Chapter 3

Cameras and Other Imaging Devices

Elements of Photogrammetry with Applications in GIS

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1. Introduction

➢ Camera

- Definition: “a lightproof chamber or box in which the image of an exterior object is projected upon a sensitized plate or film, through an opening usually equipped with a lens or lenses, shutter, and variable aperture.”

- Imaging device may be better term for photogrammetric acquisition.

- The remarkable success of photogrammetry in recent years is due in large part to the progress in developing precision cameras, especially to the perfection of lenses with high resolution and negligible distorsion.

- Classification of imaging device: frame camera (2D image), strip camera (= linear array sensors, or pushbroom (빗자루) scanners), and flying spot scanners (= whiskbroom scanners)

- Aerial scanners must be capable of exposing in rapid succession a great number of photographs: short cycling times, fast lenses, and efficient shutters

2. Metric Cameras for Aerial Mapping

- Single lens frame camera

  - Are the most common for aerial mapping.

  - Often classified according to their angular field of view.

    1) Normal angle (up to 75°)
    2) Wide angle (75 ° to 100 °)
    3) Superwide angle (greater than 100 °)

$$\alpha = 2tan^{-1}\left(\frac{d}{2f}\right)$$

The angular filed of view of 152 mm-focal length with 230 mm-square format is…94°

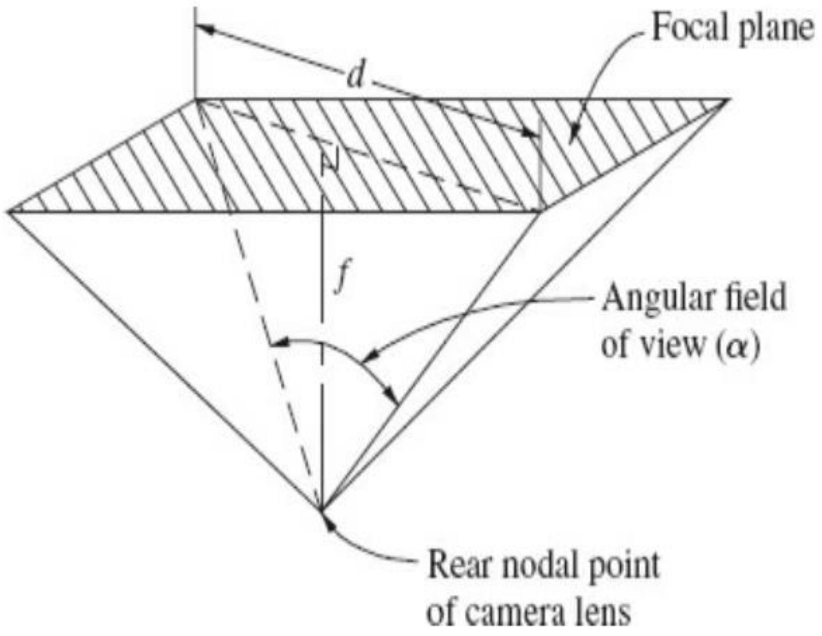


FIGURE 3-1 Angular field of view of a camera.

