Chapters 1 – 5

- Chapter 1:
  - Photogrammetry: Definition, introduction, and applications
- Chapters 2 – 4:
  - Electro-magnetic radiation
  - Optics
  - Film development and digital cameras
- Chapter 5:
  - Vertical imagery: Definitions, image scale, relief displacement, and image to ground coordinate transformation

CE59700: Chapter 6

Image Coordinate Measurements

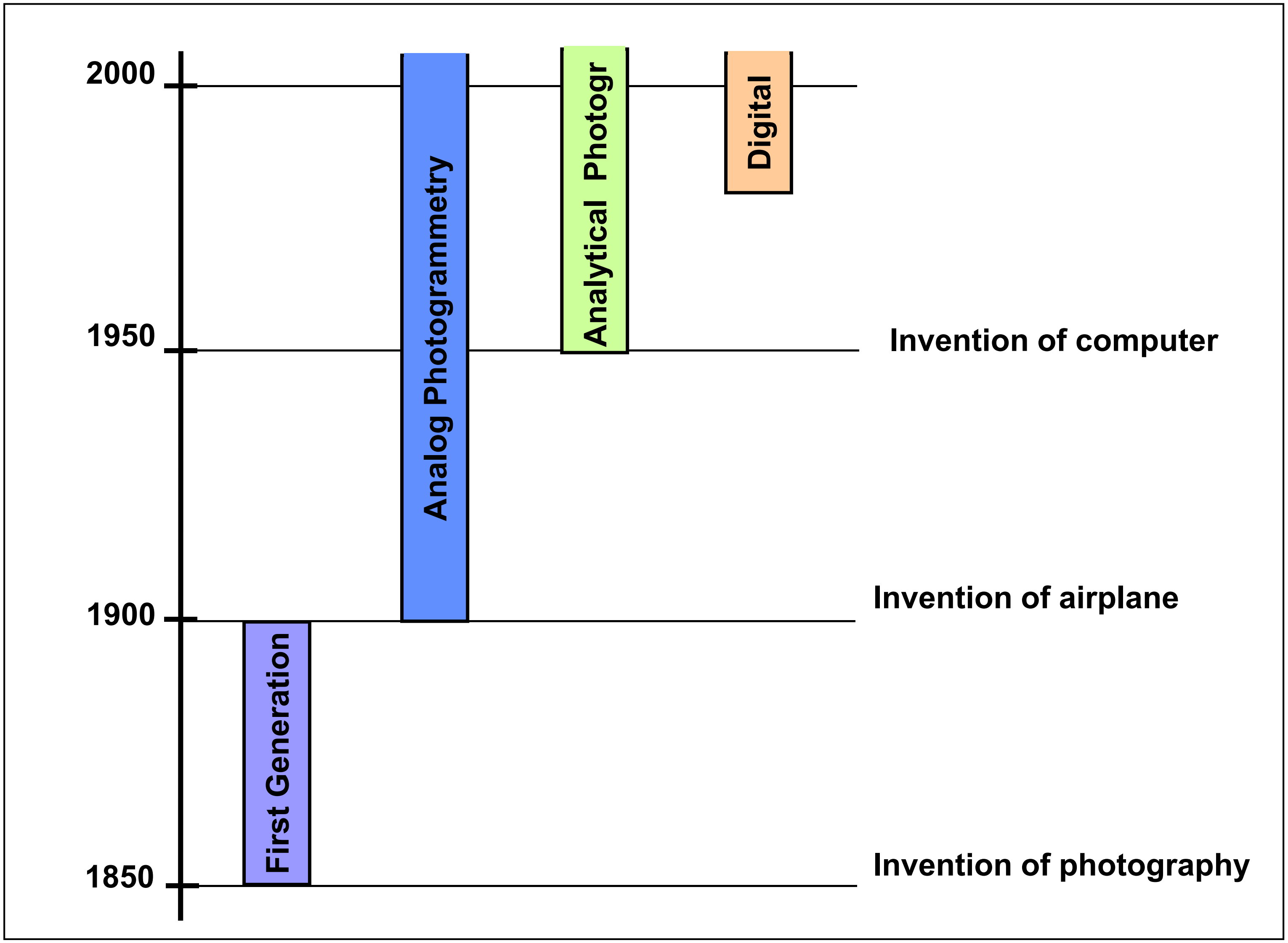
Overview

- Image coordinate measurements in analog, analytical, and digital environments
- Comparators: mono and stereo-comparators
- Automatic comparators
- Comparator-to-image coordinate transformation
- Reduction/refinement of image coordinate measurements:
  - Radial and de-centering lens distortions
  - Atmospheric refraction
  - Earth curvature

Measurement & Reduction of Image Coord.

- Objective of photogrammetry:
  - Derive ground coordinates of object points from measured image coordinates
- Thus, photogrammetric processing starts with the measurement of image coordinates.
- We are going to discuss how to perform this task in:
  - Analog or analytical environment (i.e., using analog images)
  - Digital environment (i.e., using digital images)

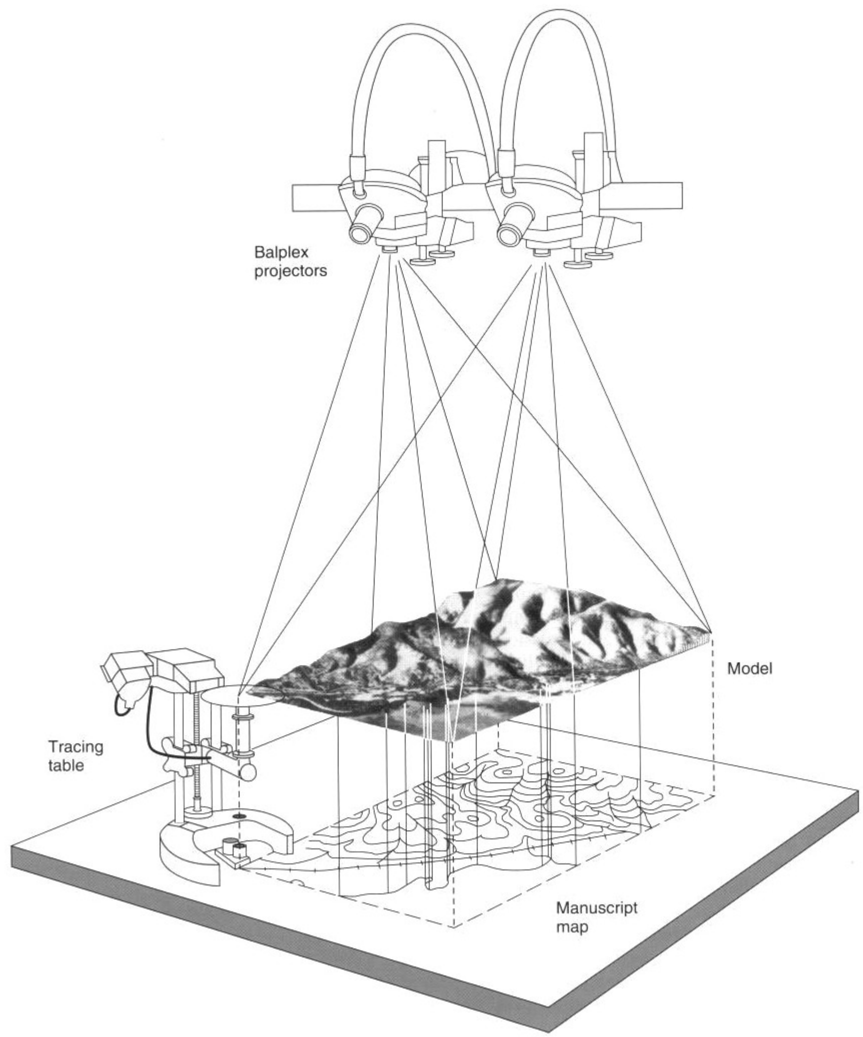
Different Generations of Photogrammetry



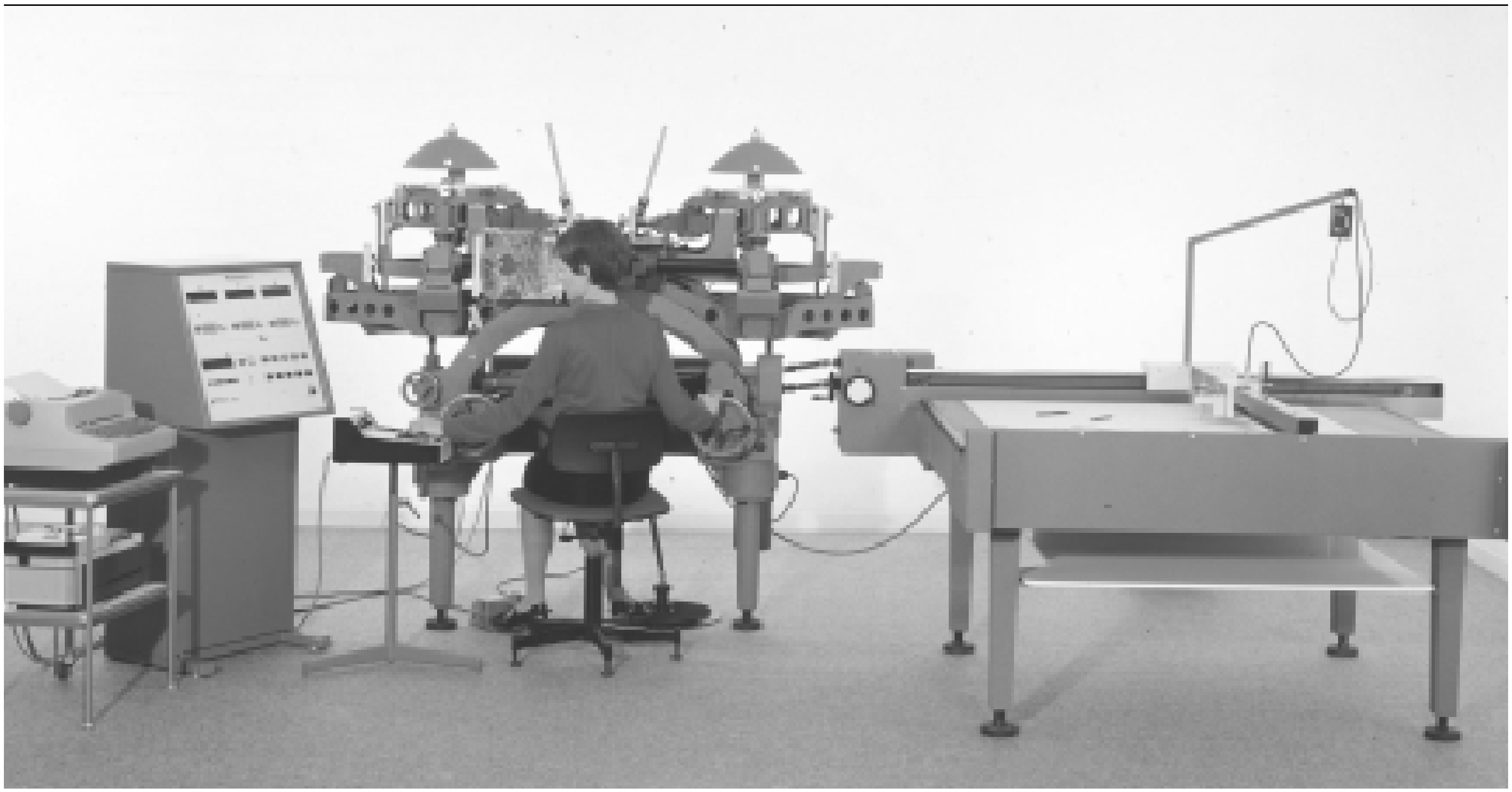
Different Generations of Photogrammetry

- Analog photogrammetry:
  - Analog imagery + stereo-viewing controlled by optical and mechanical devices
  - Analog output
- Analytical photogrammetry:
  - Analog imagery + stereo-viewing controlled by computers
  - Digital output
- Digital photogrammetry:
  - Digital imagery + stereo-viewing controlled by computers
  - Digital output
  - Automation capabilities (automatic matching and DEM generation)

Analog Photogrammetry



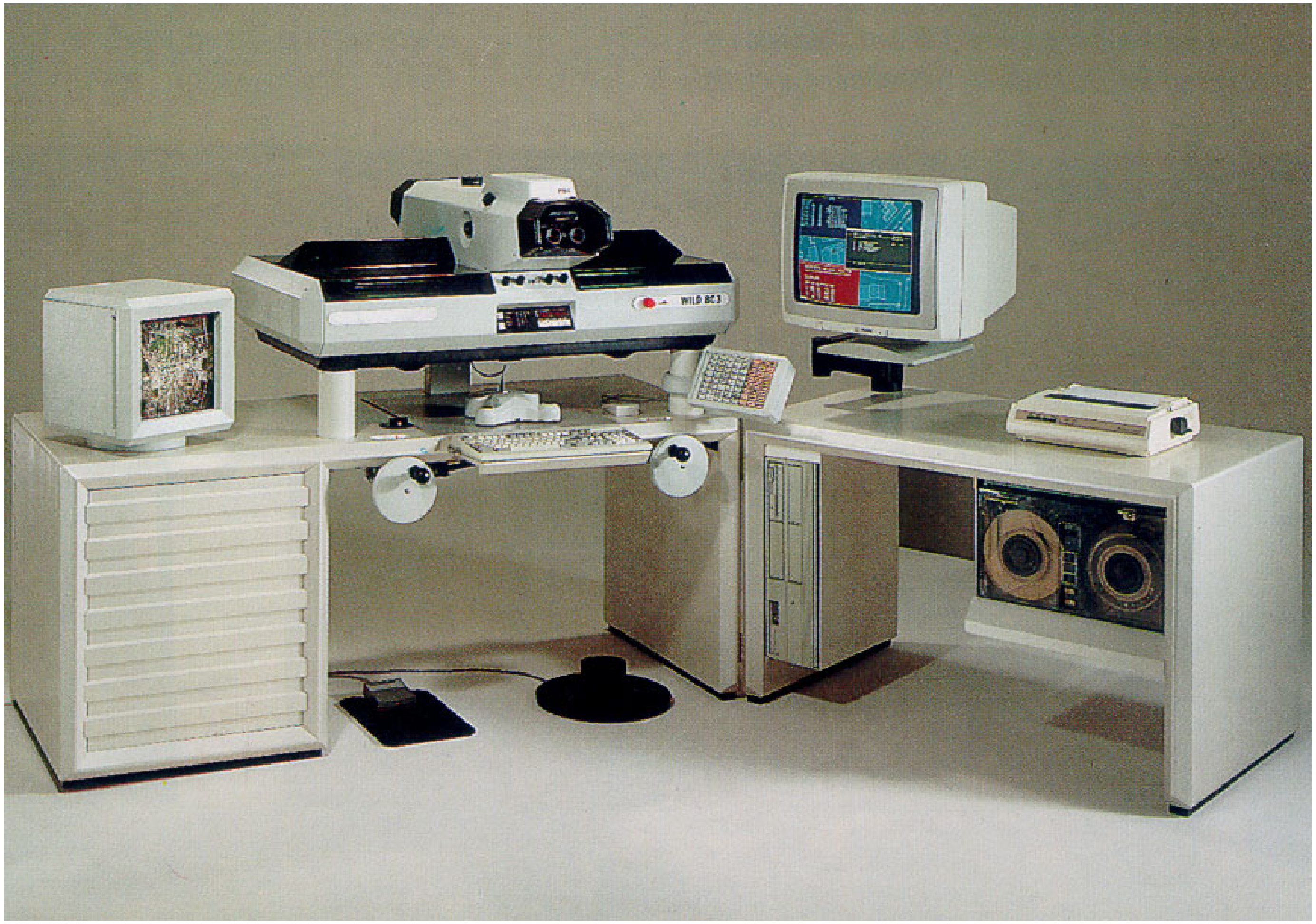
Analog Photogrammetry



Wild A8 Analog Plotter

http://www.wild-heerbrugg.com/photogrammetry.htm

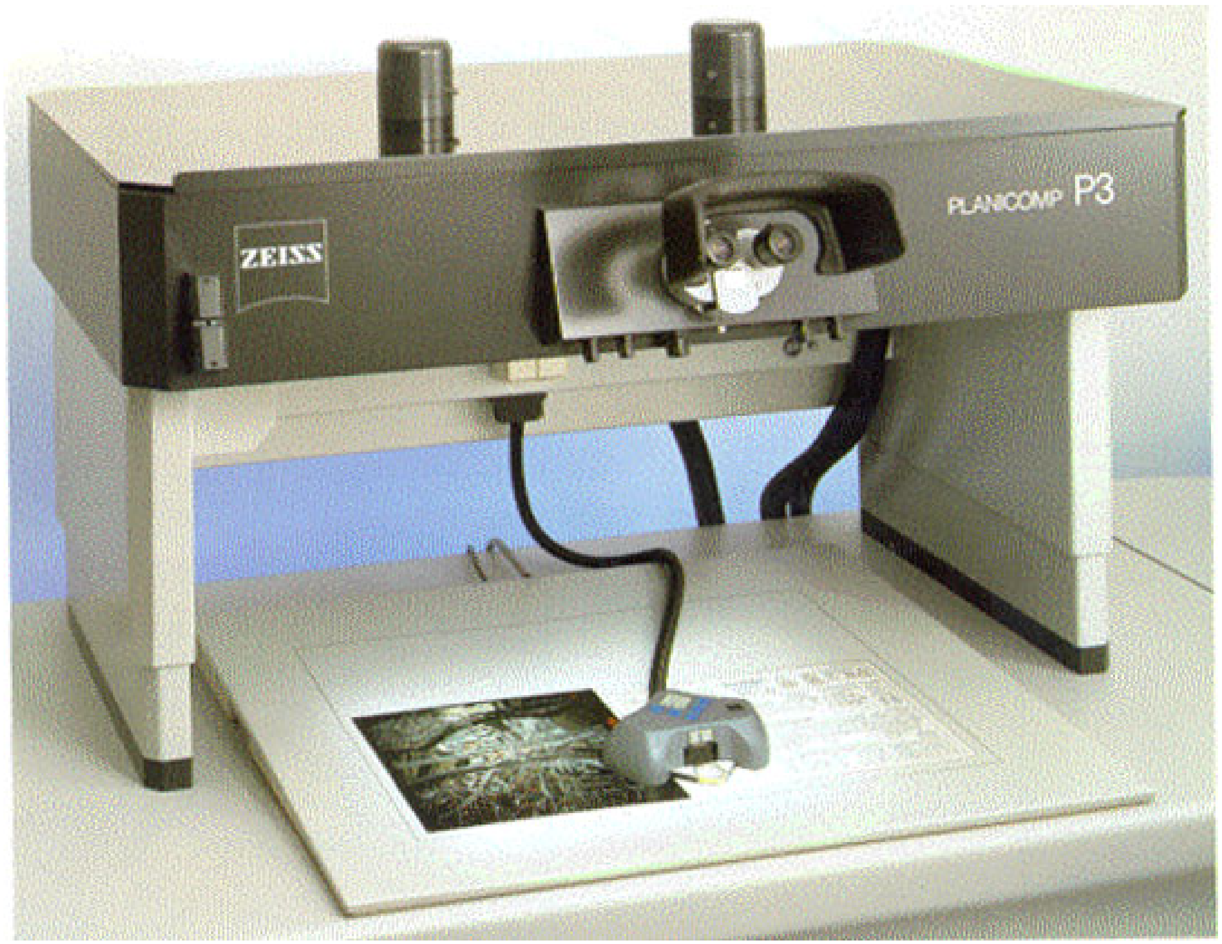
Analytical Photogrammetry



BC3 Analytical Plotter

http://mundogeo.com/wp-content/uploads/2000/portugues/infogeo/04/pag48b.jpg

Analytical Photogrammetry



Ziess P3 Analytical Plotter

http://www.cardinalsystems.net/help5/digconfig_image056.jpg

Analytical Photogrammetry

Stereo-viewing & Stages

http://www.cardinalsystems.net/help5/digconfig_image056.jpg

Digital Photogrammetry

http://www.dammaps.com/Images/KLT-Softcopy.jpg

ImageStation 2002 Digital Photogrammetric Workstation (DPW)

