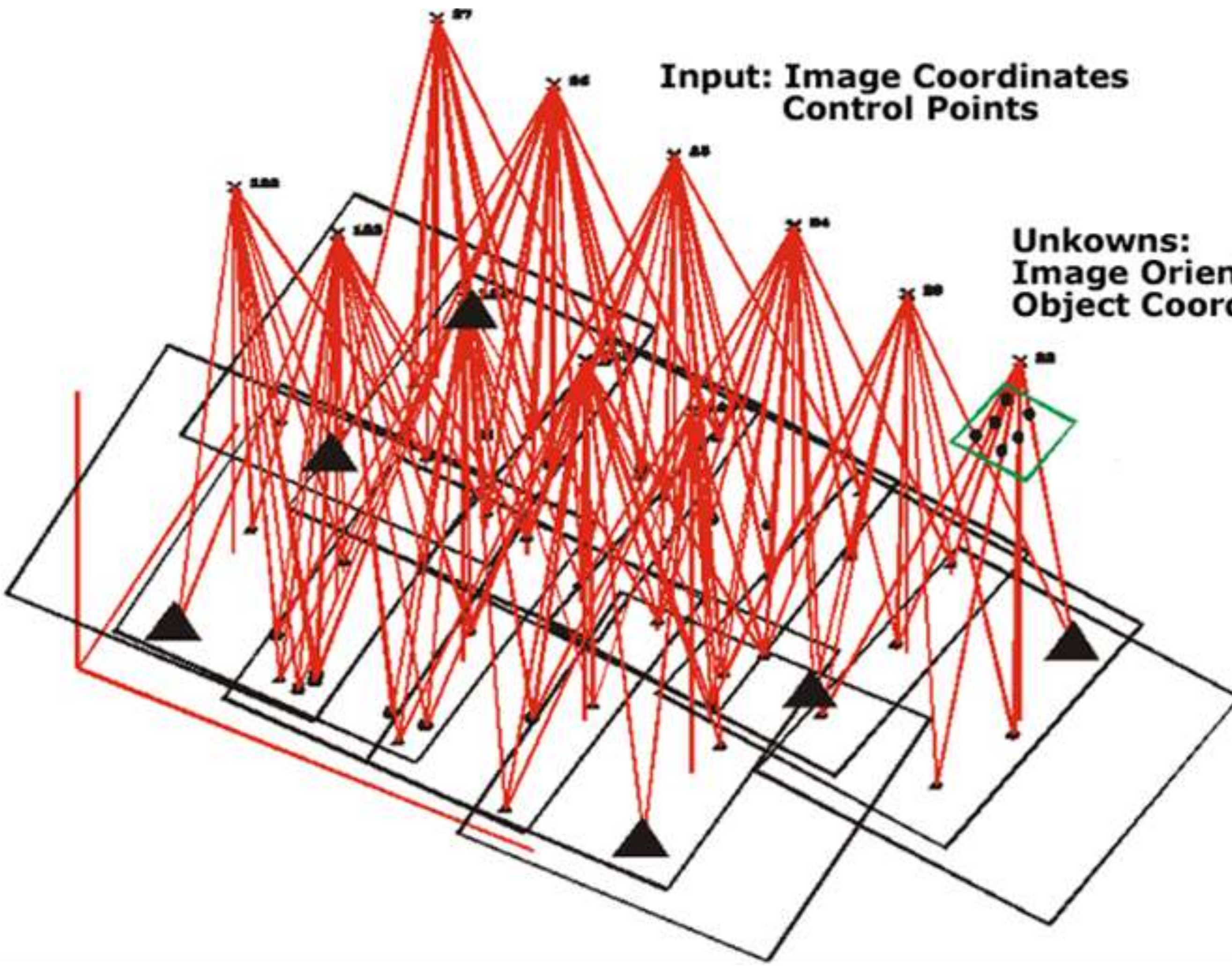
$$x_a = x_o - f\left[\frac{m_{11}(X_A - X_L) + m_{12}(Y_A - Y_L) + m_{13}(Z_A - Z_L)}{m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L)}\right]$$

$$y_a = y_o - f\left[\frac{m_{21}(X_A - X_L) + m_{22}(Y_A - Y_L) + m_{23}(Z_A - Z_L)}{m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L)}\right]$$

B-2- Exterior Orientation by Simulations bundle adjustment

- Instead of orienting pairs of photos, or strips of photos, in this process the entire block is oriented through regroups computations to compute orientation parameters for all the pairs at once.
- Each pair is then displayed and measurements are carried out by “floating” in a 3D model, and digitize needed points.