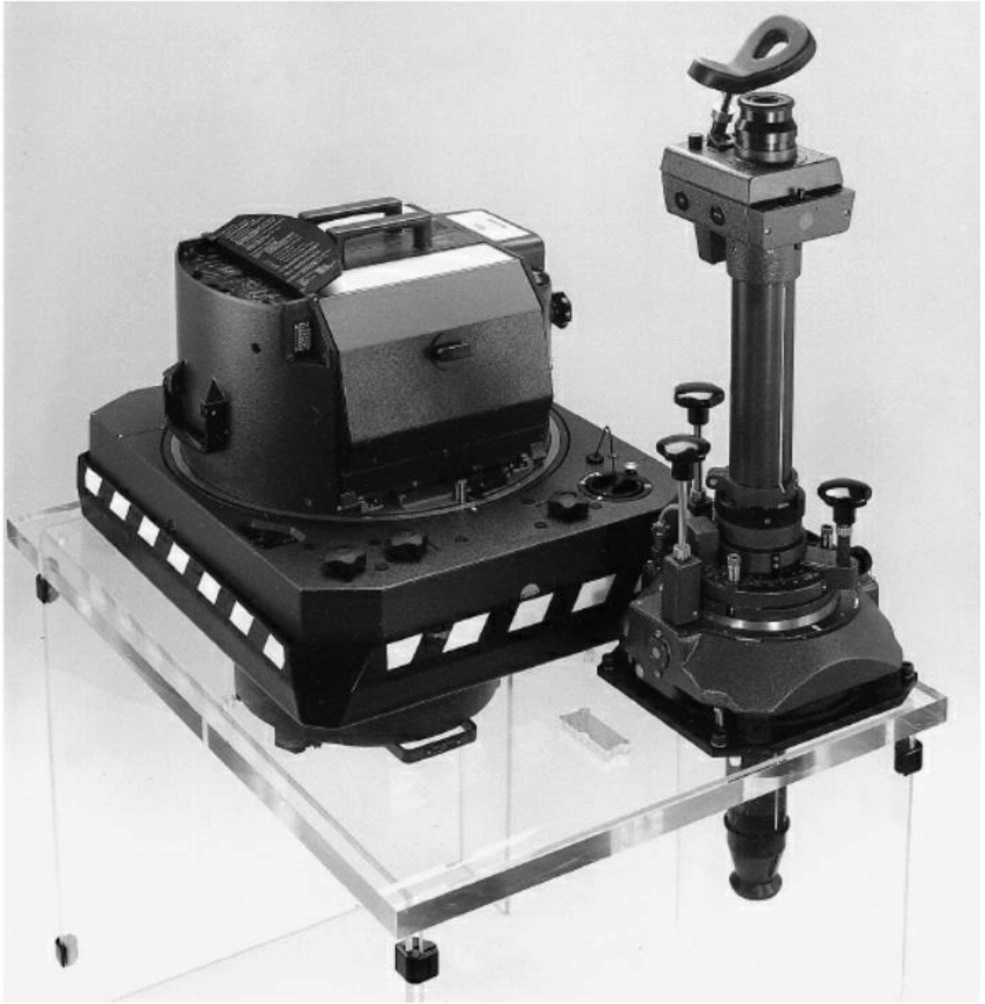


Figure 3-2 Leica RC30 aerial mapping camera. (*Courtesy LH Systems, LLC.*)

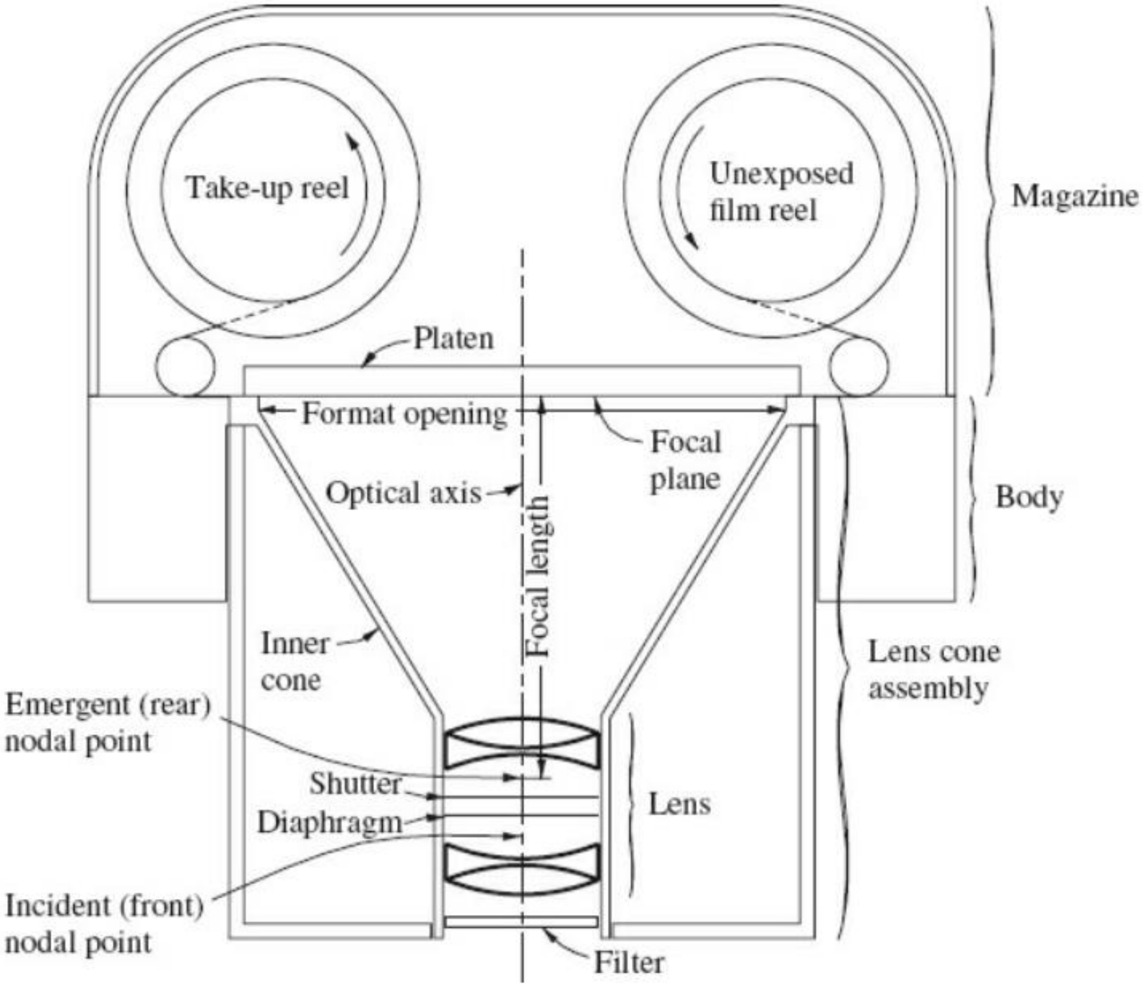


Figure 3-4 Generalized cross section of a frame aerial camera.