Digital Photogrammetry

ImagStation SSK: Stereo Softcopy Kit

http://www.solgrafperu.com/images/productos/imagestation_ssk.jpg

Digital Photogrammetry

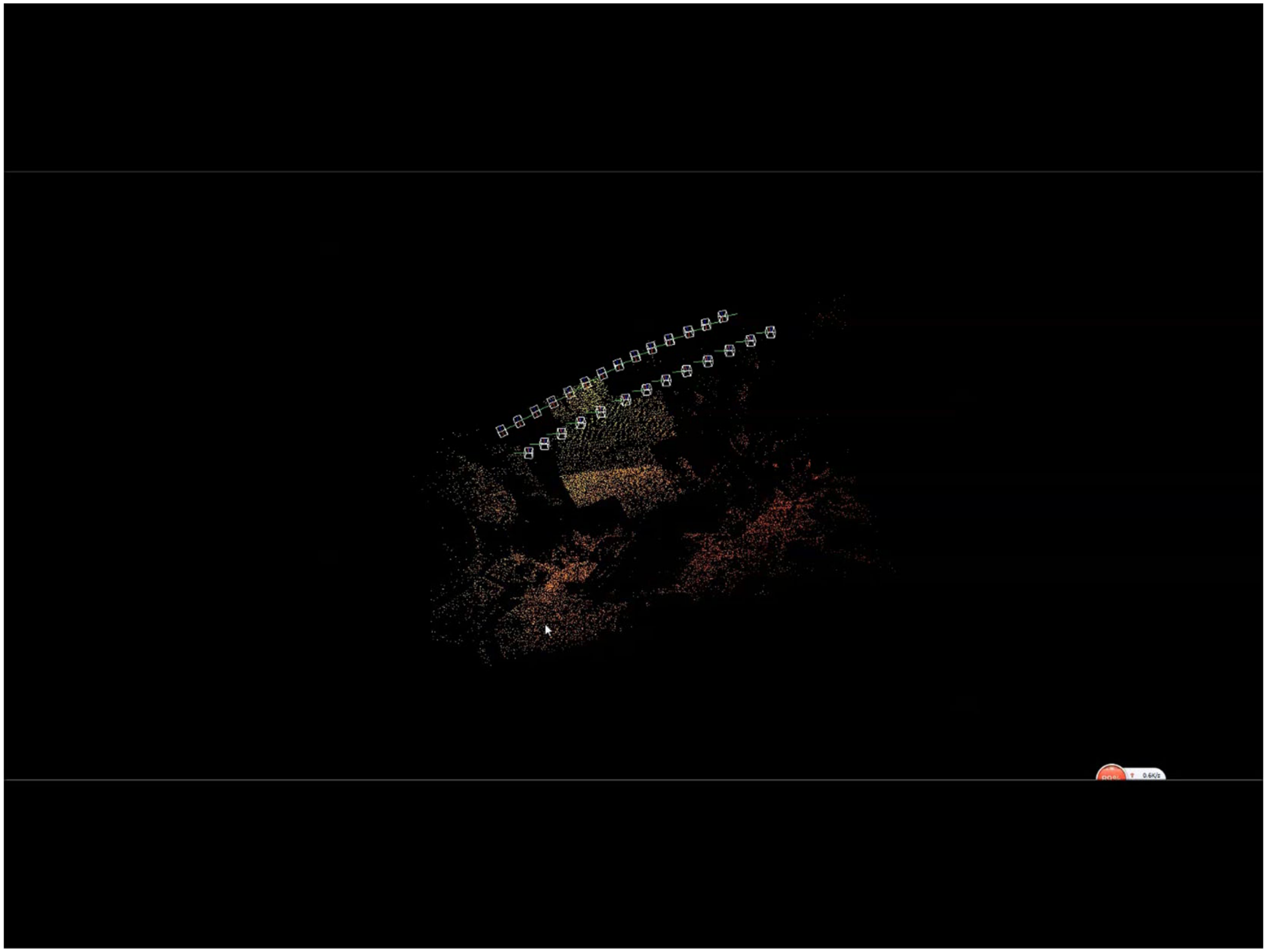
DJI Phantom 2 Vision

Digital Photogrammetry

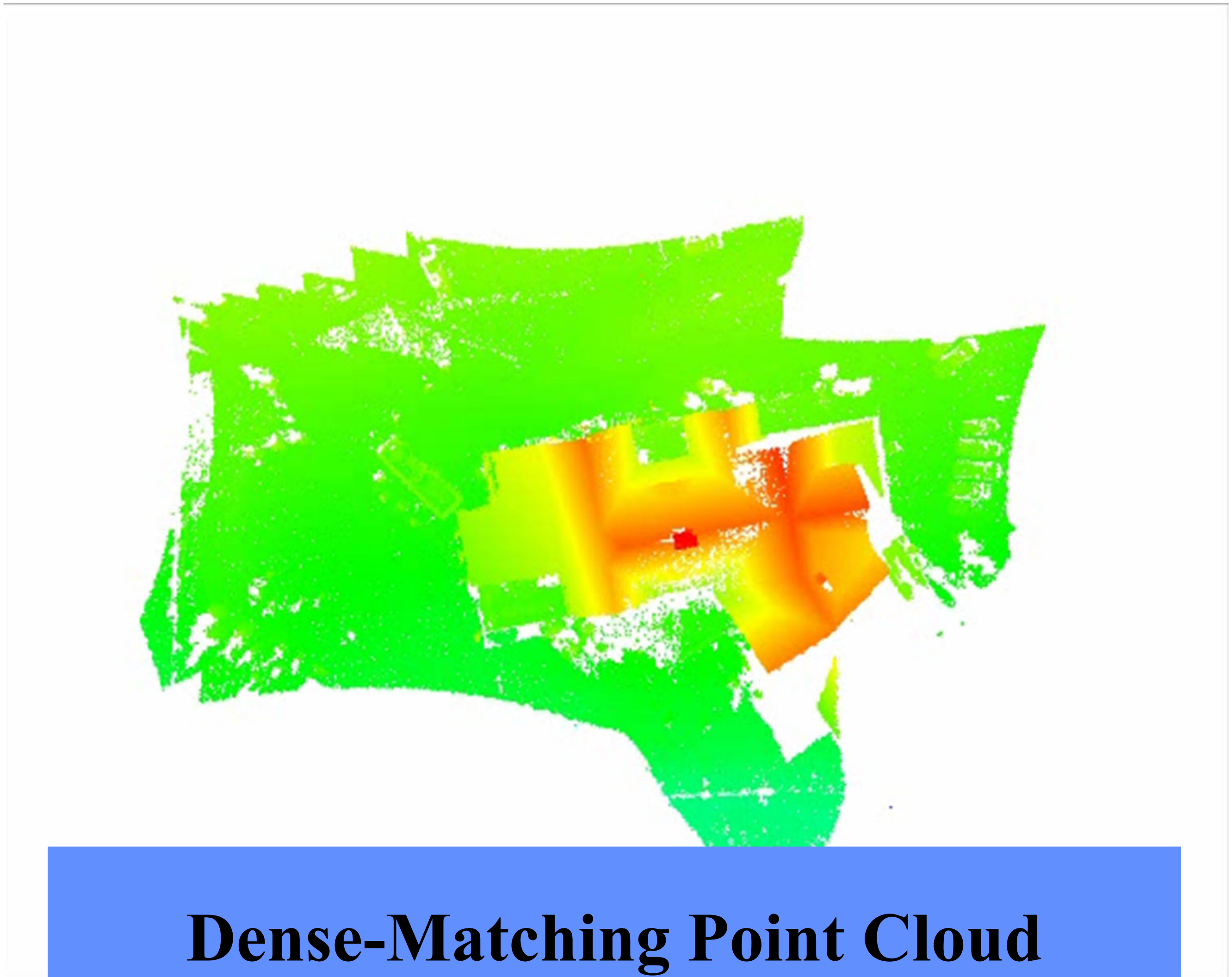
Ronald McDonald House – Calgary

Digital Photogrammetry

Digital Photogrammetry

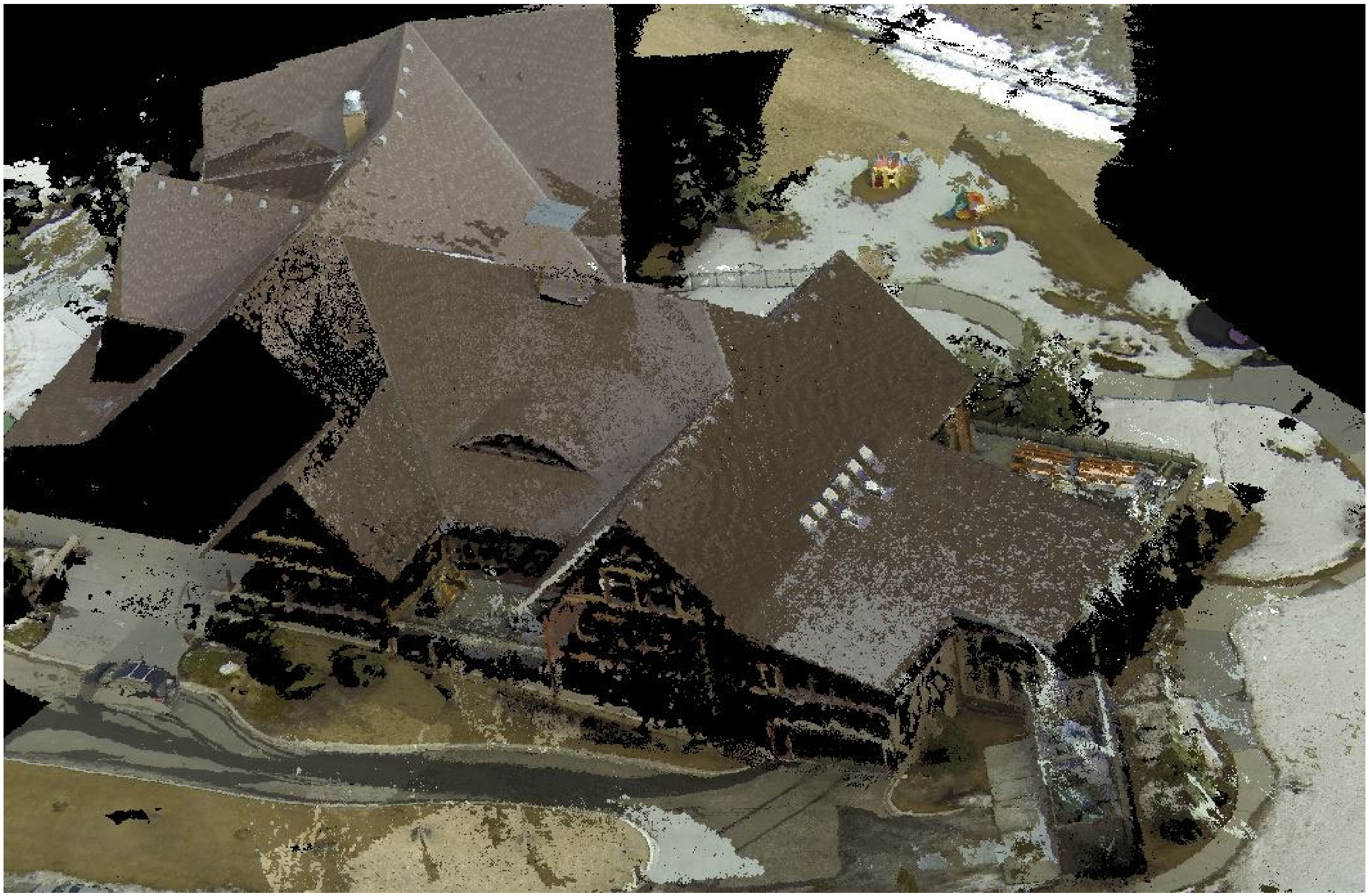


Digital Photogrammetry



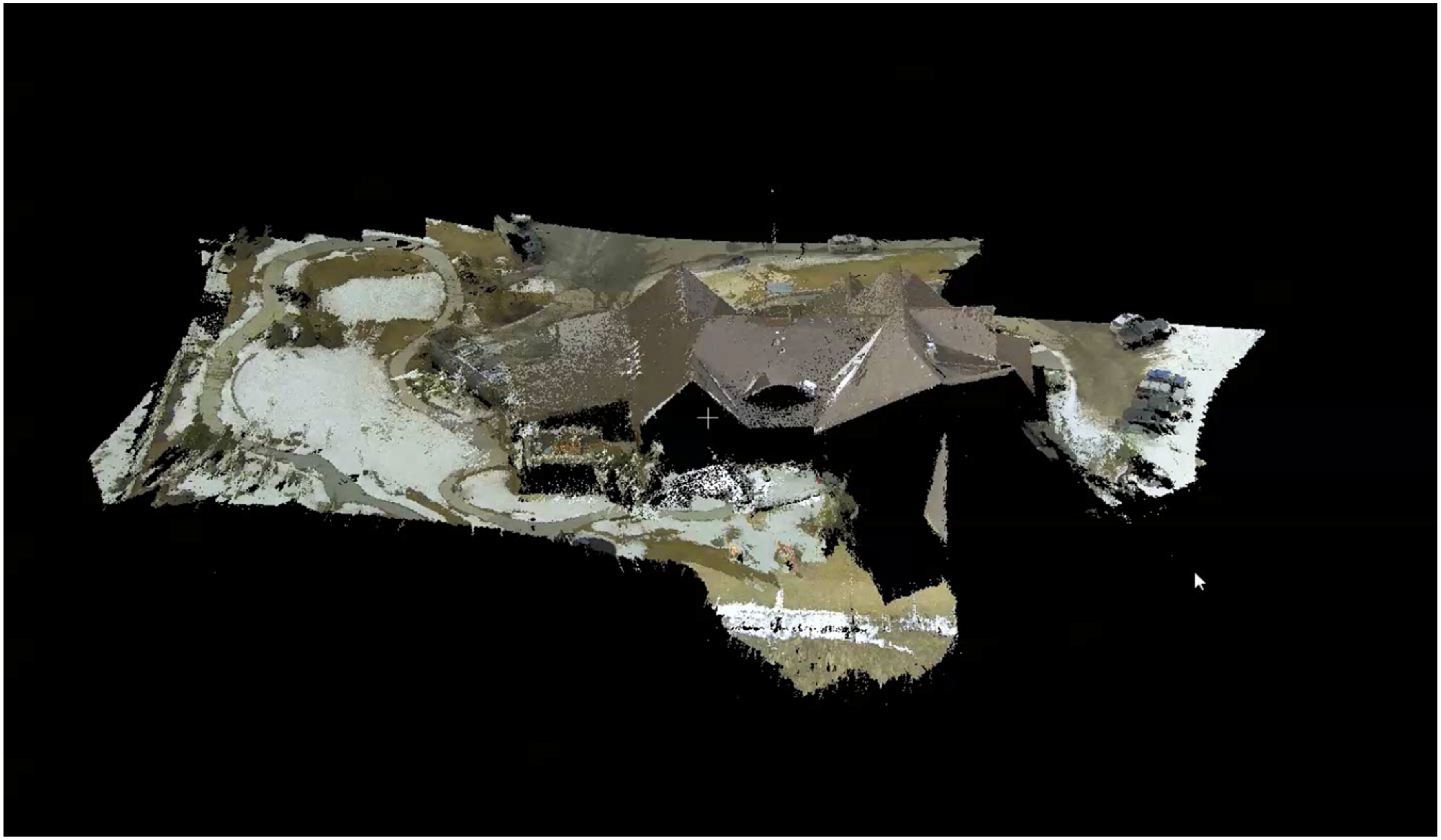
Dense-Matching Point Cloud

Digital Photogrammetry



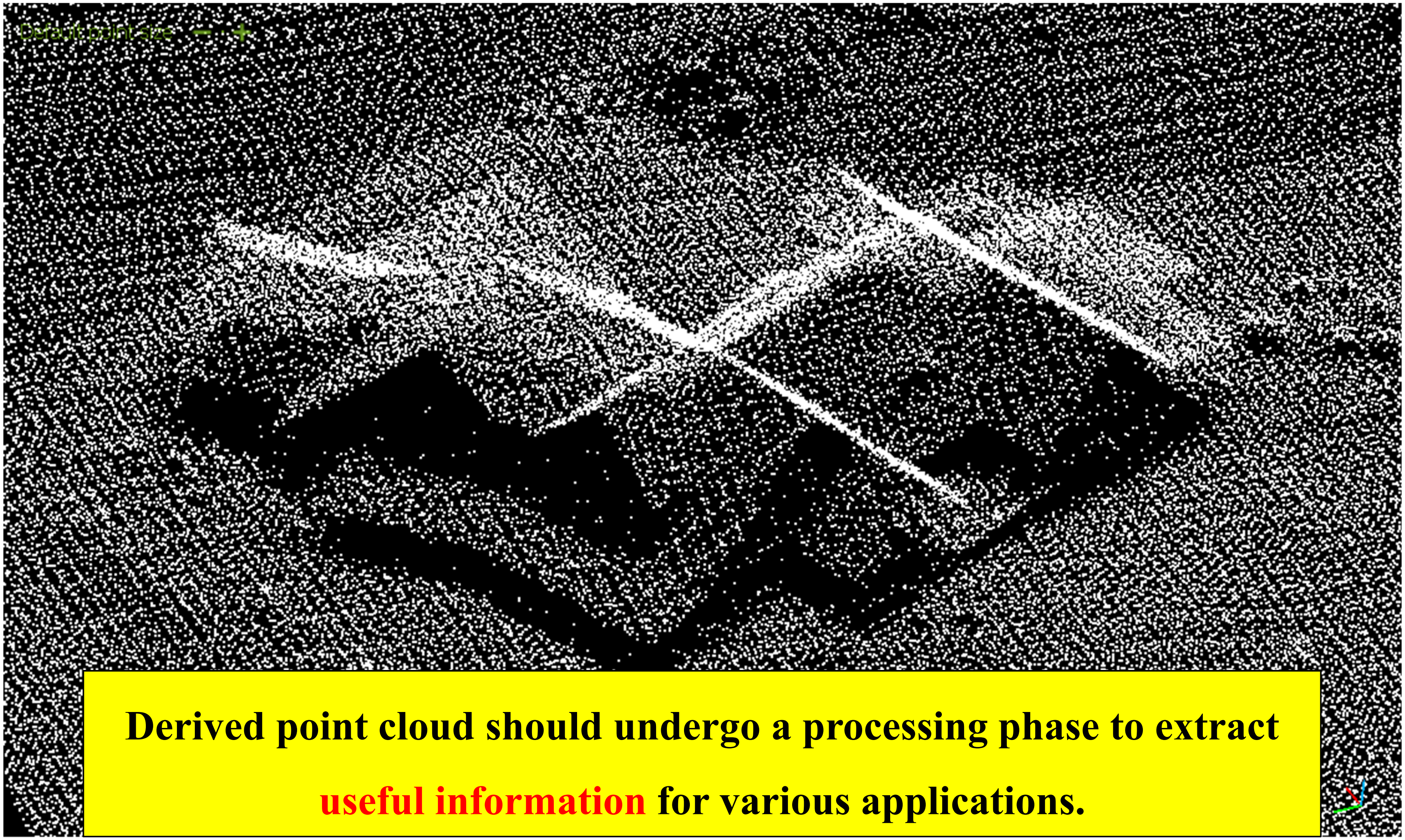
Derived Point Cloud

Digital Photogrammetry



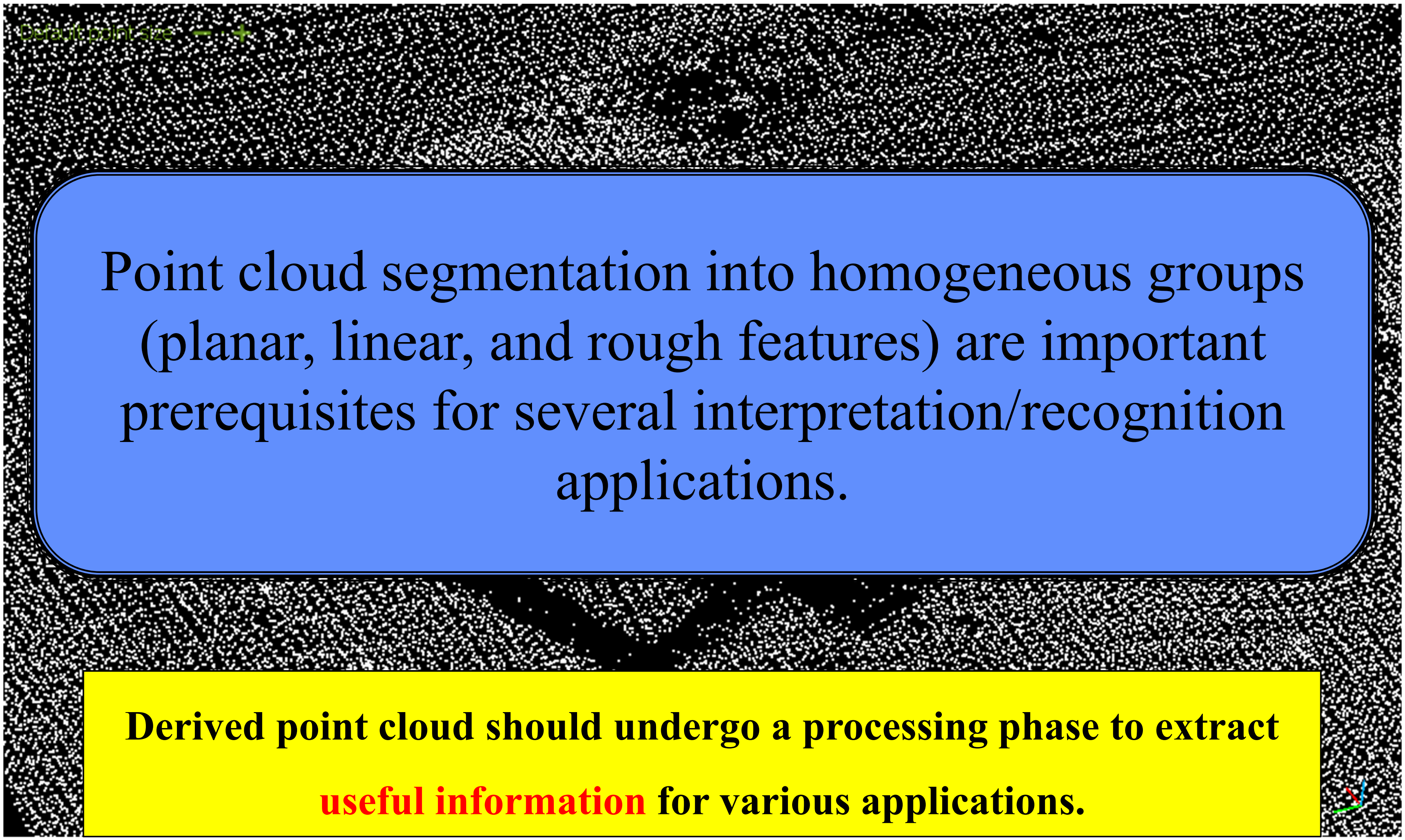
Derived Point Cloud

Digital Photogrammetry



Derived point cloud should undergo a processing phase to extract useful information for various applications.