Input: Image Coordinates
Control Points

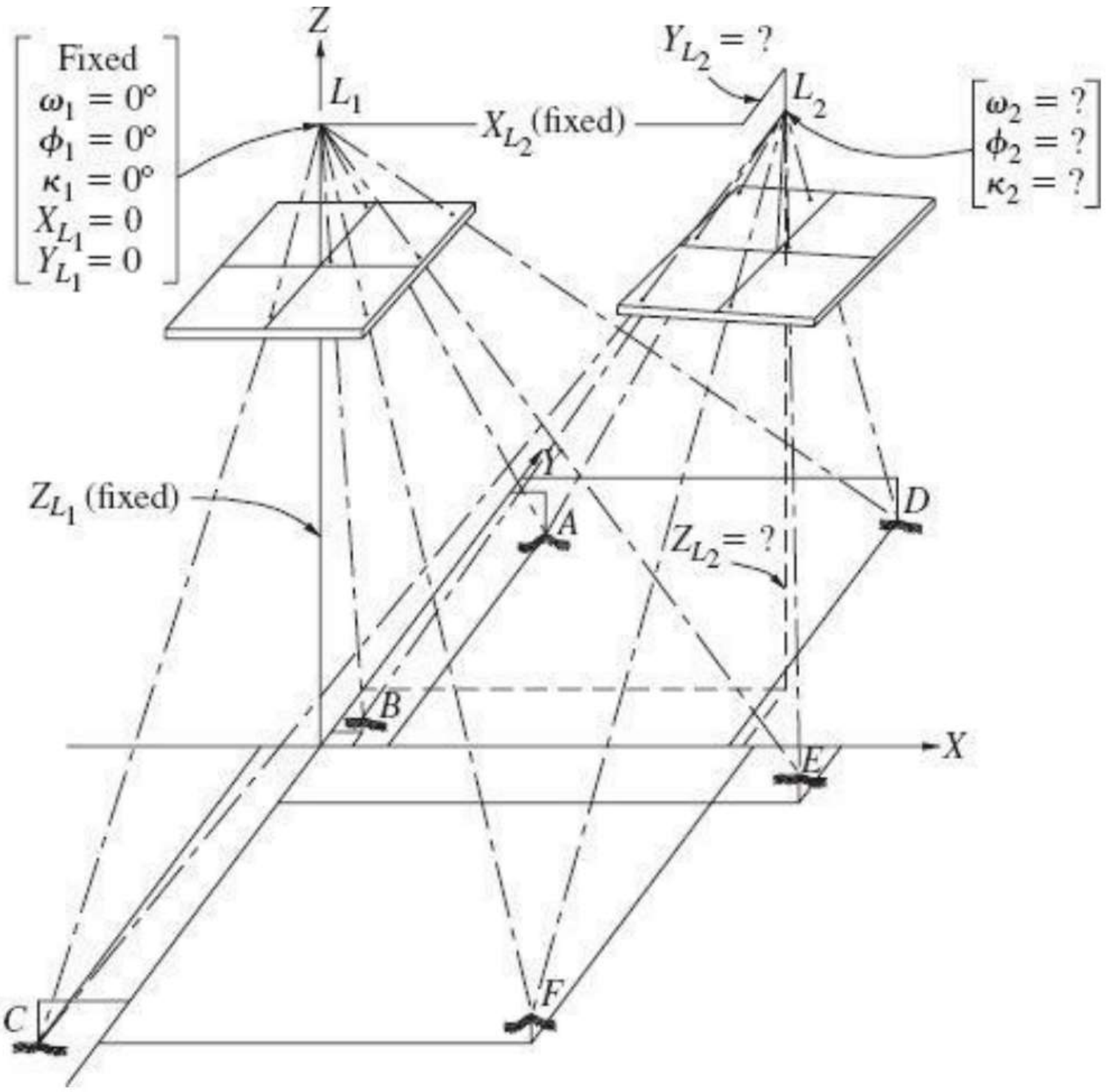


Unkowns:
Image Orientations
Object Coordinates

B-3 Exterior Orientation by Relative and then Absolute Orientation

B-3-1 Relative Orientation

- Relative orientation of a stereo pair will result in required parameters need to orient the two images relative to each other as they were in space when captured. Six elements are needed:
  - Three rotations: ω, ϕ, κ around the three axes of the photograph
  - Three values for distances between the exposure stations.



Analytical relative orientation of a stereopair.