3. Main Parts of Frame Aerial Cameras

- Camera magazine: houses the reels which hold exposed and unexposed film

- Camera body: is one-piece casting having drive mechanism in it . A cycle consists of (1) advancing the film (2) flattering the film, (3) cocking the shutter, (4) tripping the shuter.

- Lens cone assembly: contains lens, shutter, and diaphragm

4. Focal Plane and Fiducial Marks

- Focal plane of an aerial camera is the plane where all incident light rays are brought to focus.

- Camera fiducial marks are usually four or eight in number and situated in the middle of the sides of the focal plane. Besides providing a coordinate reference for the principal point and image points, fiducials allow for correction of film distortion (shrinkage and expansion) since each photograph contains the images of these stable control points

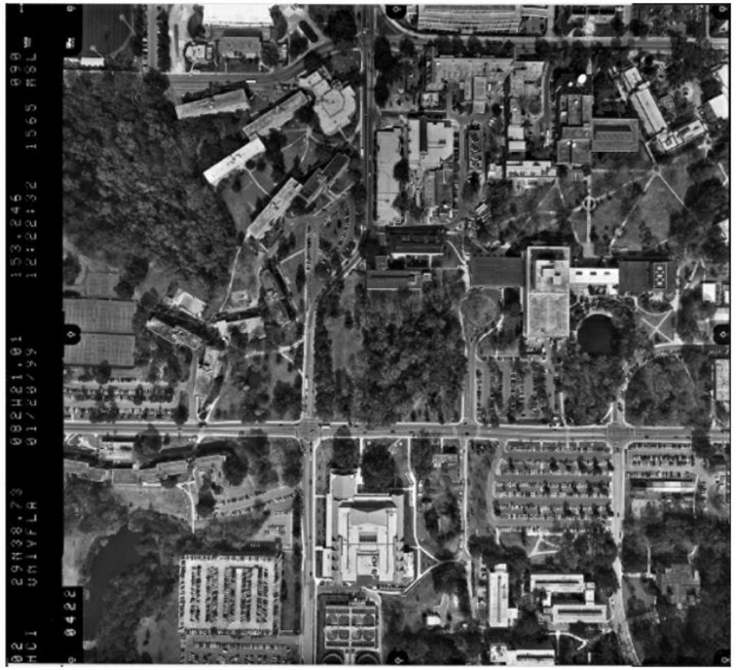


FIGURE 1-2 Vertical aerial photograph. (*Courtesy Hoffman and Company, Inc.*)

5. Shutters

- Due to moving speed of an aircraft images will move across the focal plane during exposure → the shutter be open for a very short duration which ranges from 1/100 to 1/1000s.

- Example 3-1 An aerial camera with forward-motion compensation and a 152.4-mm focal length is carried in an airplane traveling at 200 kilometers per hour (km/h). If the flying height above the terrain is 3500 m and if the exposure time is 1/500s, what distance (in millimeters) must the film be moved across the focal plane during exposure in order to obtain a clear image? *Answer: 0.005 mm*

$$D=\left(200\frac{\text{km}}{\text{h}}\right)\left(\frac{1}{500}\text{s}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right)\left(\frac{1000\text{ m}}{1\text{ km}}\right)=0.11\text{ m}$$

$$d=0.11\text{ m}\left(\frac{152.4\text{ mm}}{3500\text{ m}}\right)=0.005\text{ mm}$$

5. Shutters

- Between-the-lens shutters or focal-plane shutters are common.

- Common types of the between-the-lens shutters are leaf type, blade type, and rotating-disk type.