Digital Photogrammetry



Point cloud segmentation into homogeneous groups (planar, linear, and rough features) are important prerequisites for several interpretation/recognition applications.

Derived point cloud should undergo a processing phase to extract useful information for various applications.

Digital Photogrammetry

Digital Photogrammetry

Digital Photogrammetry

Image Coordinate Measurements

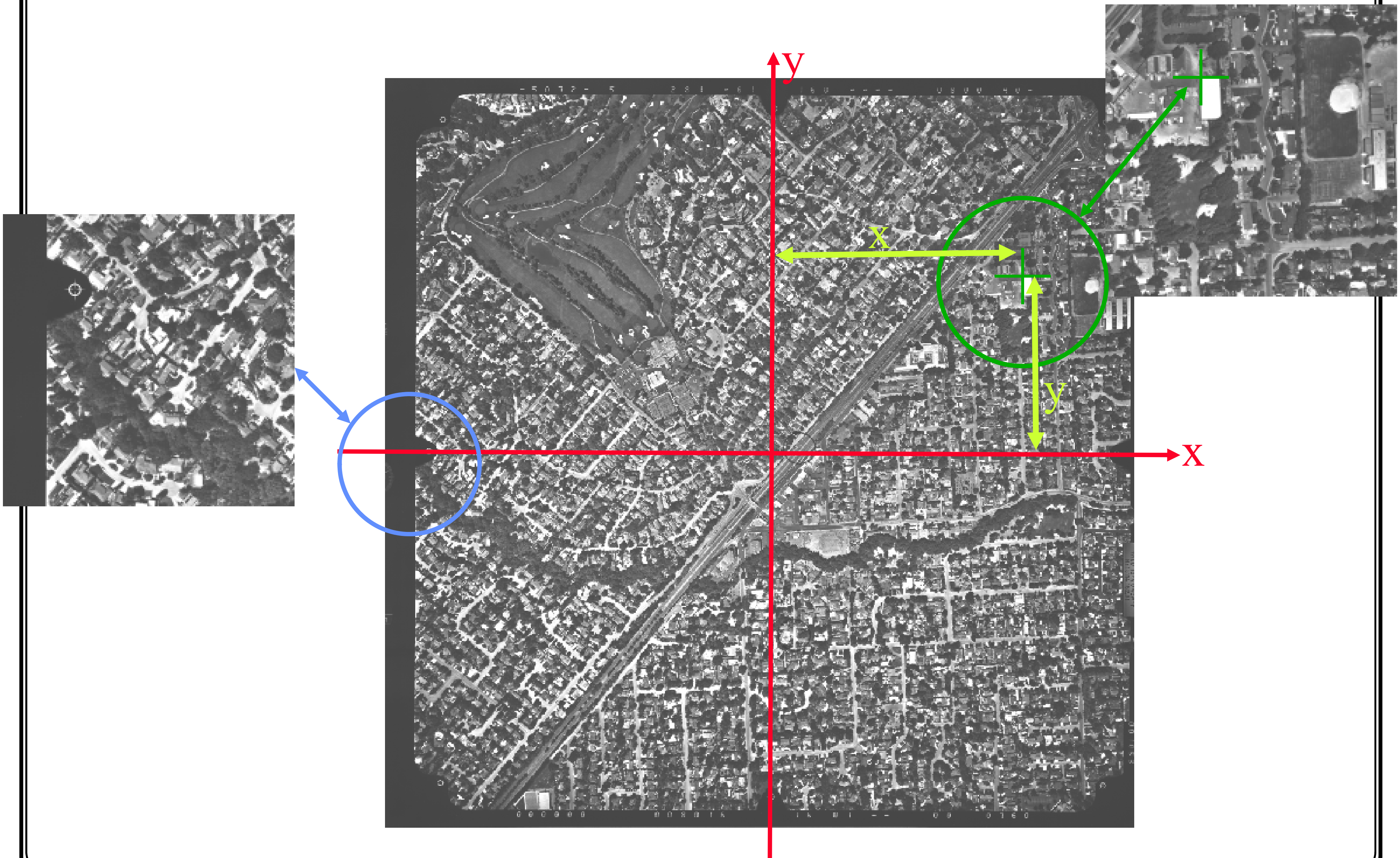
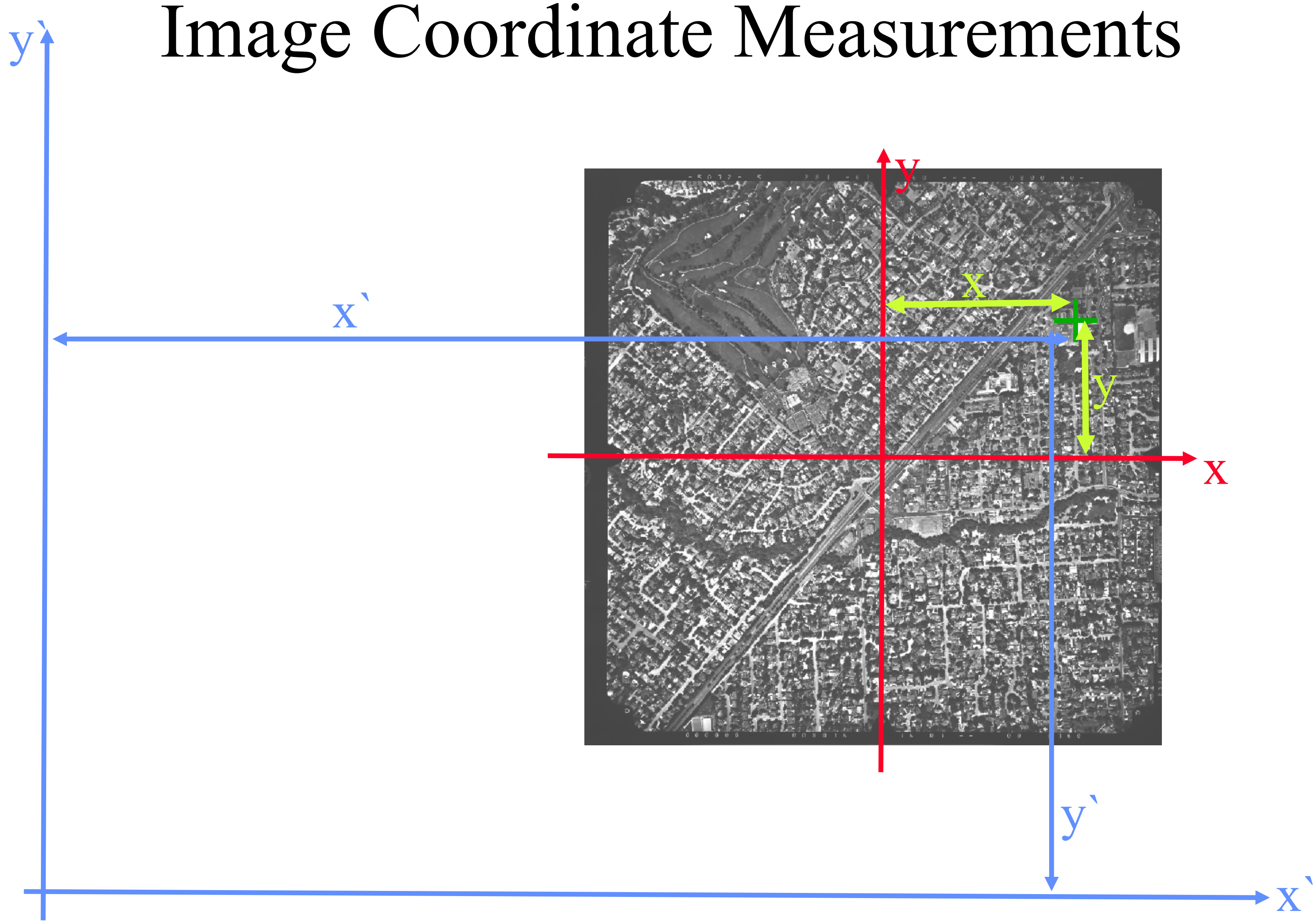


Image Coordinate Measurements



Comparator coordinates (x`, y`) → Image coordinates (x, y)

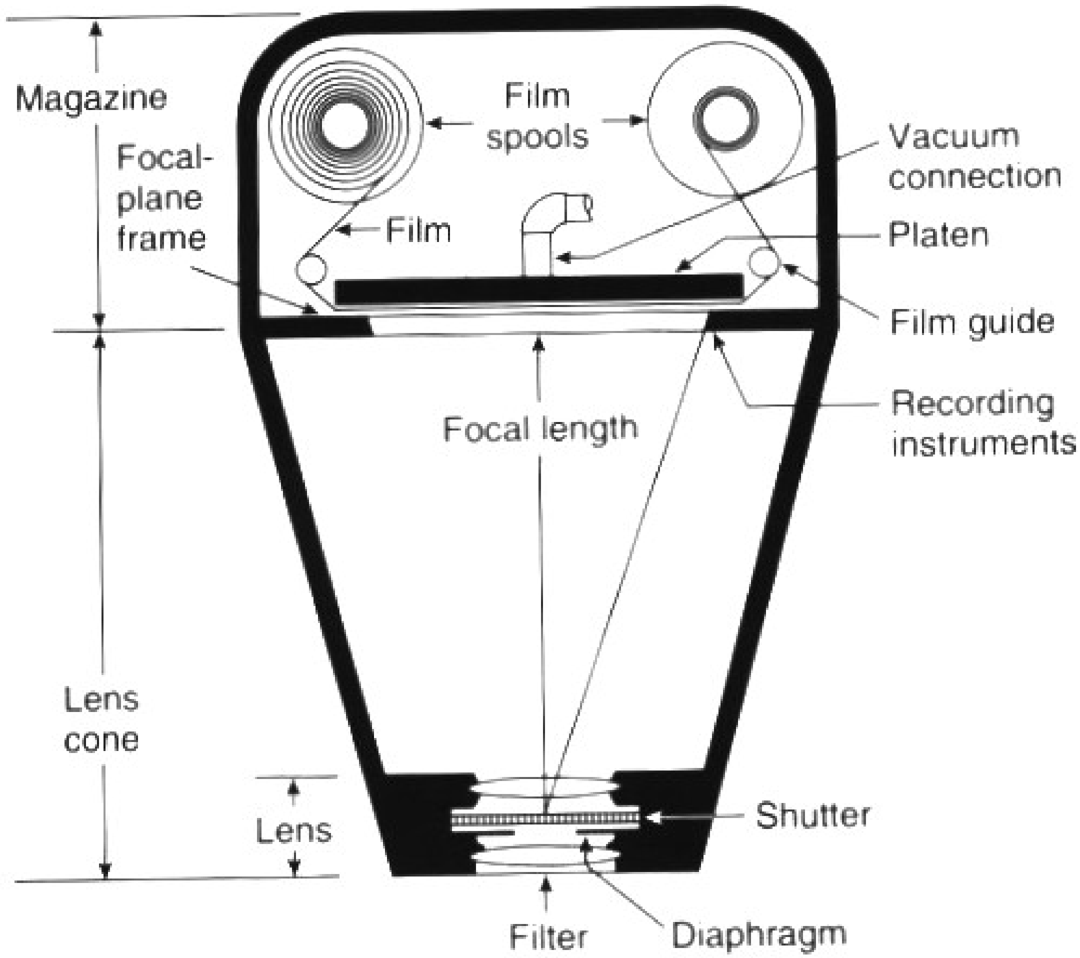
Image Coordinate Measurements

- We cannot directly measure the image coordinates of features of interest.
- We use machines (known as comparators) to measure the coordinates relative to the machine coordinate system.
  - Output: Machine/comparator coordinates
- The machine/comparator coordinates are reduced to image coordinates (i.e., relative to the image coordinate system).

Coordinate Measurements in Analog Images

Comparators

Analog Cameras



http://cmapspublic.ihmc.us/rid=1235786230204_282179246_24695/Photogramm%C3%A9trie%20-%20Cam%C3%A9ras%20a%C3%A9riennes%20analogiques.jpg

Analog Cameras

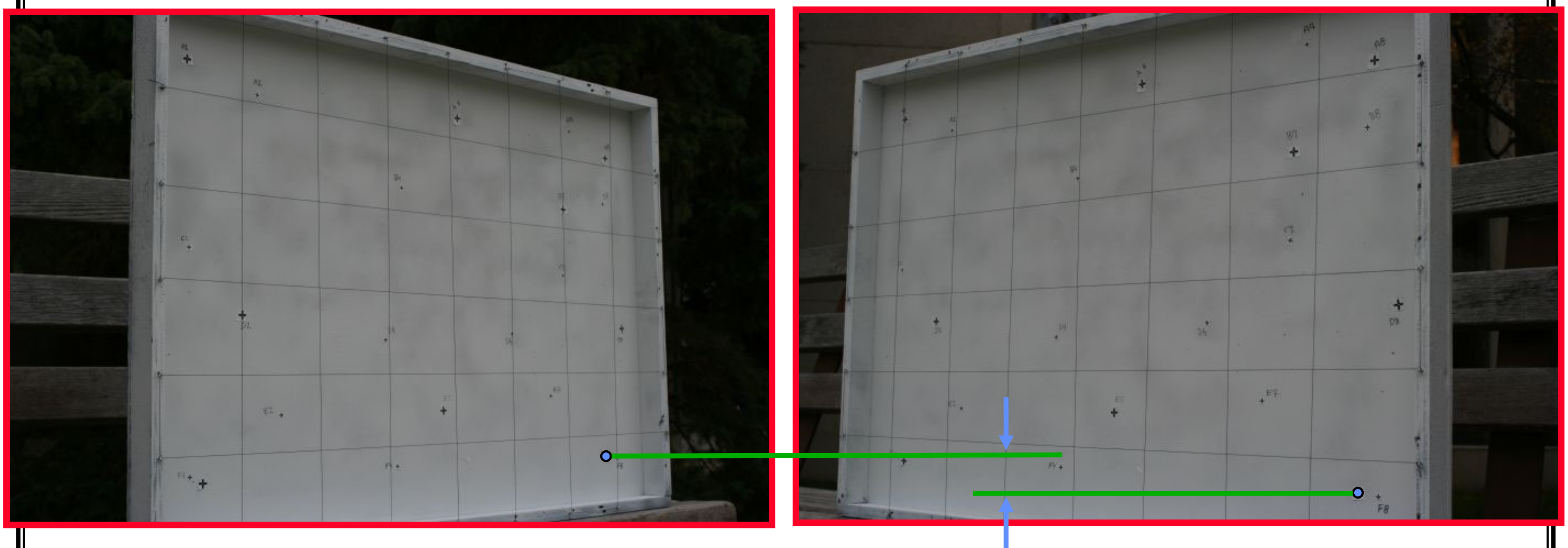
RC 30

http://www.kasurveys.com/Sensors.html

Comparators

- Comparators are highly accurate machines for measuring the xy-coordinates of selected points in the image plane.
- Comparators can be classified into:
  - Mono-comparators: coordinates are measured in one image at a time.
  - Stereo-comparators: coordinates are measured in a stereo-pair simultaneously.