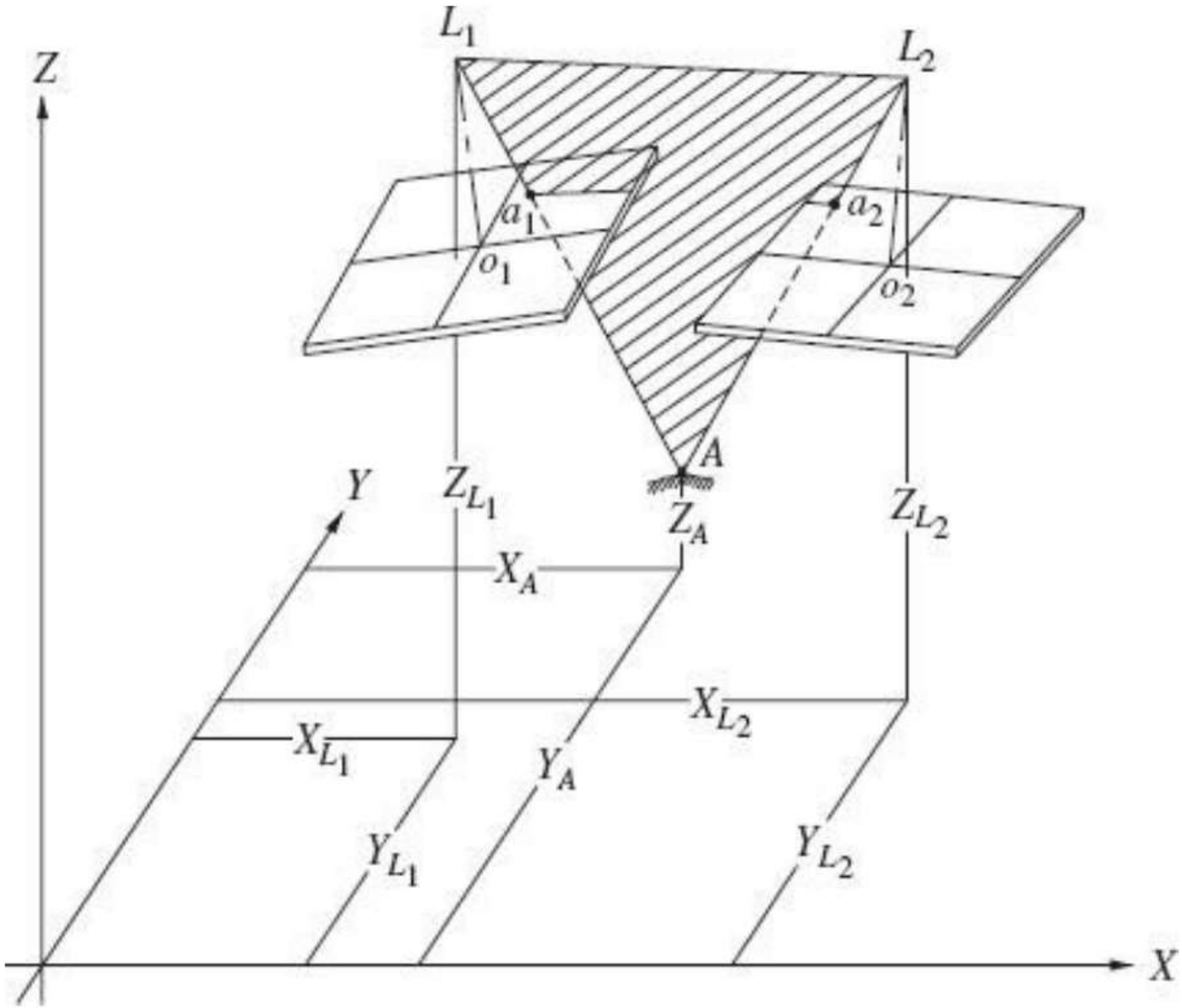
B-3 Exterior Orientation by Relative and then Absolute Orientation

B-3-2 Absolute Orientation

- At this point, camera parameters such as focal length and location of center are calibrated, the orientation of images relative to each other is known.
- The two images can be used to produce a stereo model, but not to actual scale or coordinates.
- Absolute orientation is the process of scaling the stereo model to actual dimensions and apply realistic coordinates.
- Absolute orientation is done by
  - measuring photo coordinates of known ground coordinates; or
  - Equipping the camera with precise GPS system, IMU, and gyroscopes to account for tilts.

Solution for ground coordinates by Space Intersection

- Once the EO is done using of the three methods explained earlier, a stereo model can be developed and ground coordinates, including elevations, can be measured
- The solution is done using a space intersection by the coplanarity condition



The *coplanarity* condition.

Ground Control for Photogrammetry

- Each model requires three horizontal and four vertical control points.
- Control points are chosen before (marked) or after (usually) and measured by ground surveying
- Using “Aerial Triangulation” control can be intensified on the photos
- Differential precise GPS on board may eliminate the need for ground control.
- Less control is needed in case of a simultaneous bundle adjustment of photographs.

Automation of Professional Photogrammetric Production

- Auto correlation between corresponding images of the same feature allows for automated orientation and surface (DTM) production.
- However, human interference is necessary to edit the resulting model and digitize maps.

End of Lecture