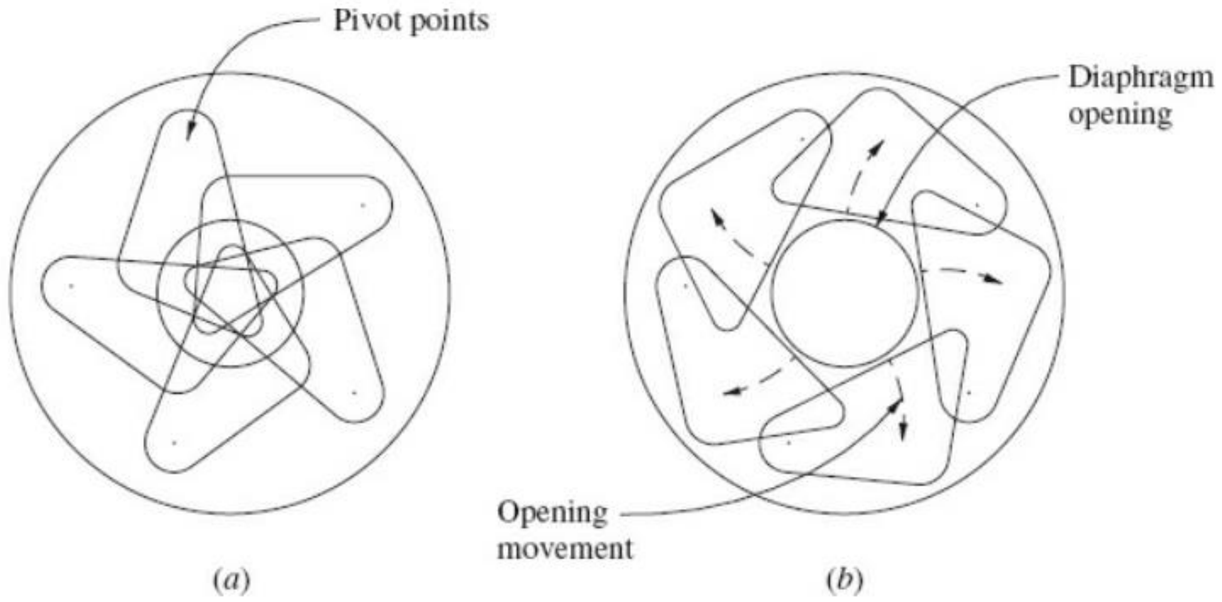


Figure 3-5 Schematic diagrams of a leaf-type shutter. (*a*) Shutter closed; (*b*) shutter open.

9. Digital Mapping Cameras

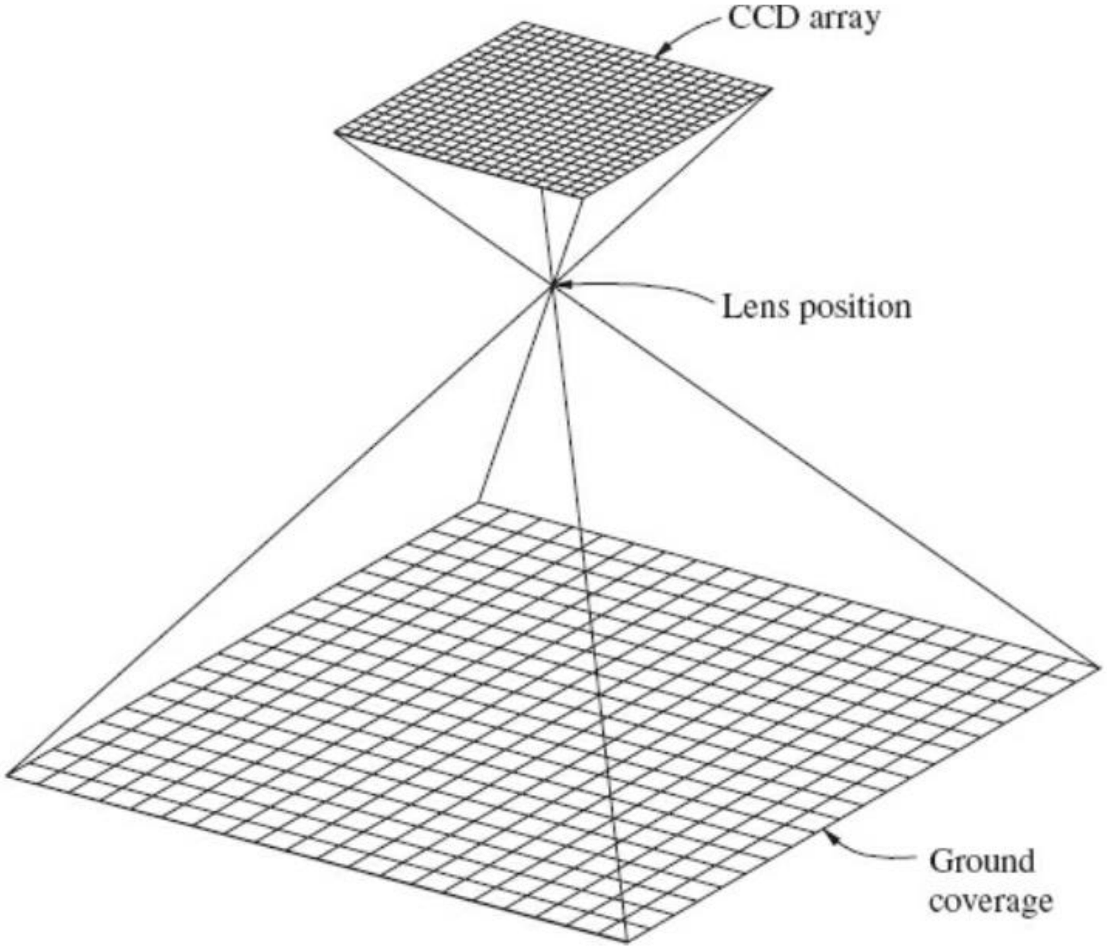


FIGURE 3-10 Geometry of a digital frame camera.