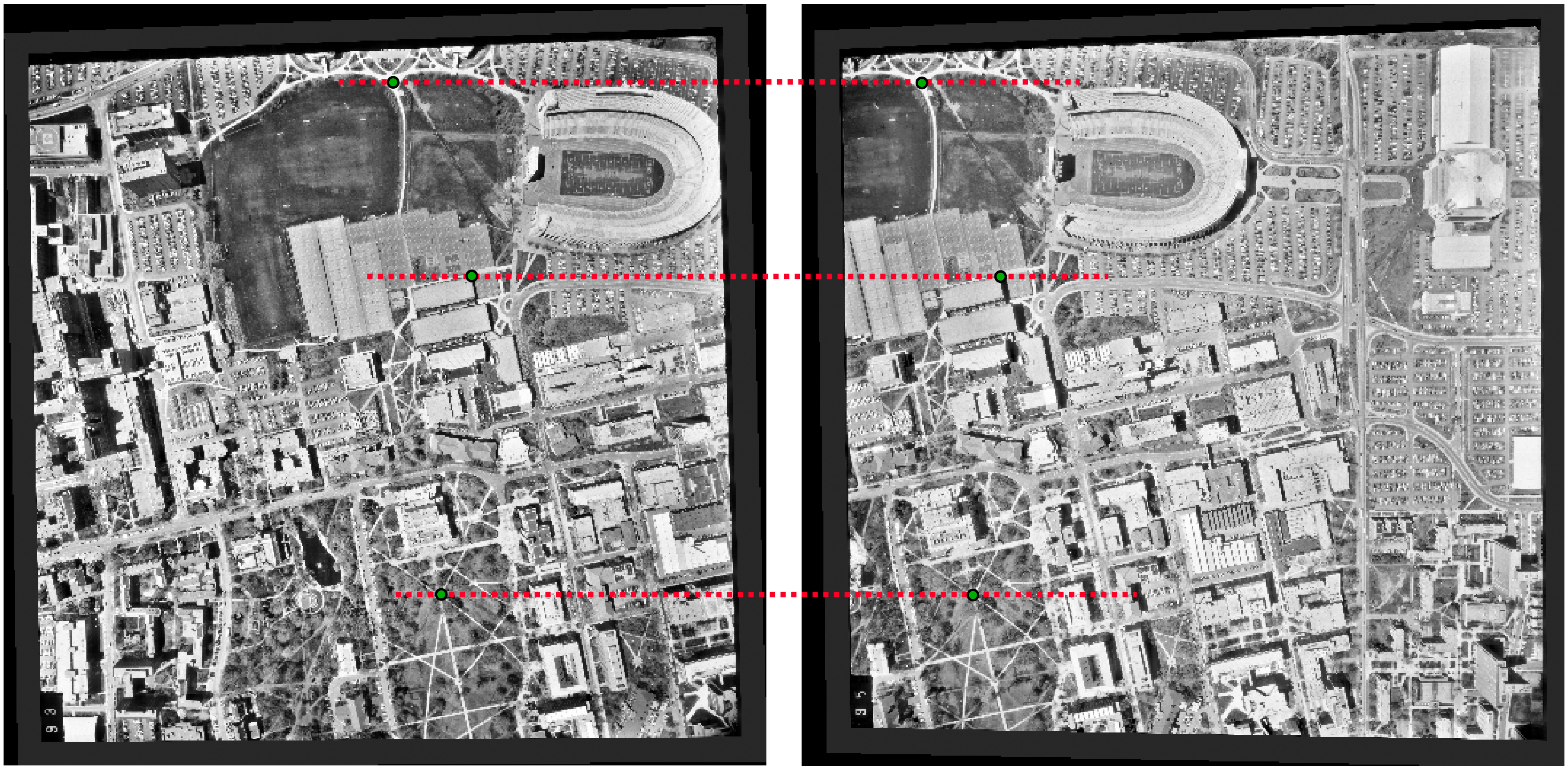
Stereo-Imaging



y-Parallax

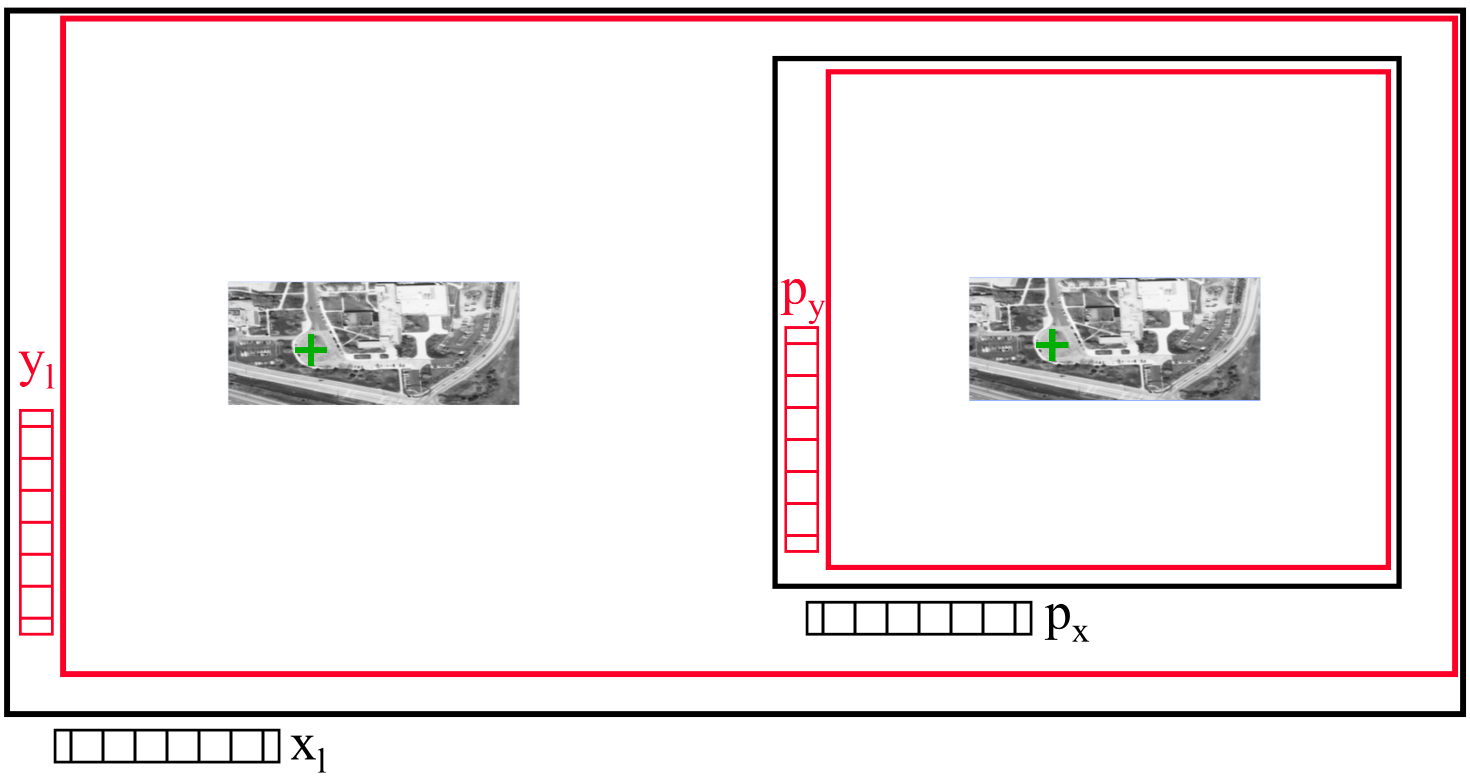
Convergent Imagery

Stereo-Imaging



No y-parallax → Normal Case Imagery

Stereo-Comparators



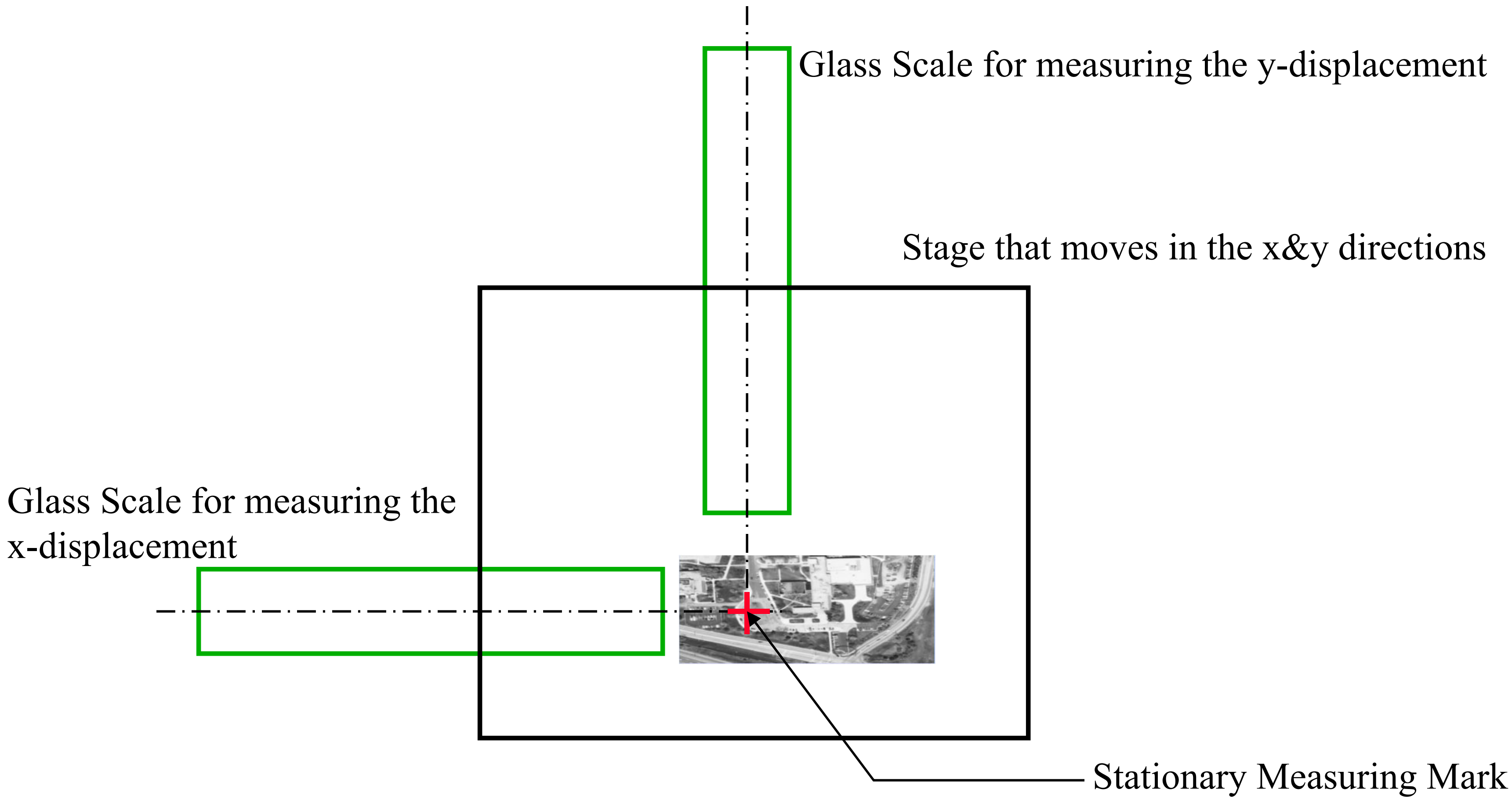
Stereo-Comparators

- Two stages on top of which the two images of a stereo-pair are mounted.
- If no y-parallax exists, points can be selected and measured stereoscopically (i.e., in 3-D).
- Condition for stereoscopic viewing:
  - $d\omega$ and $d\phi$ between the two images are small.
  - There is no vertical/y parallax.

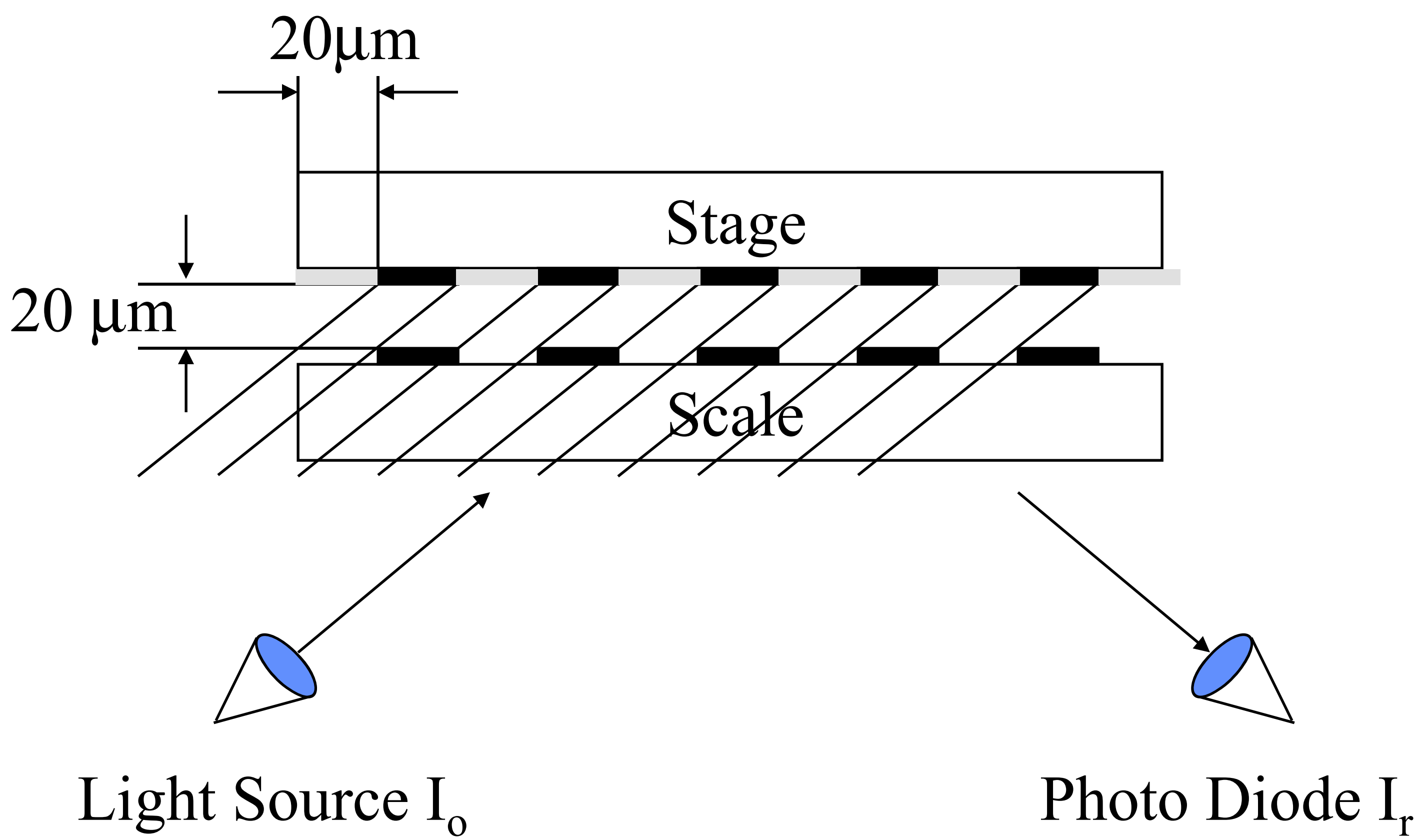
Stereo-Comparators

- Measurements:
  - ($x`_l$, $y`_l$) stage coordinates in the left image
  - (p_x, p_y) offsets (parallax) to the conjugate point in the right image
- $x`_r = p_x + x`_l$
- $y`_r = p_y + y`_l$
- Advantage: Points are selected stereoscopically → Higher accuracy → Less mis-matches.
- Disadvantage: Stereoscopic viewing is possible only if the rotation angles (ω, ϕ) are small.

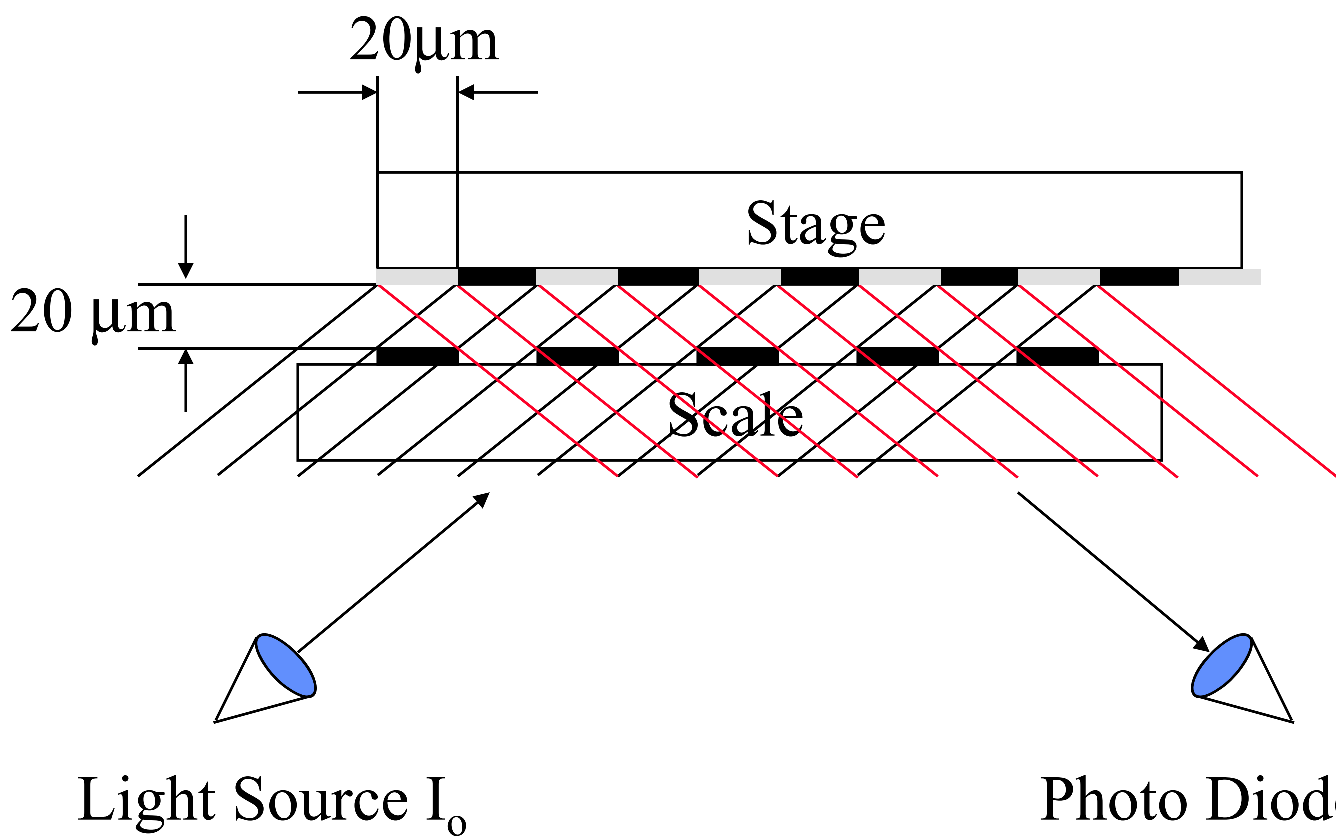
Mono-Comparators



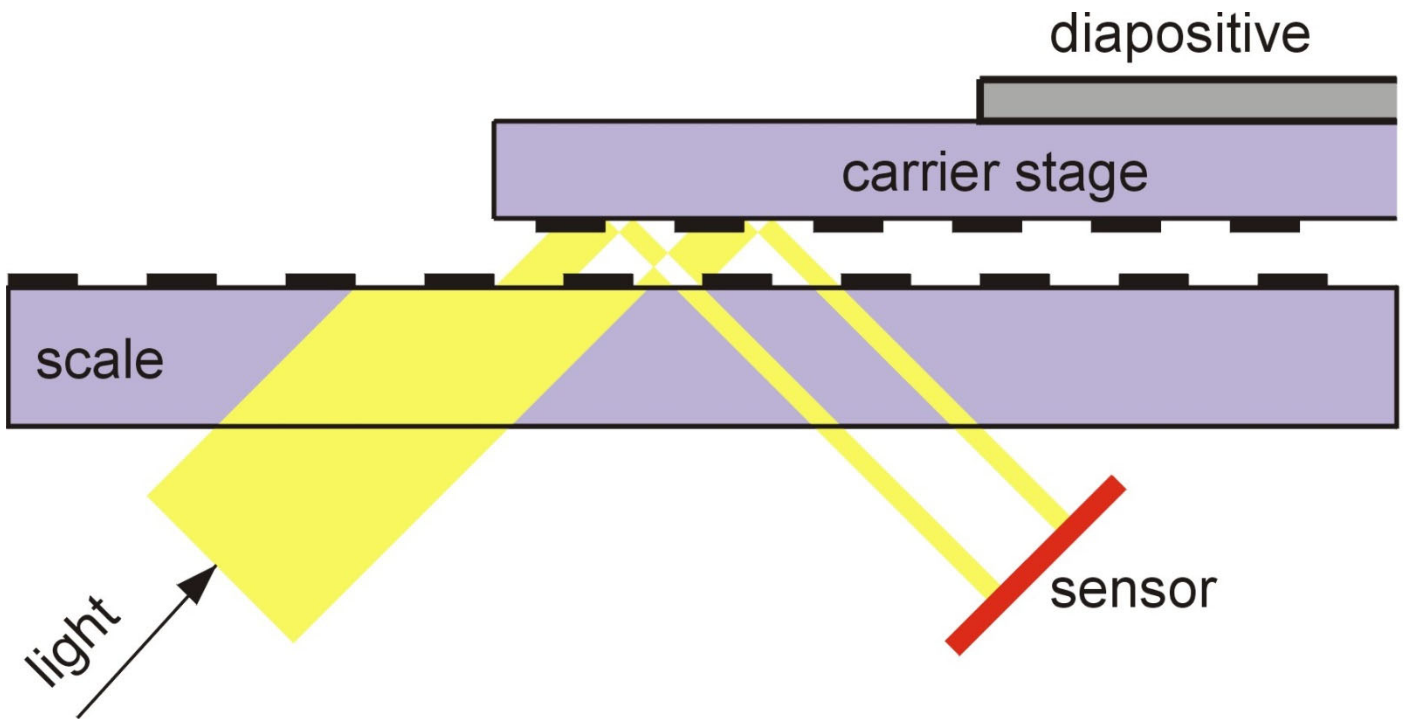
Measurement of Stage Movement



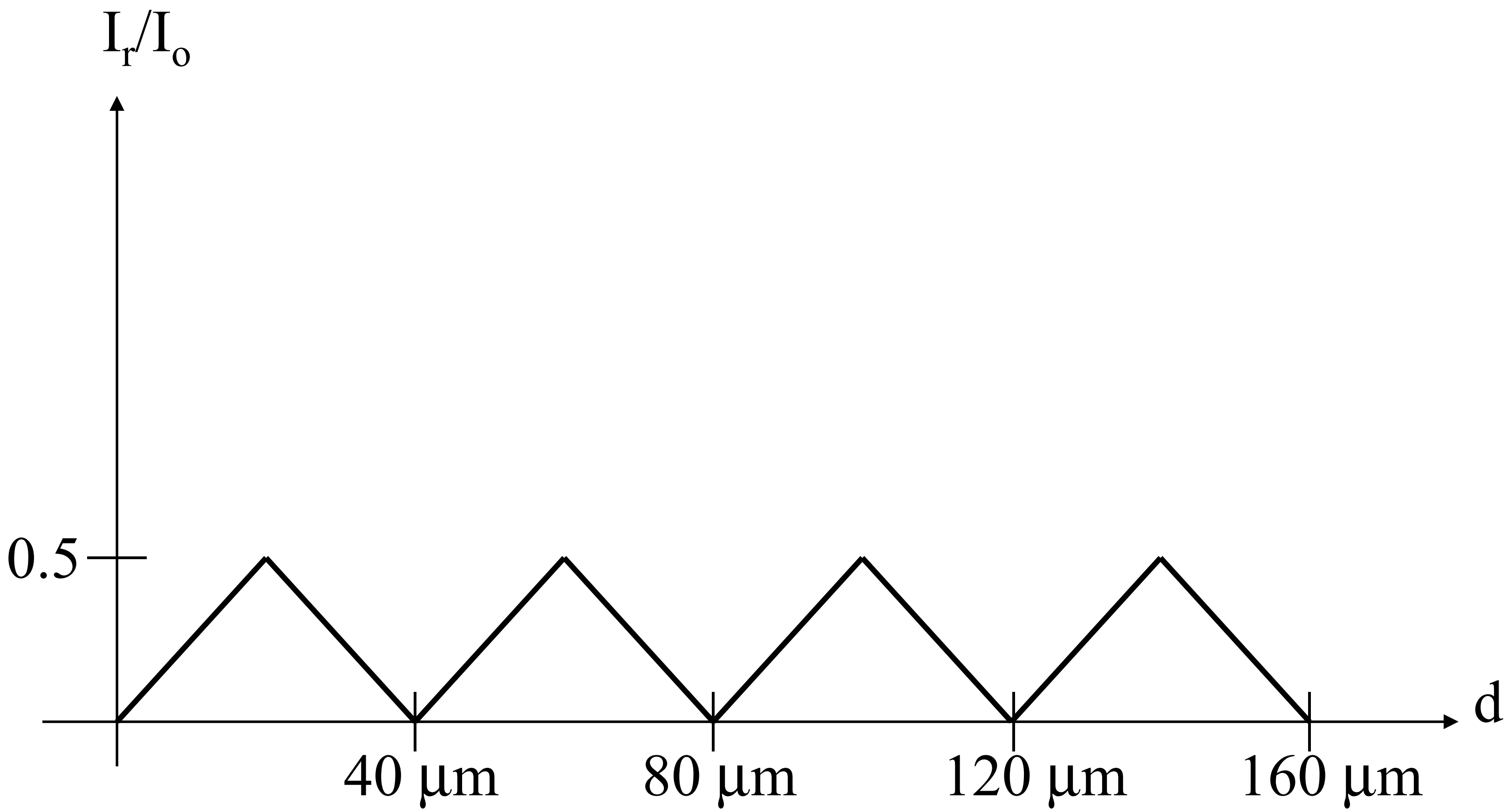
Measurement of Stage Movement



Measurement of Stage Movement



Measurement of Stage Movement



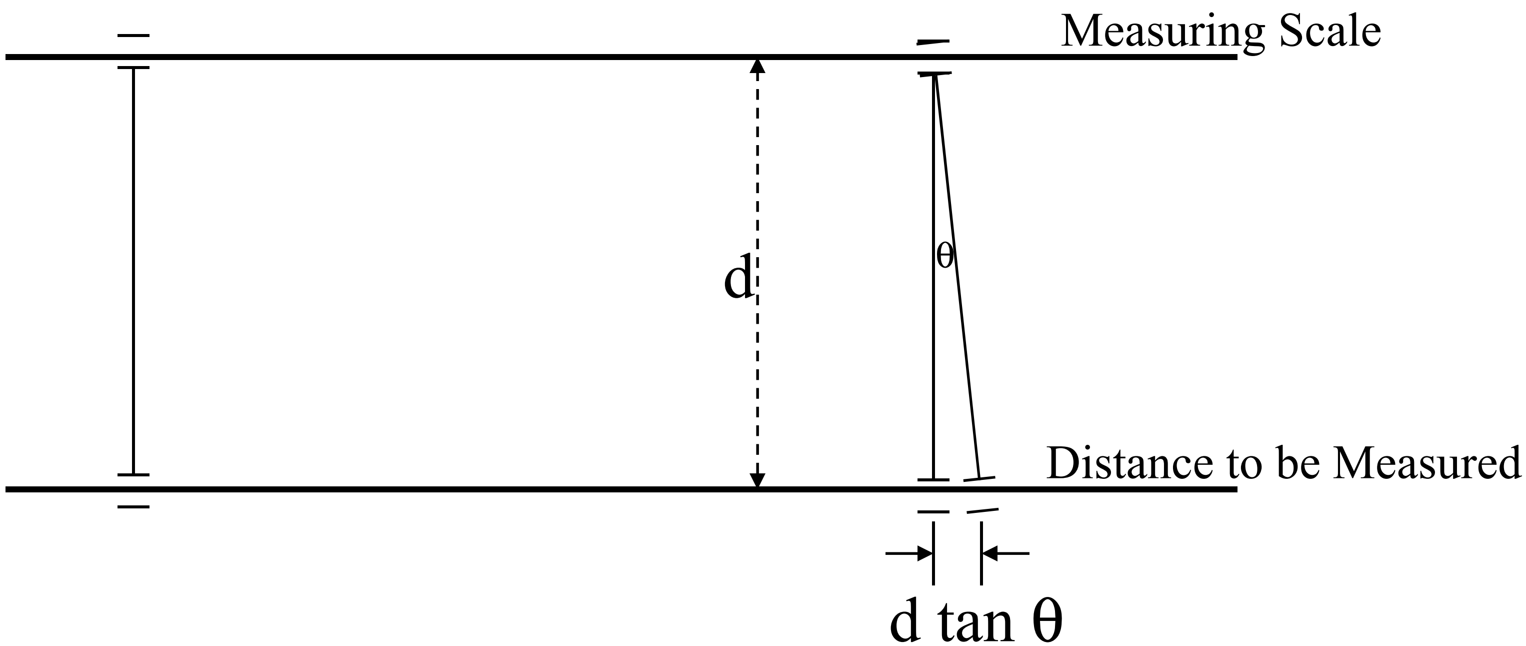
Measurement of Stage Movement

- The number of maxima and minima in the current from the photo diode is proportional to the stage displacement.
- Using linear interpolation, we can measure displacements as small as 1µm.

Abbe's Rule

- The accuracy of the comparator depends on the spacing between the distance to be measured and the measuring scale.
- Abbe's rule states that the distance to be measured and the measuring scale should be along a straight line (to achieve the highest accuracy possible).

Abbe’s Rule



Comparators

- Stereo Comparators:
  - \+ Points are selected in 3-D.
  - \+ More accurate
  - \+ Less mis-matches
  - – More expensives
  - – Larger in size
  - – Cannot be used for convergent imagery (Aerial imagery only)
- Mono Comparators:
  - – Points are selected in 2-D.
  - – Less accurate
  - – More mis-matches
  - \+ Less expensive
  - \+ Smaller in size
  - \+ Can be used with any kind of imagery (Aerial & close range)

Point Transfer Devices

- Point transfer devices physically mark the points on the emulsion using a needle or a small drill.
- Points are viewed stereoscopically.
- Point transfer devices + mono-comparators will yield an accuracy which is similar to that obtained from stereo-comparators.

Point Transfer Devices

http://www.ebay.ca/itm/POINT-TRANSFER-DEVICE-HEERBRUGG-WILD-PUG-4-PUG4-Avioimage-Mapping-Photogrammetry-/150781495683

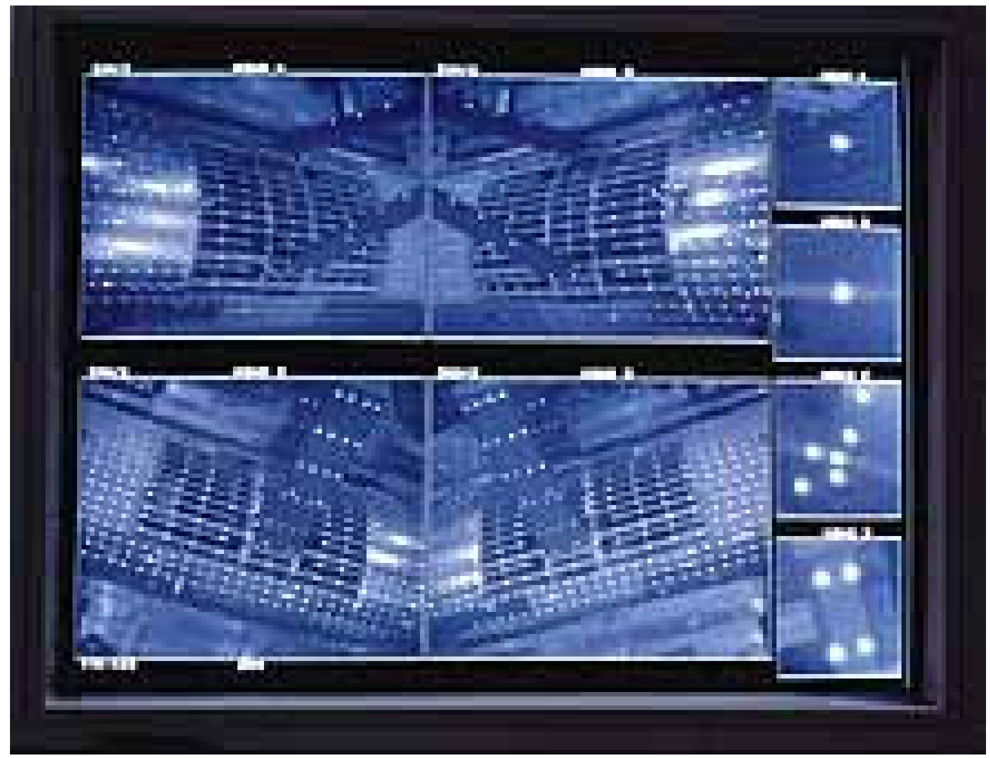
Point Transfer Devices

Automatic Comparators

- Stage (comparator) coordinates are measured automatically.
- The stage is moved in the xy-directions by means of high precision servo-motors.
- For this type of comparators, we use retro-reflective targets:
  - When they are illuminated at the moment of exposure, they produce high contrast to their background.

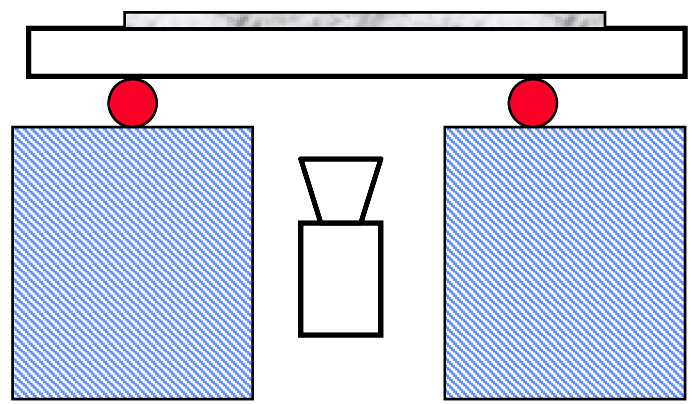
Retro-reflective Targets

Retro-reflective Targets



http://archives.sensorsmag.com/articles/0600/71/main.shtml

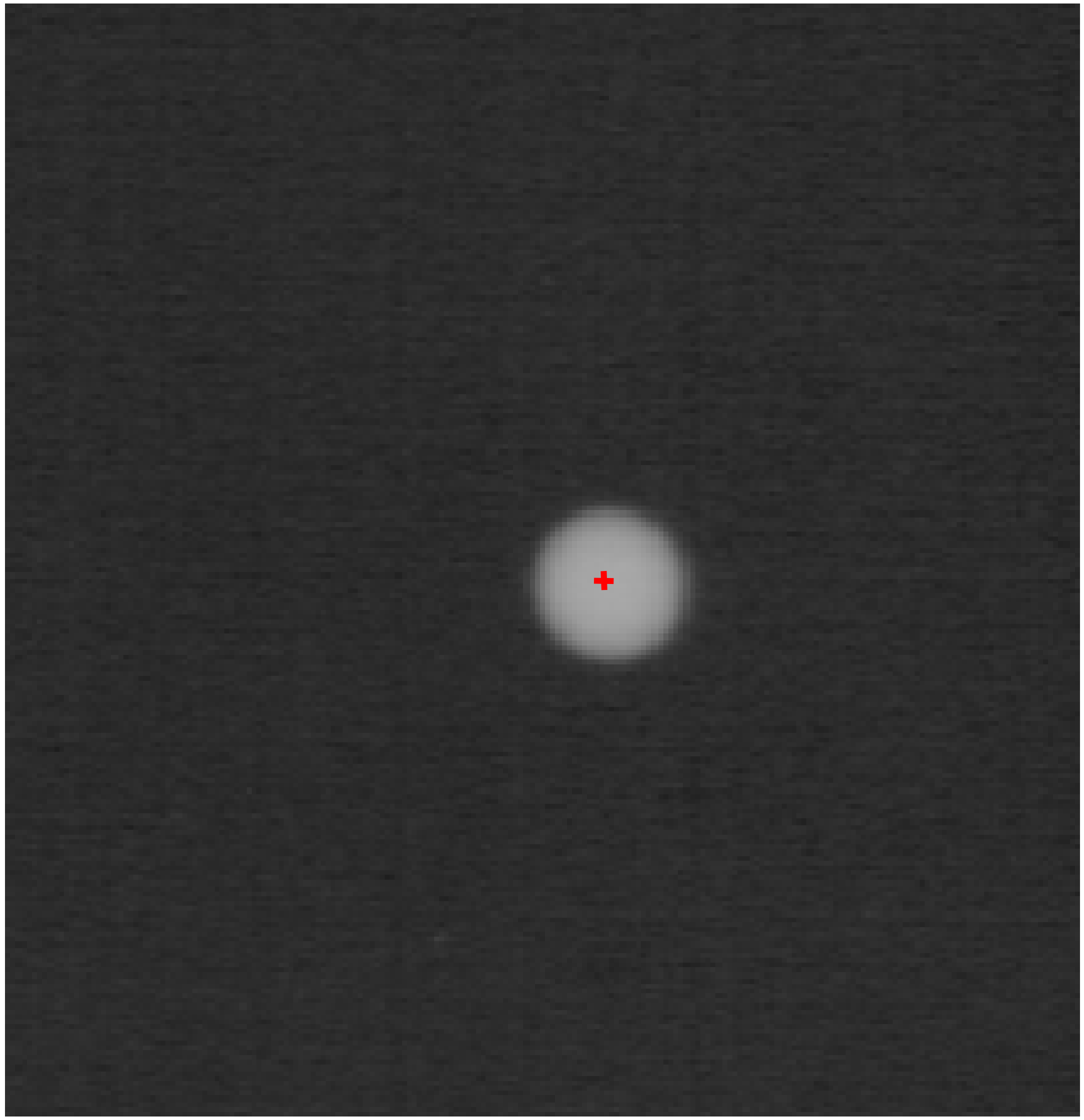
Automatic Comparators



Automatic Comparators

- Approximate locations of the targets in the image are available.
- The stage is driven to the approximate locations of the targets.
- This part of the image is digitized by a CCD camera.
- Through a simple thresholding and centroid extraction algorithm, one can determine the stage coordinates of the target under consideration.

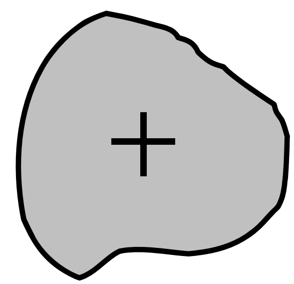
Centroid Extraction



Centroid Extraction

$$x_c = \frac{\sum (g_i - g_{th})\ x_i}{\sum (g_i - g_{th})}$$

$$y_c = \frac{\sum (g_i - g_{th})\ y_i}{\sum (g_i - g_{th})}$$



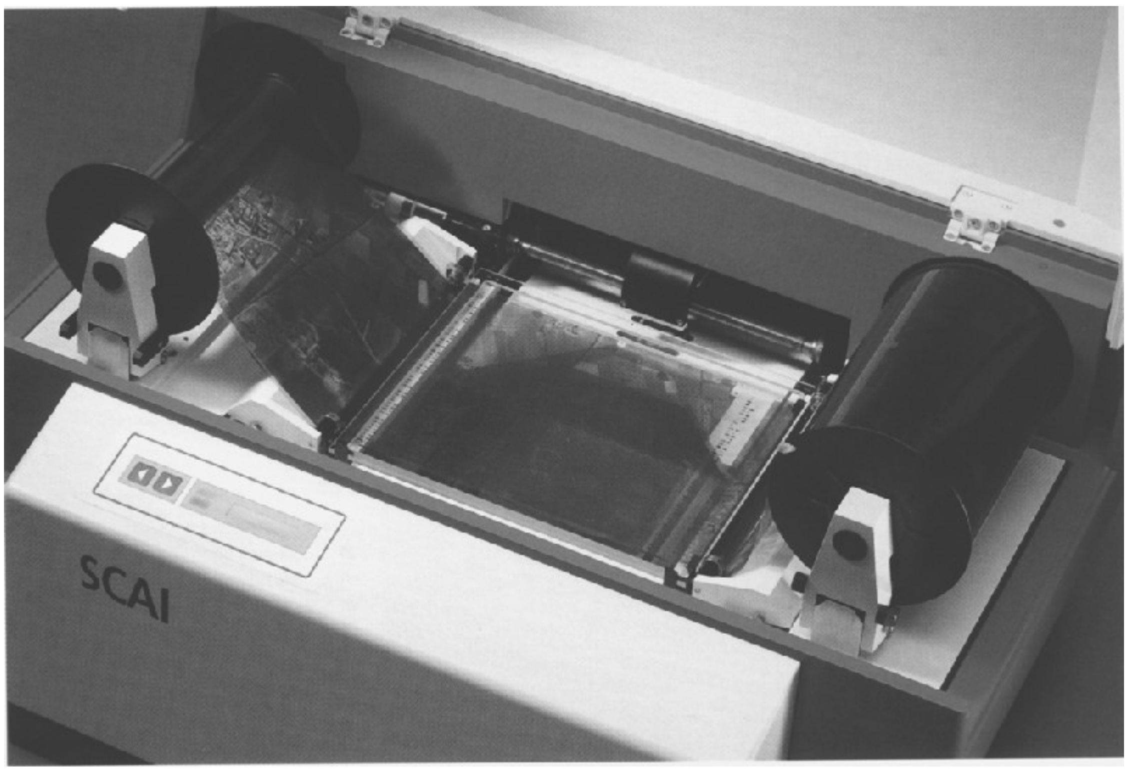
- The summation is carried over all the pixels that belong to the blob.

Coordinate Measurements in Digital Images

Pixel Coordinates

Digital Images

- Digital images can be obtained through either:
  - Scanning analog images (Scanners), or
  - Directly using digital cameras.