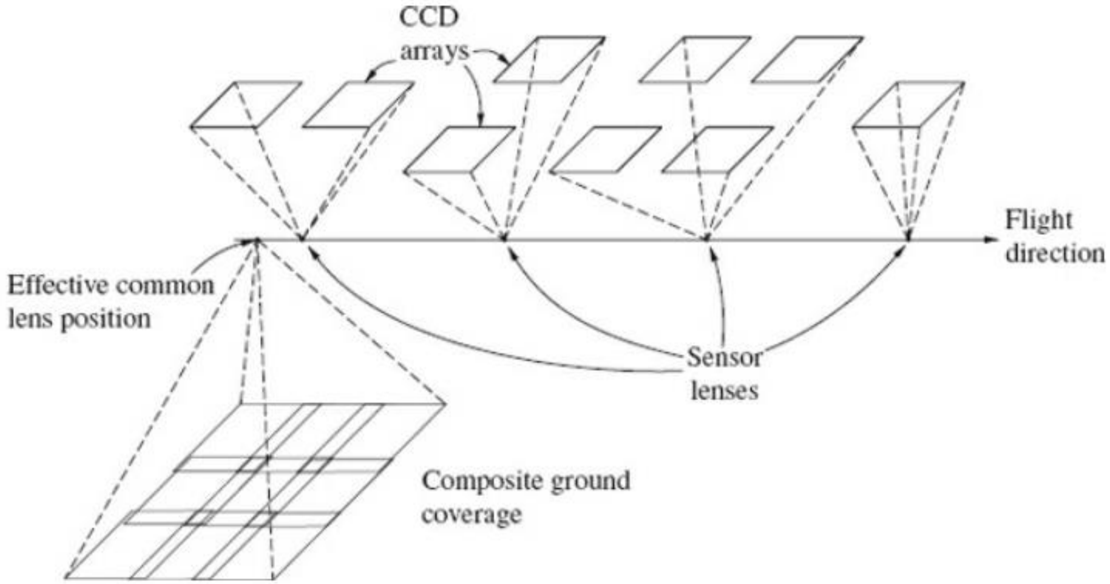


FIGURE 3-12 Multiple frame capture method of the UltraCam Eagle.

9. Digital Mapping Cameras

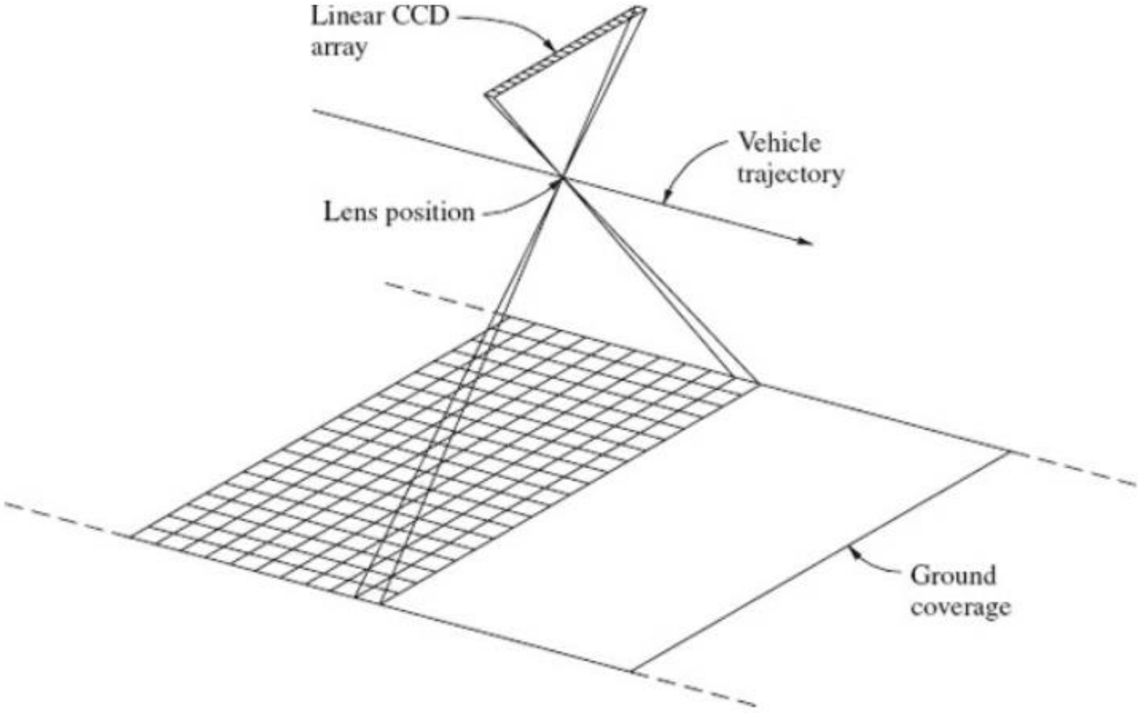


Figure 3-13 Geometry of a linear array sensor.

Figure 3-14 Raw image (*a*) from an airborne linear array sensor exhibiting distortion caused by air turbulence. Rectified image (*b*) obtained by correcting the raw image using GPS/INS measurements.

10. Camera Calibration

- Calibration methods can be classified into laboratory, field, and stellar methods of which laboratory method is most frequently used. The lab. calibration device includes multicollimator & goinometer.

- Multicollimator (다중시준)-using method consists of photographing an array of targets whose relative positions are accurately known and determining elements of interior orientation by which (theoretically) perfect image locations are compared with camera-produced image positions.