Photogrammetric Scanner

http://cmapspublic.ihmc.us/rid=1J5T5YMZV-15ZNLP5-1JMD/Balayeur%20optique.bmp

Digital Cameras

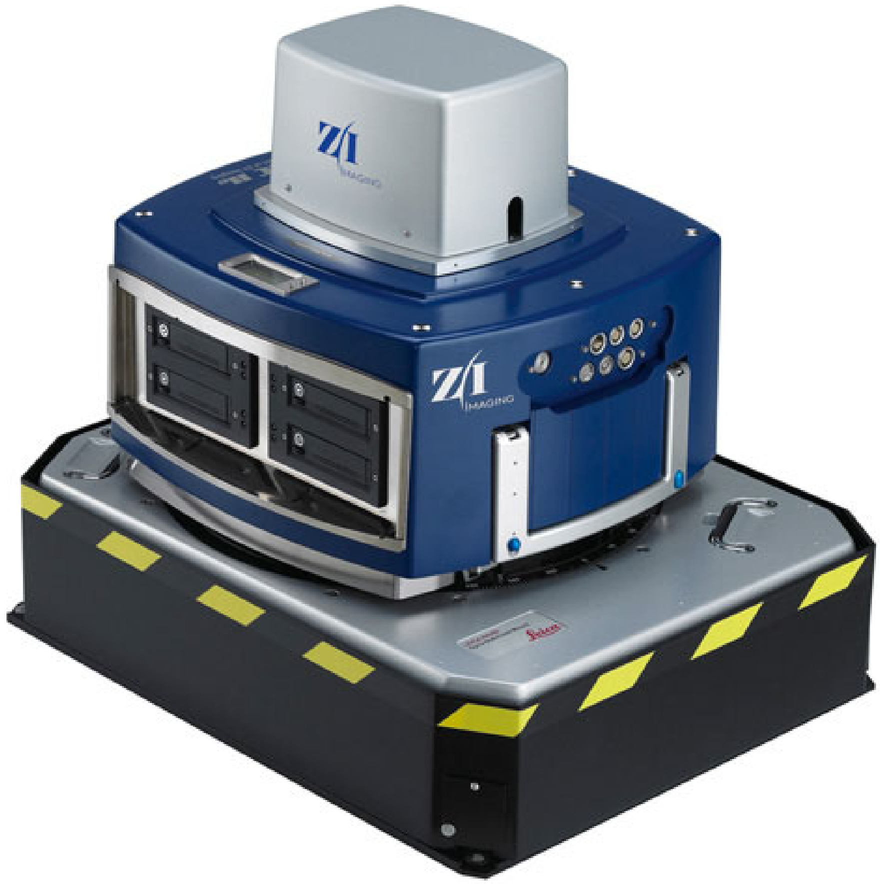
- A digital camera captures an image through a sensor called CCD (*Charge Coupled Devices*) or CMOS (*Complementary Metal-Oxide Semiconductor)*.
  - CCD/CMOS is a chip consisting of an array of light sensitive photo-cells.
- This sensor has light sensing dots called pixels.
- The actual resolution of a camera is controlled by the total number and size of pixels that are located on the CCD/CMOS sensor.
- The more pixels a digital camera has on its sensor, the larger the pictures you can take.

Digital Mapping Camera (DMC™)

http://cmapspublic.ihmc.us

- Digital frame camera developed by Z/I Imaging
- It is a turnkey digital camera designed to support aerial photogrammetric missions
- Resolution: 14kx8k

Digital Mapping Camera: Z/I DMC IIe 250

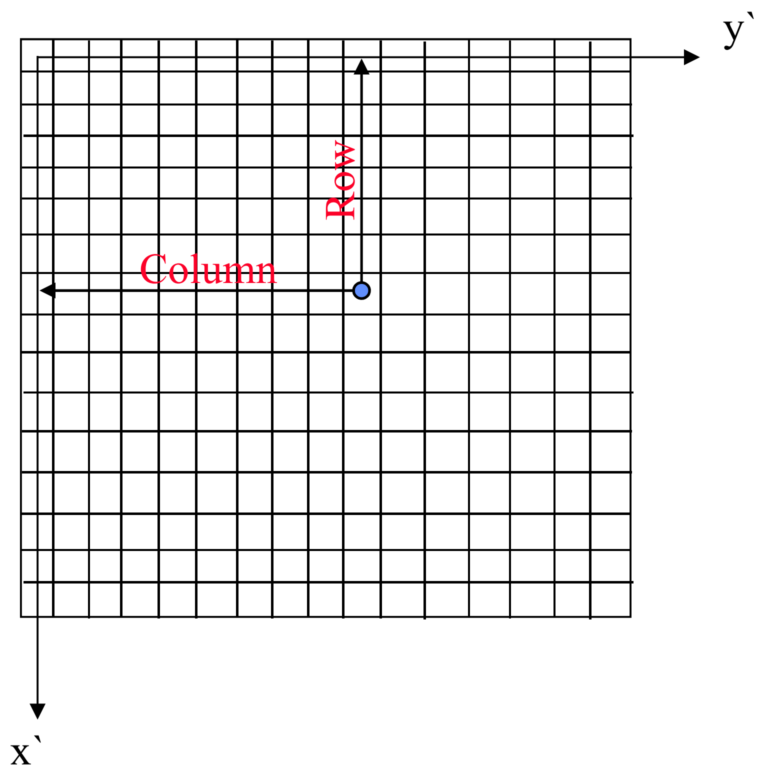


Source: Z/I Imaging

Z/I DMC IIe 250 (16,768x14,016 image format)

- Single PAN CCD and four multispectral cameras

Digital Images



Pixel Coordinates are analogous to comparator coordinates.

Comparator to Image Coordinate Transformation

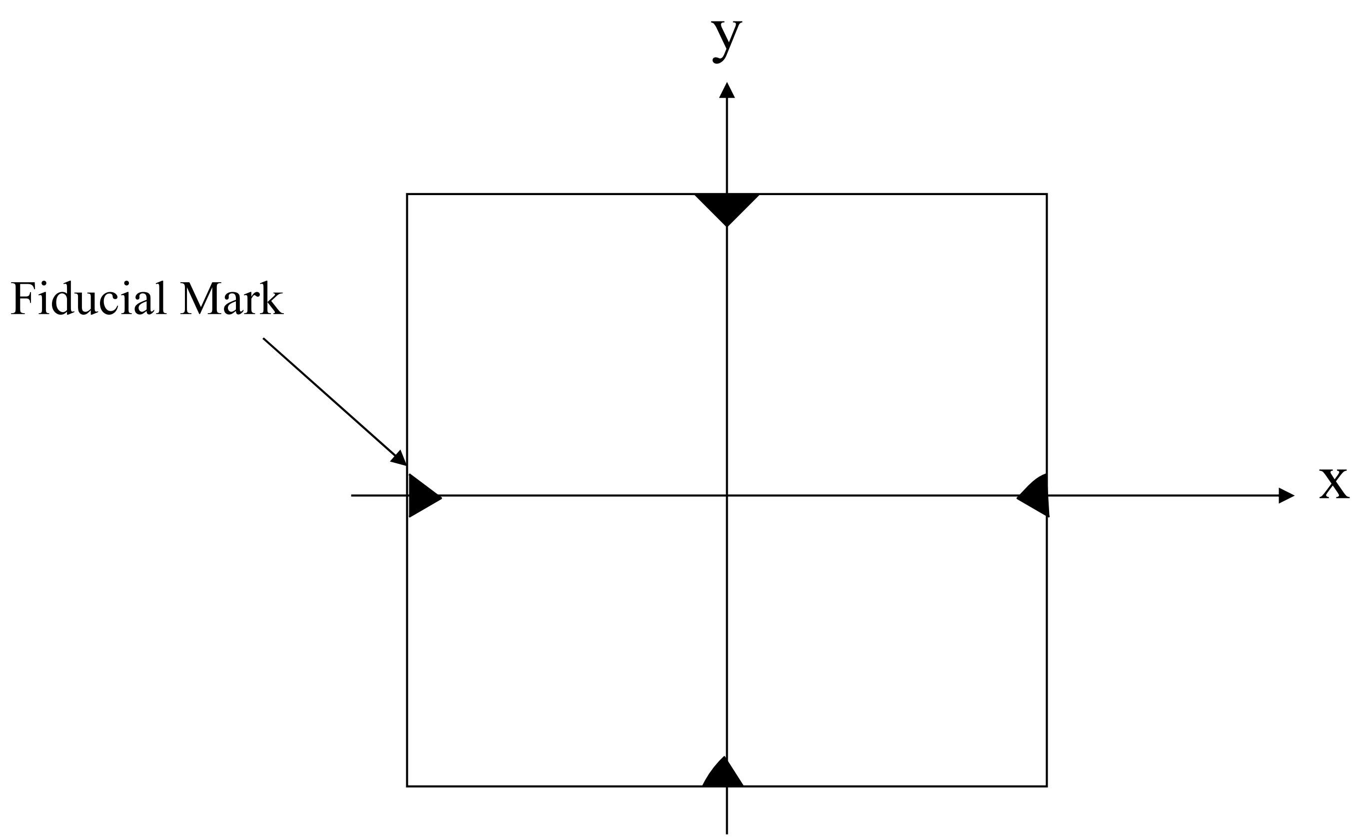
Deriving Image Coordinates

- Comparators measure the coordinates of selected points relative to the comparator coordinate system (x`, y`) – comparator/machine coordinates.
- We are interested in the coordinates of these points w.r.t. the image coordinate system (x, y).
- Thus, we need to reduce the comparator coordinates into image coordinates.

Comparator to Image Coordinate Transformation

Images Acquired by Analog Cameras

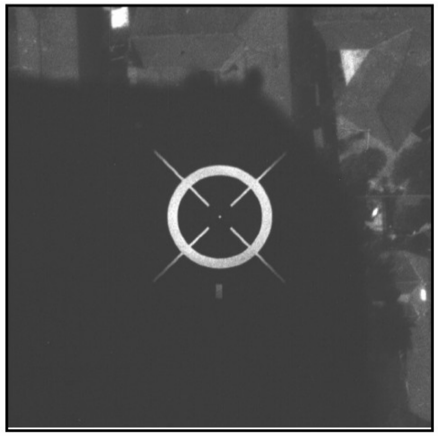
Image Coordinate System



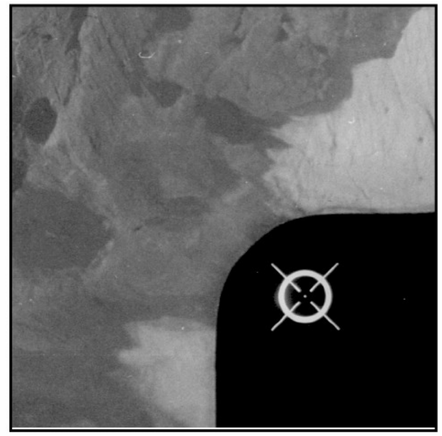
Fiducial Marks

- Fiducial marks are small targets on the body of analog metric cameras.
- Their positions relative to the camera body are known through a calibration procedure.
- They define the image coordinate system.
- In that system, the position of the perspective centre is known.
- Form, number, and distribution of Fiducial marks depend on the camera manufacturer.

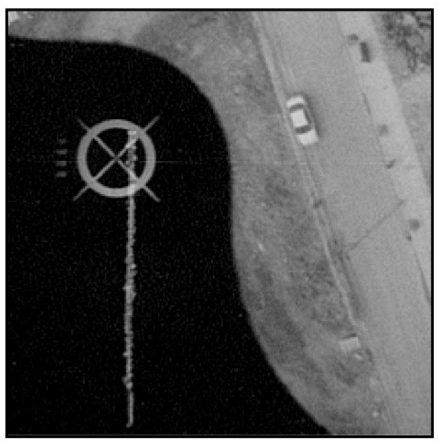
Sample Fiducial Marks



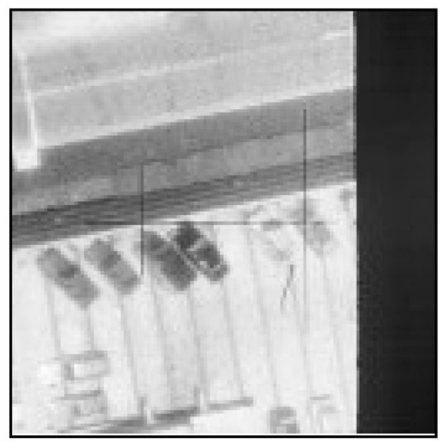
(a)



(b)



(c)

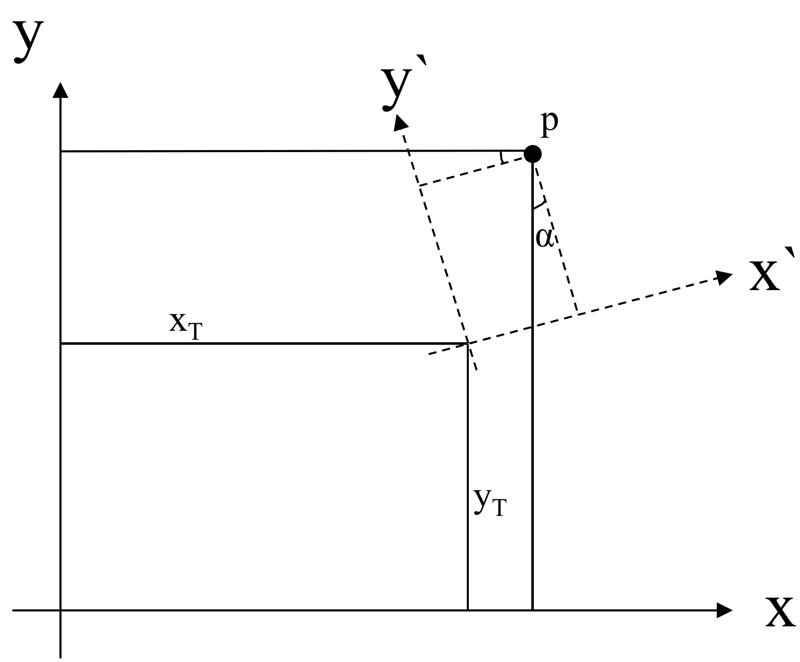


(d)

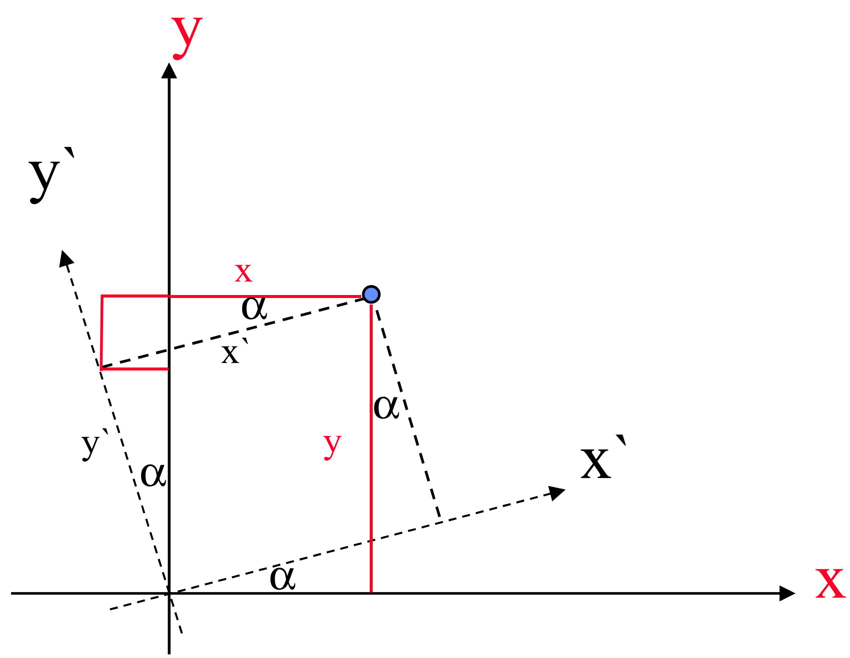
Comparator to Image Coord. Transformation

- Alternatives:
  - Two dimensional similarity transformation
    - Four parameters
  - Affine transformation
    - Six parameters
  - Bilinear transformation
    - Eight parameters
  - Projective transformation
    - Eight parameters

2-D Similarity Transformation



2-D Similarity Transformation



$$x = x` \cos(\alpha) - y` \sin(\alpha)$$
$$y = x` \sin(\alpha) + y` \cos(\alpha)$$

2-D Similarity Transformation

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x_T \\ y_T \end{bmatrix} + S \begin{bmatrix} \cos\alpha & -\sin\alpha \\ \sin\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} x' \\ y' \end{bmatrix}$$

Where:

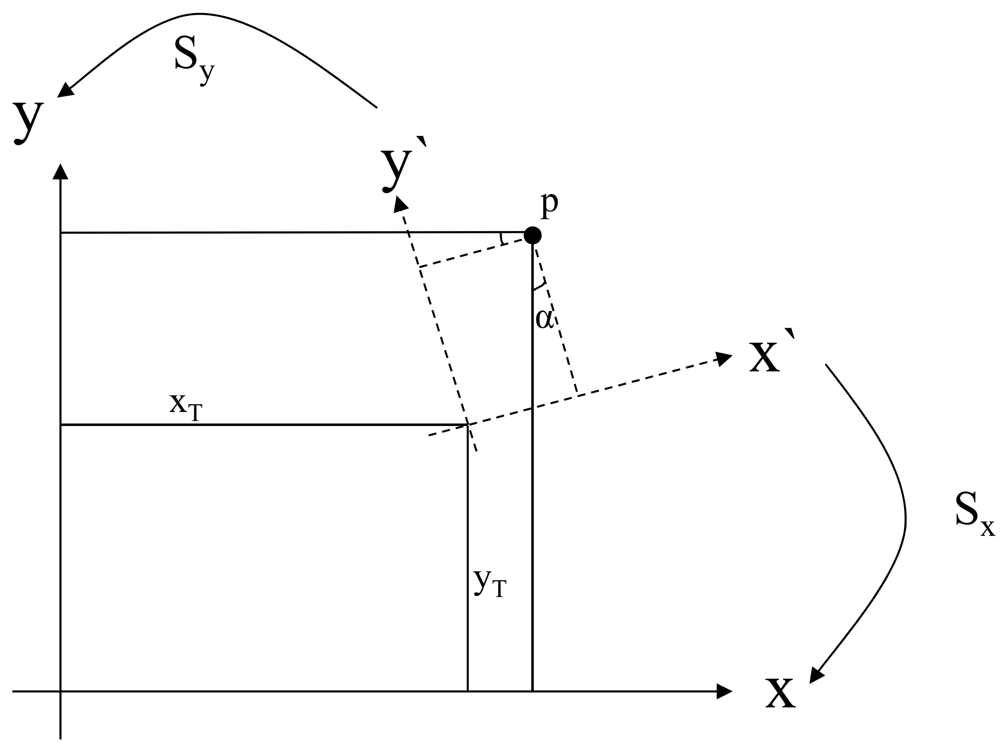
S	is a scale factor
x_T & y_T	are shifts
α	is a rotation angle
x & y	are image coordinates
x' & y'	are comparator coordinates

2-D Similarity Transformation

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x_T \\ y_T \end{bmatrix} + \begin{bmatrix} a & -b \\ b & a \end{bmatrix} \begin{bmatrix} x' \\ y' \end{bmatrix}$$

$$Where \ :$$
$$a = S \cos \alpha$$
$$b = S \sin \alpha$$

Scale Differences along the x and y axes



Scale Differences along the x and y axes

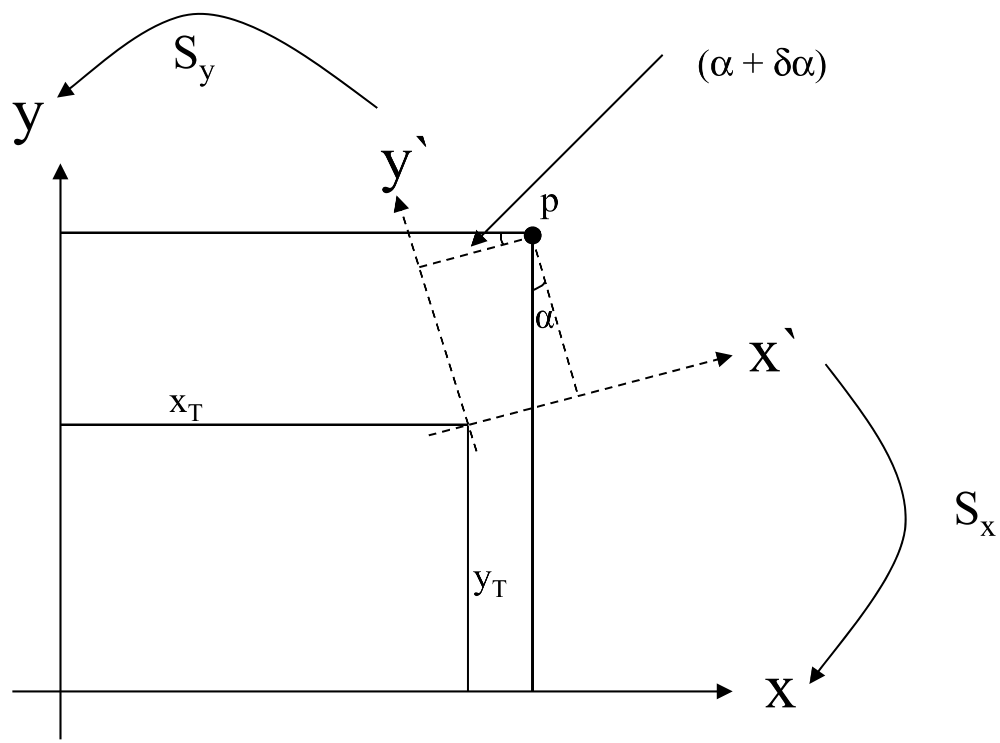
$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x_T \\ y_T \end{bmatrix} + \begin{bmatrix} S_x \cos\alpha & -S_y \sin\alpha \\ S_x \sin\alpha & S_y \cos\alpha \end{bmatrix} \begin{bmatrix} x' \\ y' \end{bmatrix}$$

Where :

S_x *is the scale factor along the* $x-$*axis*

S_y *is the scale factor along the* $y-$*axis*

Non-Orthogonality of Comparator Axes



Non-Orthogonality of Comparator Axes

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x_T \\ y_T \end{bmatrix} + \begin{bmatrix} S_x \cos(\alpha + \delta\alpha) & -S_y \sin\alpha \\ S_x \sin(\alpha + \delta\alpha) & S_y \cos\alpha \end{bmatrix} \begin{bmatrix} x' \\ y' \end{bmatrix}$$

Where :

S_x *is the scale factor along the x − axis*

S_y *is the scale factor along the y − axis*

$\delta\alpha$ *is the non − orthogonality angle*

Affine Transformation

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a_o \\ b_o \end{bmatrix} + \begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \end{bmatrix} \begin{bmatrix} x' \\ y' \end{bmatrix}$$

Where :

$$a_o = x_T$$

$$a_1 = S_x \cos(\alpha + \delta\alpha)$$

$$a_2 = -S_y \sin\alpha$$

$$b_o = y_T$$

$$b_1 = S_x \sin(\alpha + \delta\alpha)$$

$$b_2 = S_y \cos\alpha$$

Bilinear Transformation

- It can compensate for distortions introduced during film development (e.g., film shrinkage).
- $x = a_o + a_1 x` + a_2 y` + a_3 x` y`$
- $y = b_o + b_1 x` + b_2 y` + b_3 x` y`$
- Number of involved parameters: Eight

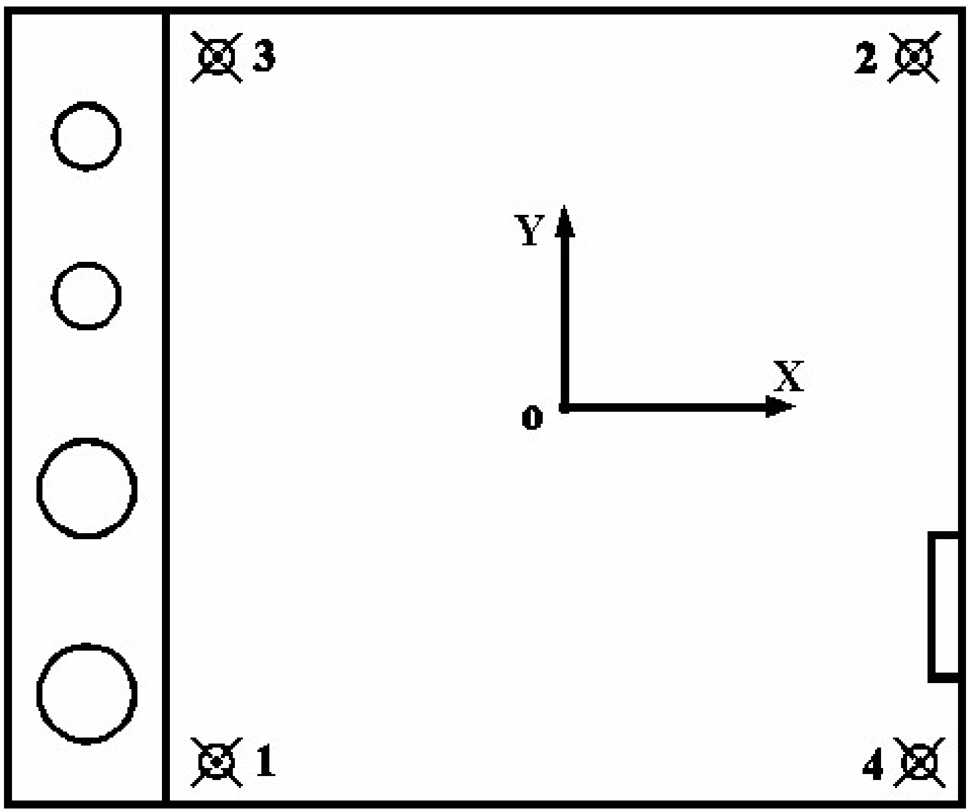
Projective Transformation

- Stage to image coordinate transformation is a plane to plane transformation.
- Projective transformation can be used.
- $x = (a_o + a_1 x` + a_2 y`) / (1 + c_1 x` + c_2 y`)$
- $y = (b_o + b_1 x` + b_2 y`) / (1 + c_1 x` + c_2 y`)$
- Number of involved parameters: Eight

Comparator to Image Coord. Transformation

- For analog metric cameras, the image coordinate system is defined by the Fiducial marks.
- The image coordinates of the Fiducial marks are available in the camera calibration certificate.
- Using the image and comparator coordinates of the Fiducial marks, we can compute the transformation parameters.

Camera Calibration Certificate (CCC)



Fiducial Marks Coordinates (CCC)

ID	x-Coordinate mm	y-Coordinate mm
01	-105.999	-105.978
02	105.996	106.022
03	-106.018	106.021
04	105.988	-105.978

Comparator-to-Image Coordinate Transformation

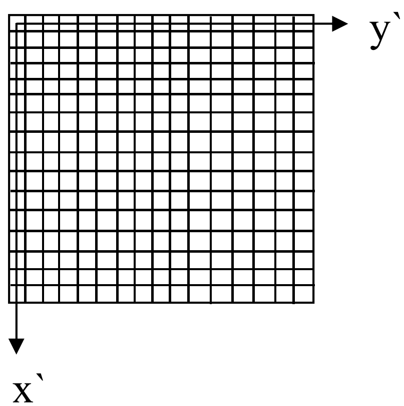
Images Acquired by Digital Cameras

Digital Cameras: Image Coordinate System

- Fiducial marks are not necessary for digital cameras since the CCD/CMOS sensor is kept fixed relative to the camera body.
- For imagery acquired by digital cameras, the image coordinate system is defined by:
  - Central rows → x-axis
  - Central columns → y-axis

Pixel-to-Image Coordinate Transformation

Digital Environment



Pixel Coordinates

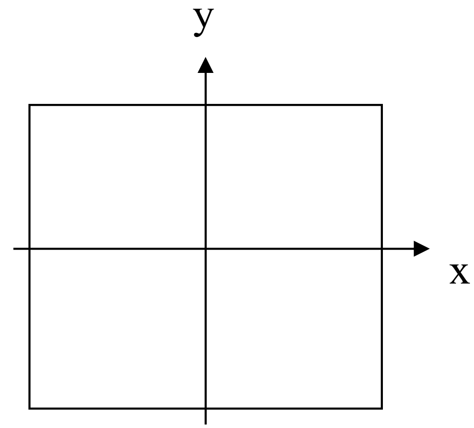


Image Coordinates

Pixel-to-Image Coordinate Transformation

Digital Environment

$$x = (y' - n_c / 2.0) \times y\_pix\_size$$

$$y = (n_r / 2.0 - x') \times x\_pix\_size$$

where :

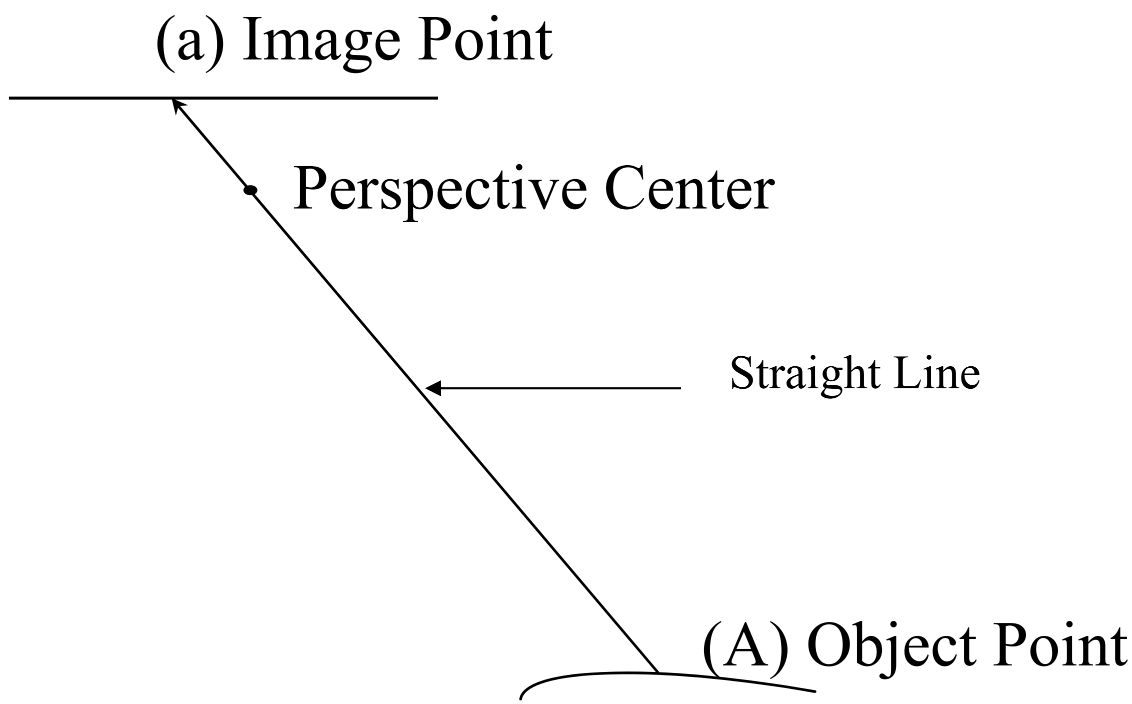
n_c	*Number of columns*
n_r	*Number of rows*
x_pix_size	*Pixel size along the row direction*
y_pix_size	*Pixel size along the column direction*

Reduction (Refinement) of Image Coordinates

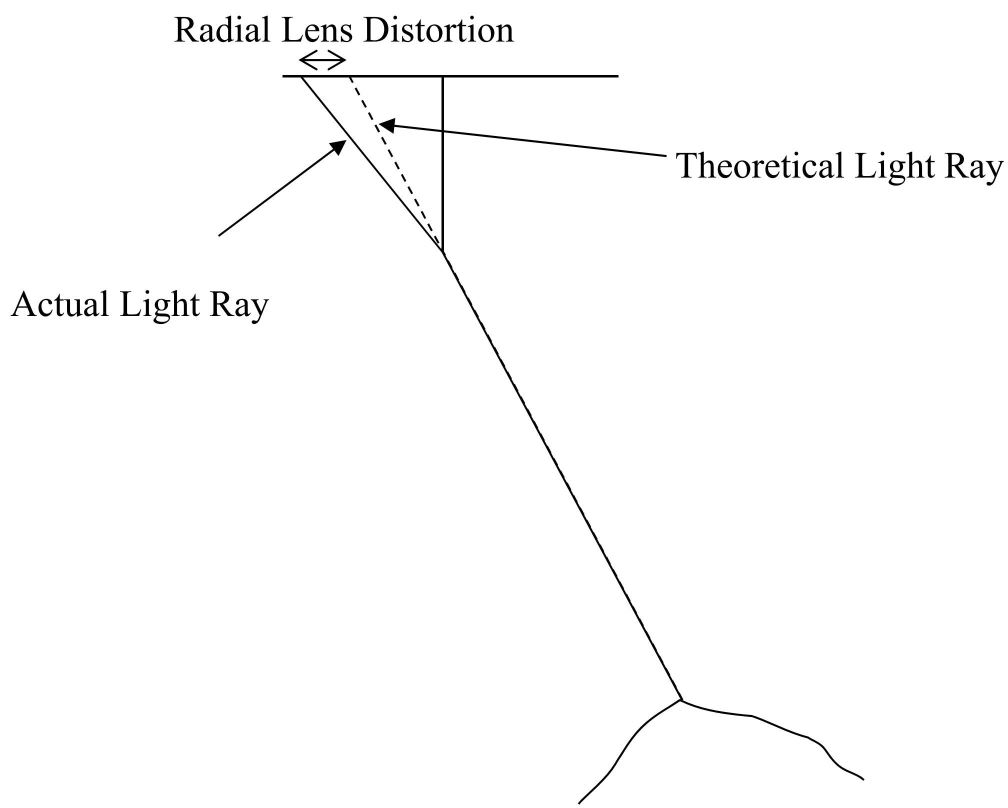
Distortion Parameters

- Distortion parameters compensate for all the deviations from the assumed perspective geometry.
- Assumed perspective geometry:
  - Object point, perspective center, and the corresponding image point lie on a straight line.
- Distortions include (for example):
  - Lens distortion (radial & de-centering)
  - Atmospheric refraction
  - Non-planar film platen

Assumed Perspective Geometry



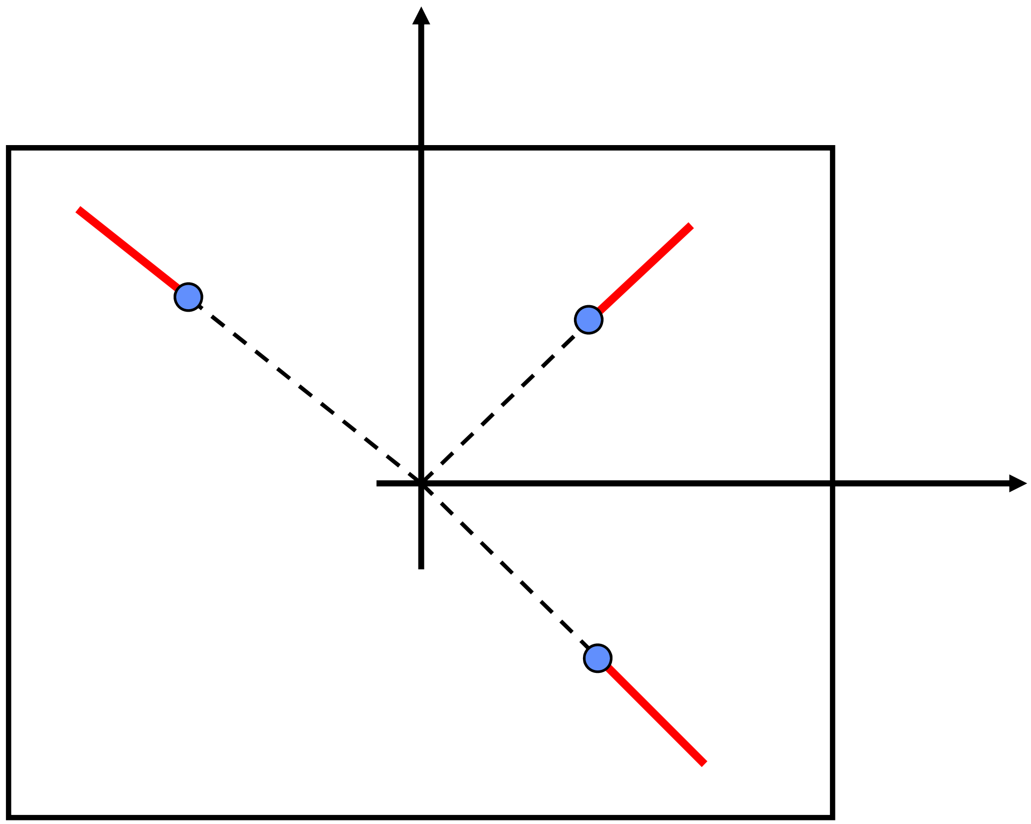
Radial Lens Distortion



Radial Lens Distortion

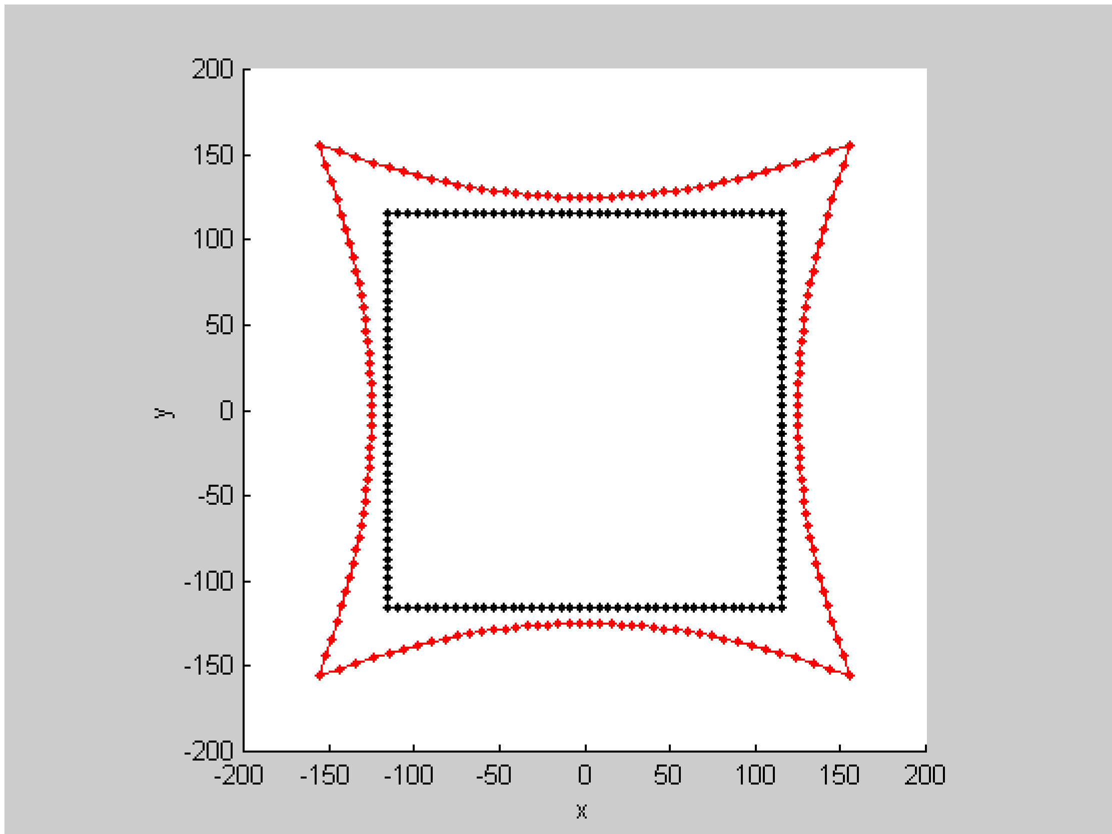
- The light ray changes its direction after passing through the perspective center.
- Radial lens distortion is caused by:
  - Large off-axial angle
  - Lens manufacturing flaws
- Radial lens distortion occurs along a radial direction from the principal point.
- Radial lens distortion increases as we move away from the principal point.