- Goniometer (측각기) method: direct measurements of projections through a camera lens of precisely positioned grid points in a camera focal plane

➢ Elements of interior orientation (내부표정요소)

1. Calibrated focal length (CFL)

- Focal length producing overall mean distribution of lens distortion
- A distance from real nodal point of the lens to principal point of the photograph

10. Camera Calibration

2. Symmetric radial lens distortion

- Symmetric component of distortion that occurs along radial lines from the principal point

3. Decentering lens distortion

- Lens distortion after compensation for symmetric radial lens distortion

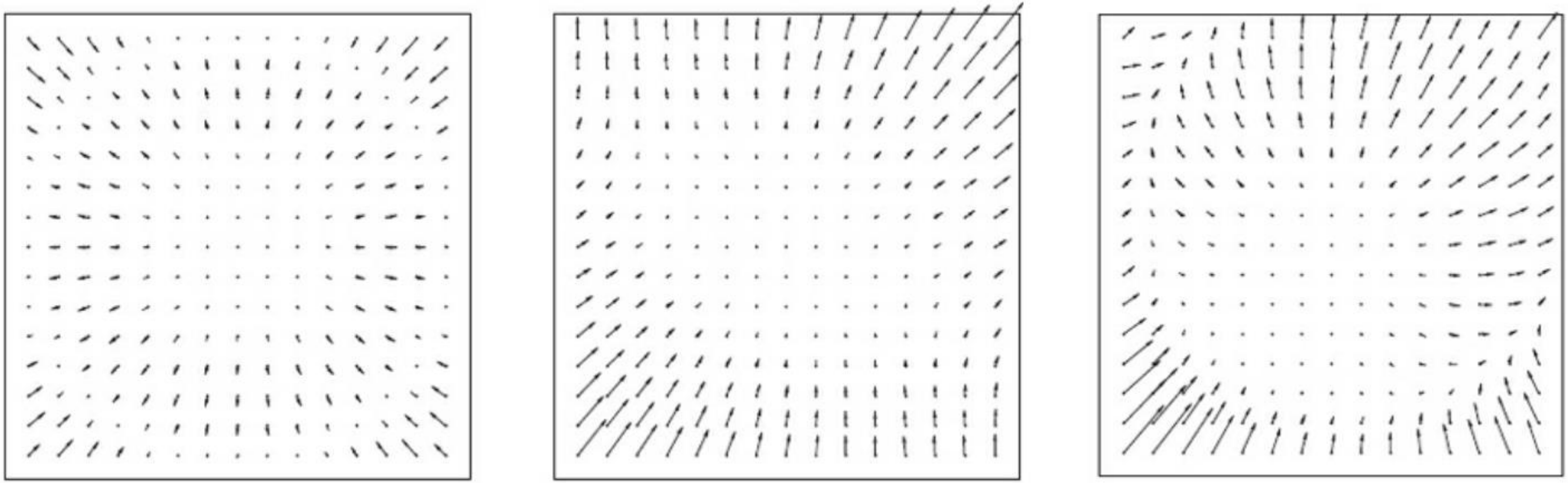
4. Principal point location

- Principal point location defined by fiducial marks (지표) can be different from center point of photograph

5 Fiducial mark coordinates

- x, y coordinates of the fiducial marks which provide 2D positional reference

10. Camera Calibration



(a) (b) (c)

Figure 3-16 Lens distortion patterns: (*a*) symmetric radial, (*b*) decentering, and (*c*) combined symmetric radial and decentering.

11. Laboratory Methods of Camera Calibration

- Multicollimator method makes an image projected through a number of individual collimators whose parallel light rays carry a cross image.

- The individual collimators are rigidly mounted in two perpendicular vertical planes where optical axes of adjacent collimators are known.

- The equivalent focal length (EFL) is computed based on distances from the center point *g* to each of the four nearest collimator crosses (ex. EFL = gf/tan θ).

- With diagonal structure of collimator crosses (Fig. 3-18), photo coordinate origin is set by the center cross ($\cong$ principal point of autocollimation) while the intersection of fiducial axes is called as an indicated principal point.

- In the goniometer laboratory procedure of camera calibration, the grid is illuminated from the rear and projected through the camera lens in the reverse direction.

11. Laboratory Methods of Camera Calibration

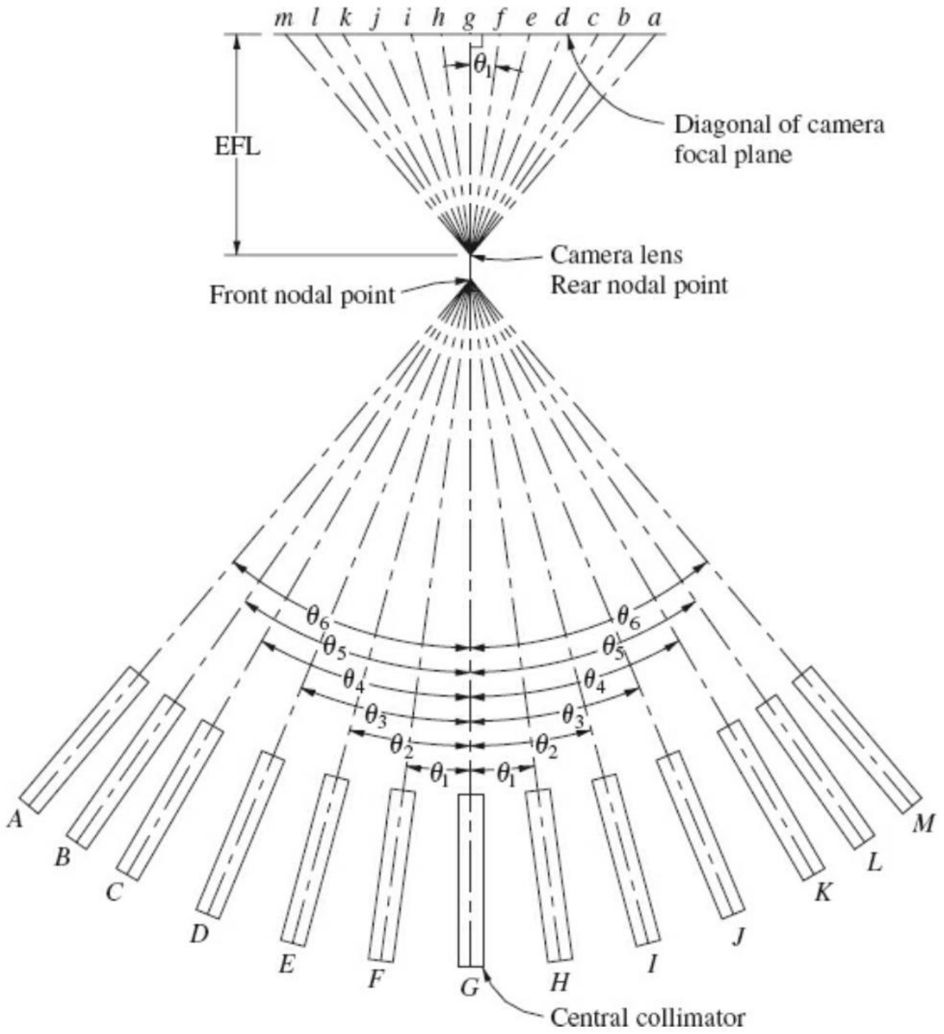


Figure 3-17 Bank of 13 collimators for camera calibration.

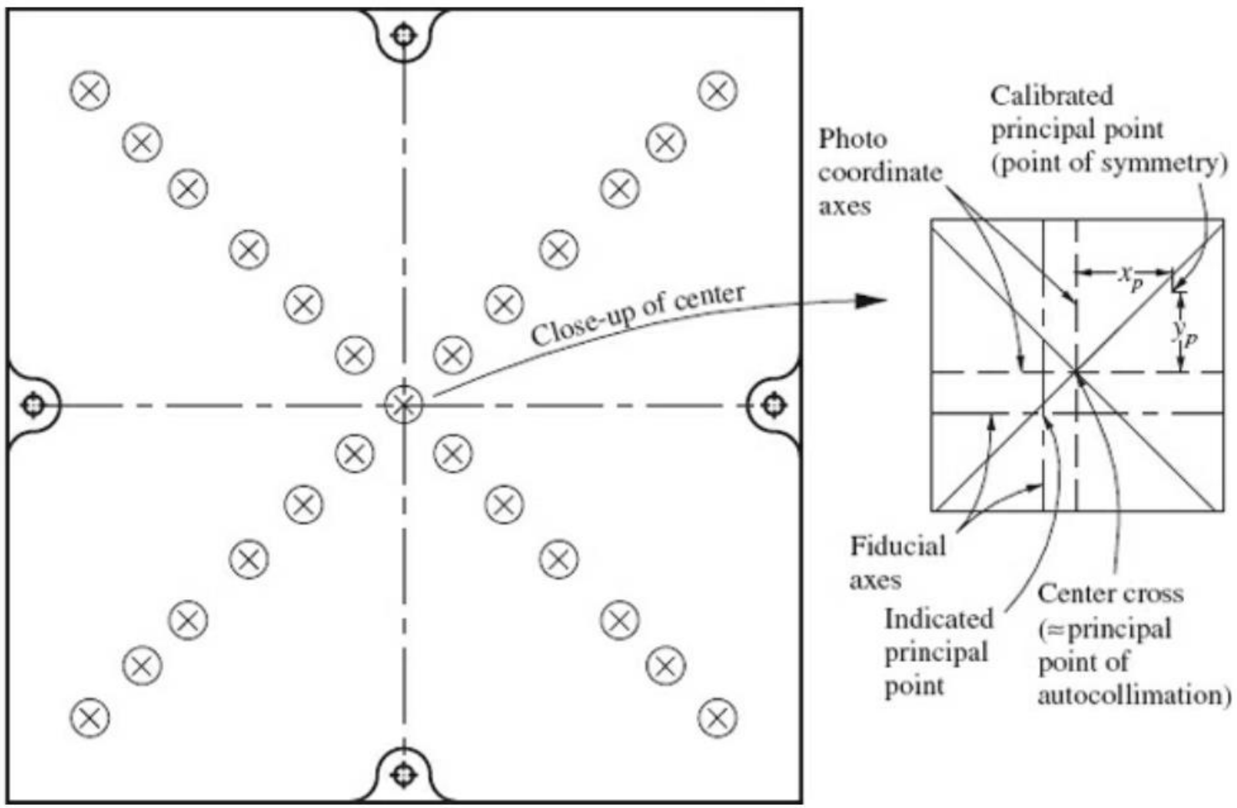


Figure 3-18 Images of photographed collimator targets and principal point definitions.

14. Calibrating the Resolution of a Camera

- Camera resolving power can be evaluated by direct count of the maximum number of lines per millimeter, or modulation transfer function (MTF)

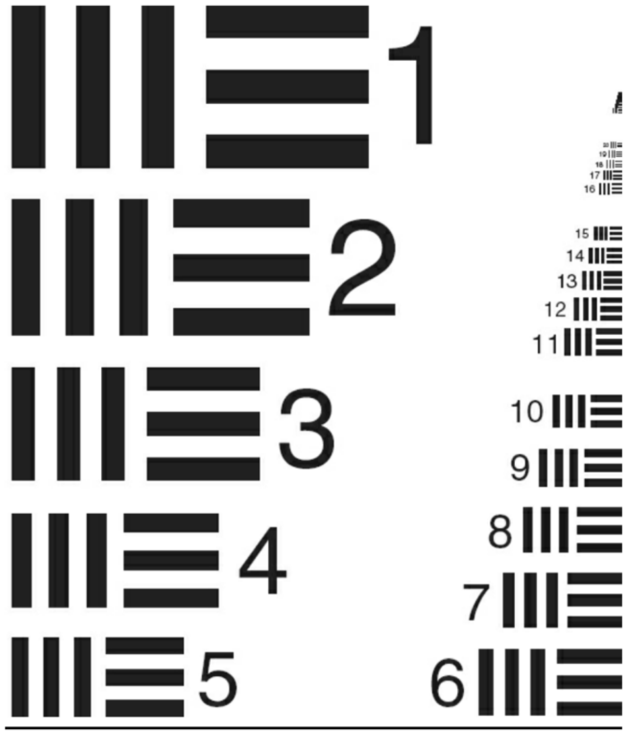


FIGURE 3-19 Resolution test pattern for camera calibration.

14. Calibrating the Resolution of a Camera

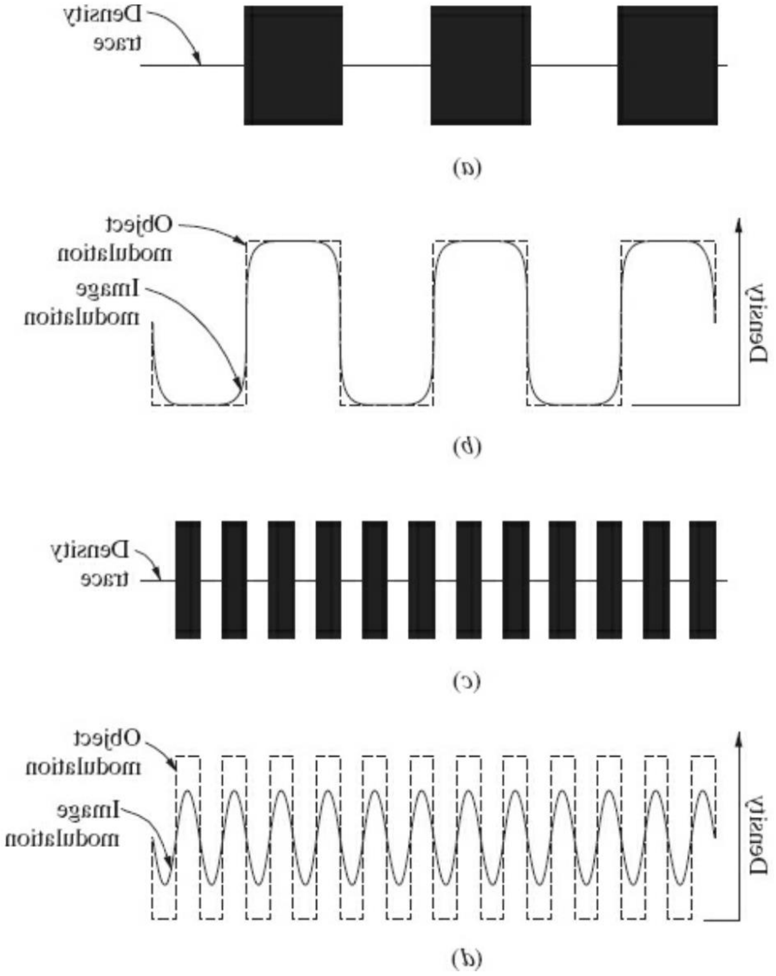


Figure 3-20 (*a*) Test object at low spatial frequency with density trace. (*b*) Density modulation of object (dashed) and image (solid). (*c*) Test object at high spatial frequency with density trace. (*d*) Density modulation of object (dashed) and image (solid). [Note that in part (*b*), the amplitude of the image modulation is the same as that of the object, corresponding to 100 percent modulation transfer. In (*d*) however, amplitude of the image modulation is one-half that of the object, corresponding to reduced modulation transfer.]