Radial Lens Distortion



Fiducial Center ≈ Principal Point

Radial Lens Distortion

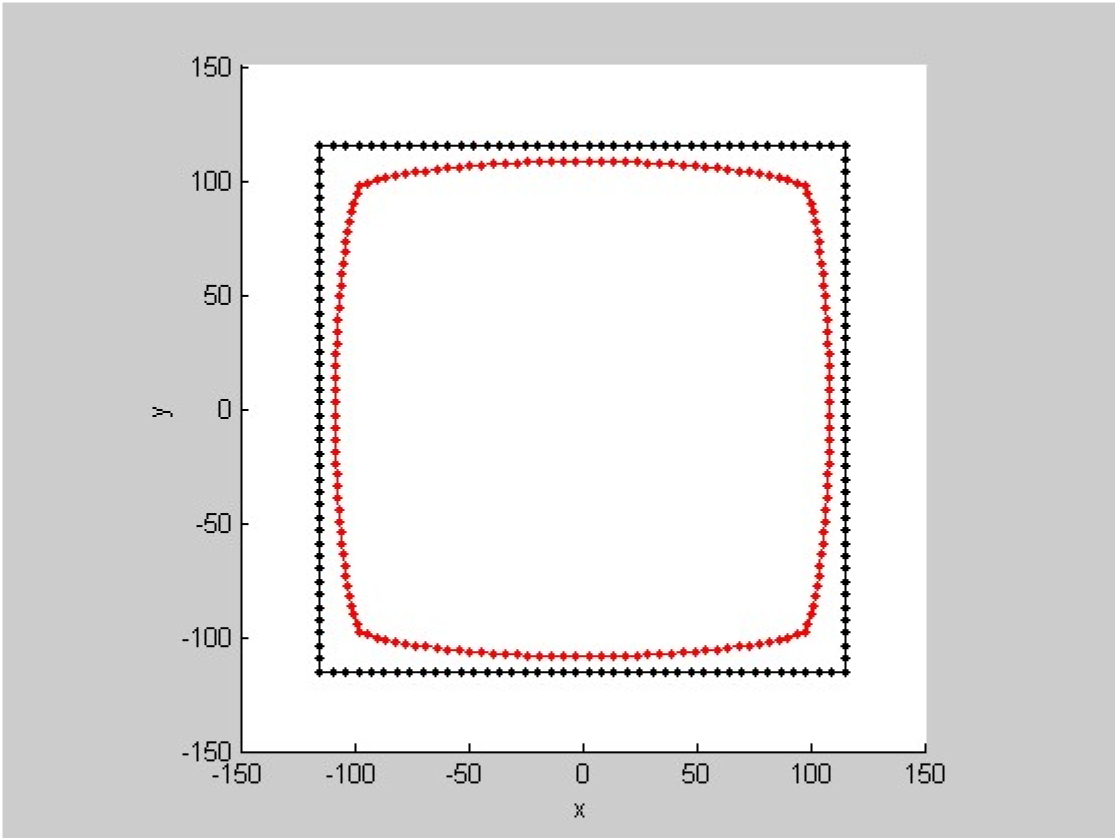


Without distortions

With distortions

Pin Cushion Type Radial Lens Distortion

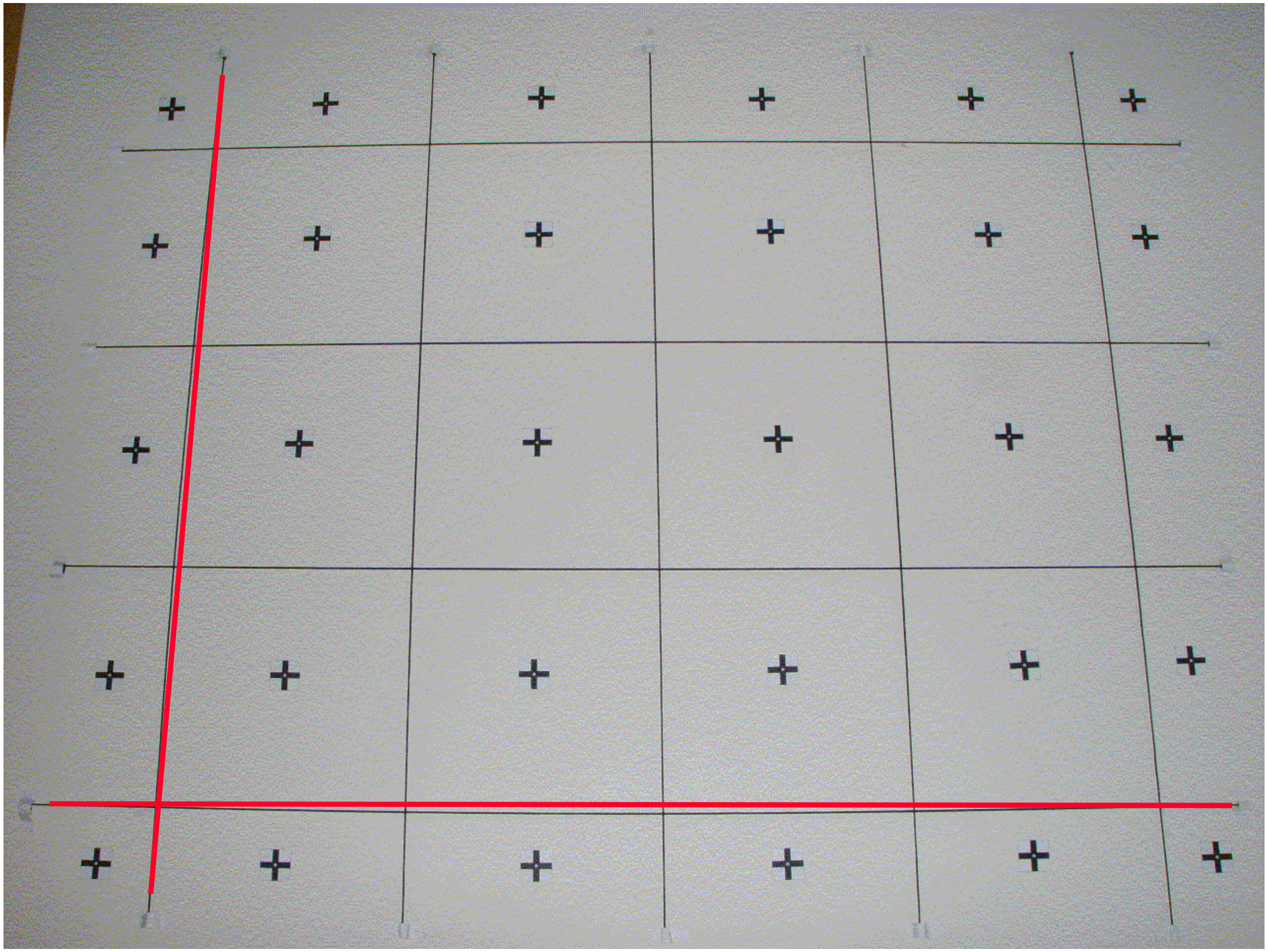
Radial Lens Distortion



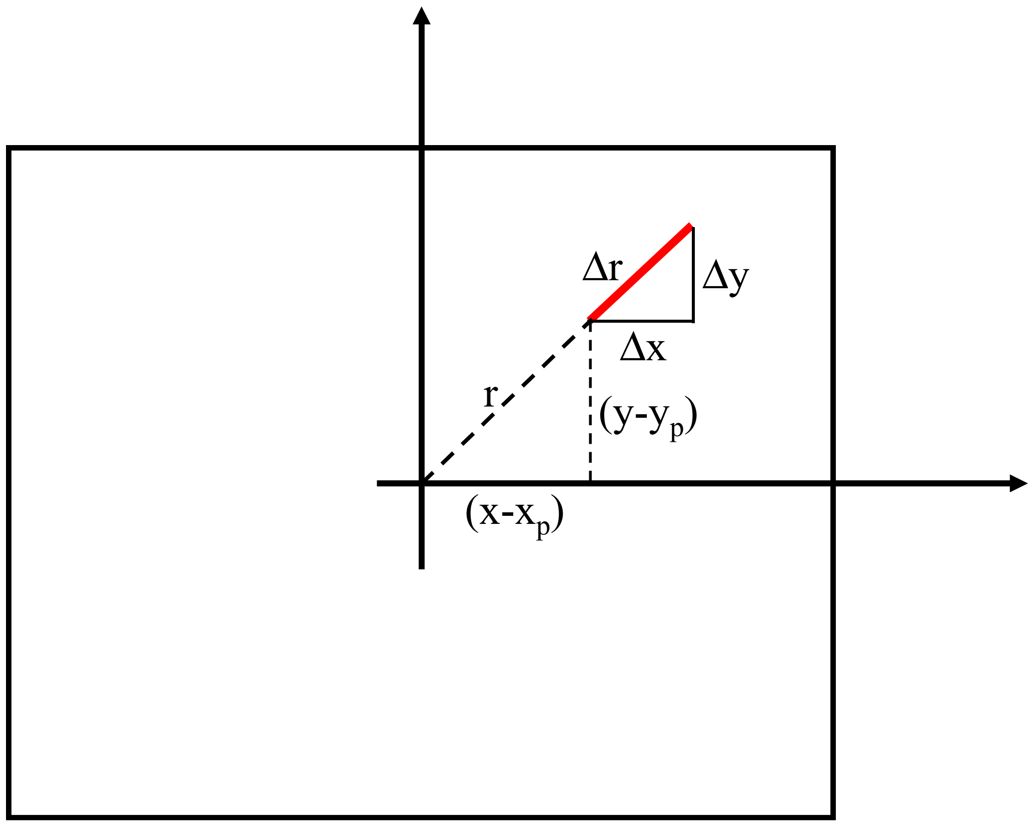
Without distortions — With distortions

Barrel Type Radial Lens Distortion

Radial Lens Distortion



Radial Lens Distortion



$$\Delta x = \Delta r * (x - x_p) / r$$
$$\Delta y = \Delta r * (y - y_p) / r$$

Radial Lens Distortion

- Radial lens distortion, Δr as a function of r, is available in the camera calibration certificate in either one of the following forms:
  - Graphical form,
  - Tabular form, or
  - Polynomial coefficients.
- Note: ***r*** is the radial distance between the principal point and the image point under consideration.

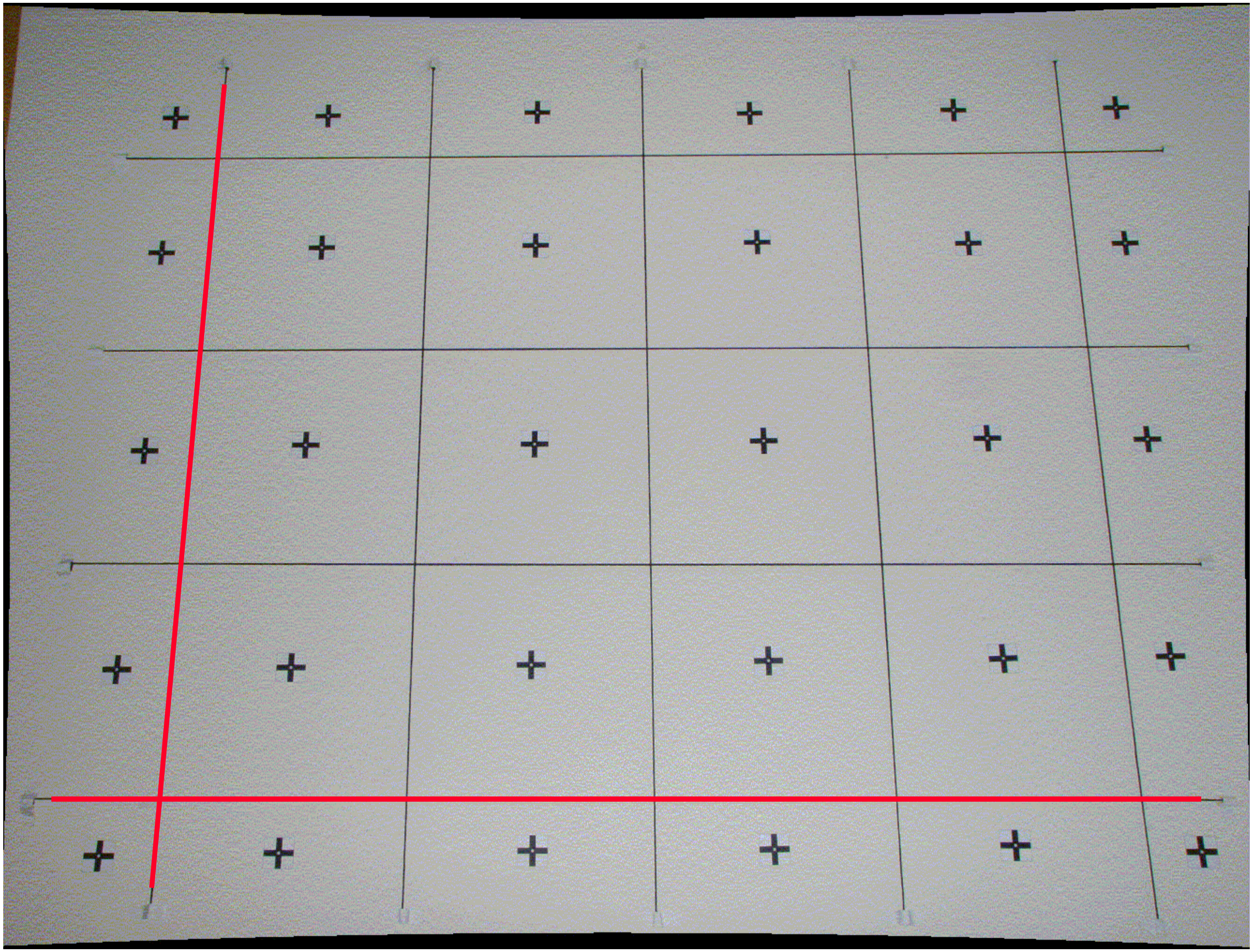
Radial Lens Distortion

$$\Delta x_{Radial\ \ Lens\ \ Distortion} = (x - x_p)\ \ (k_1 r^2 + k_2 r^4 + k_3 r^6 + ...)$$

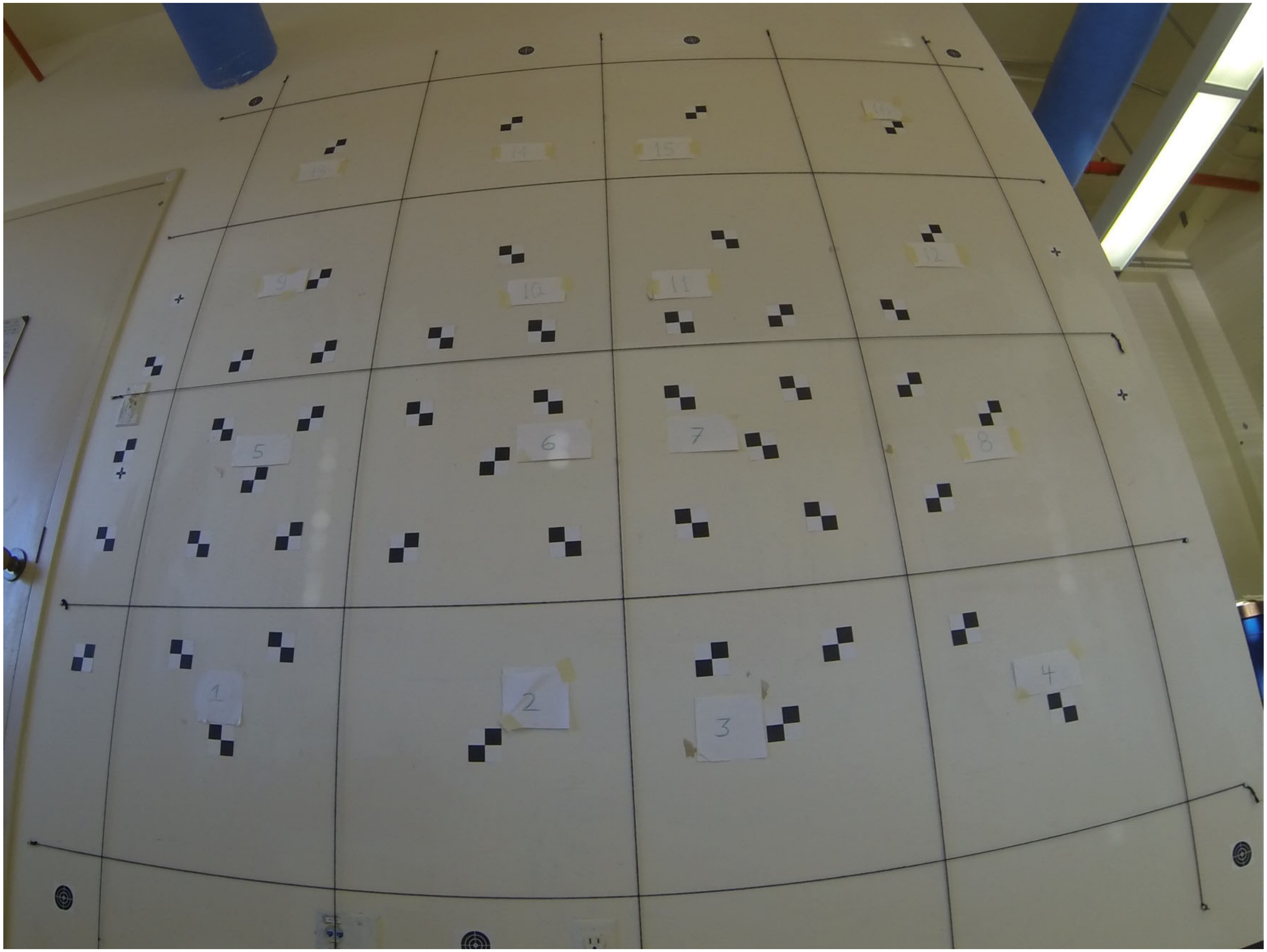
$$\Delta y_{Radial\ \ Lens\ \ Distortion} = (y - y_p)\ \ (k_1 r^2 + k_2 r^4 + k_3 r^6 + ...)$$

where: $r = \{(x - x_p)^2 + (y - y_p)^2\}^{0.5}$

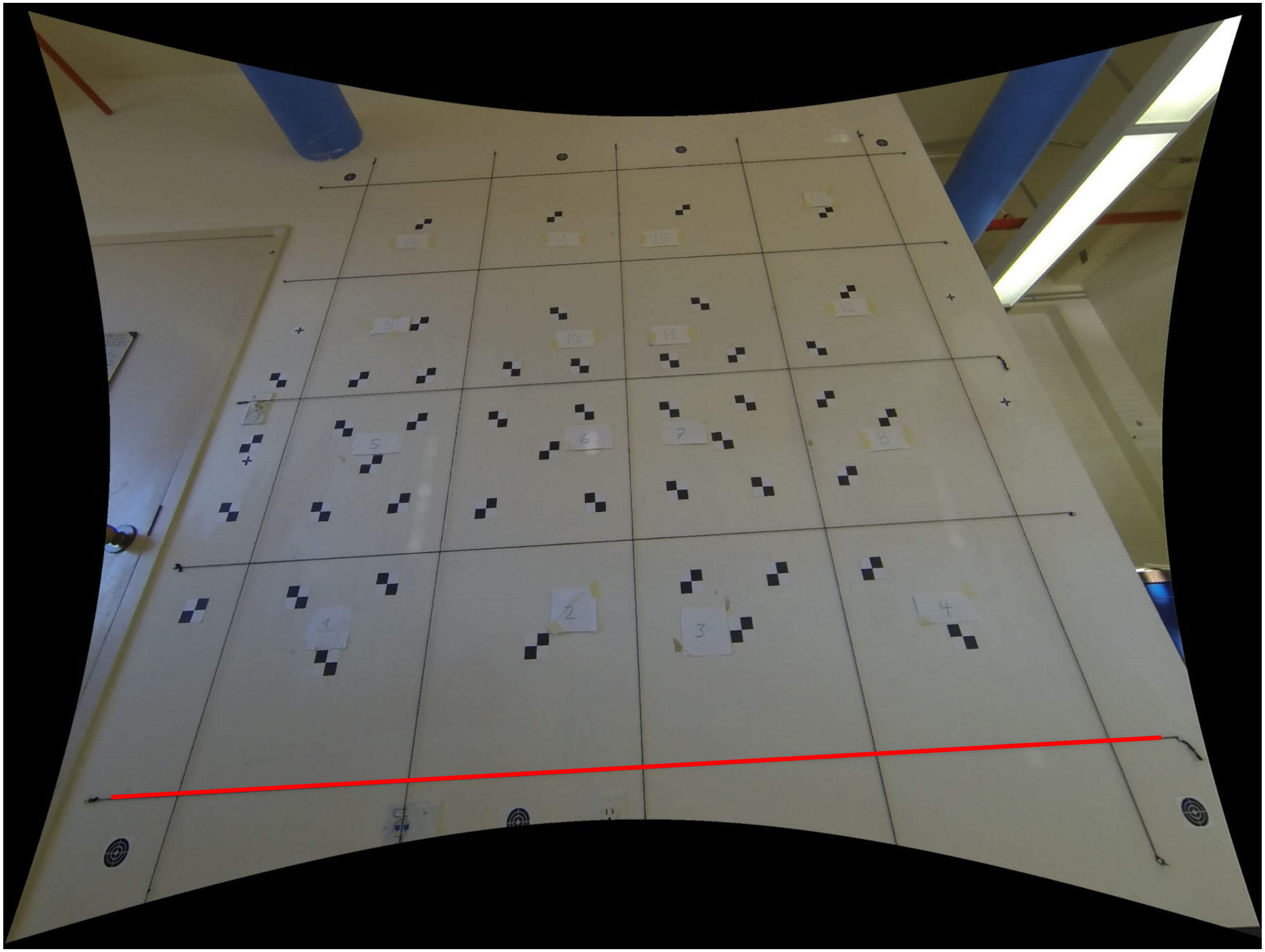
After Removing Radial Lens Distortion



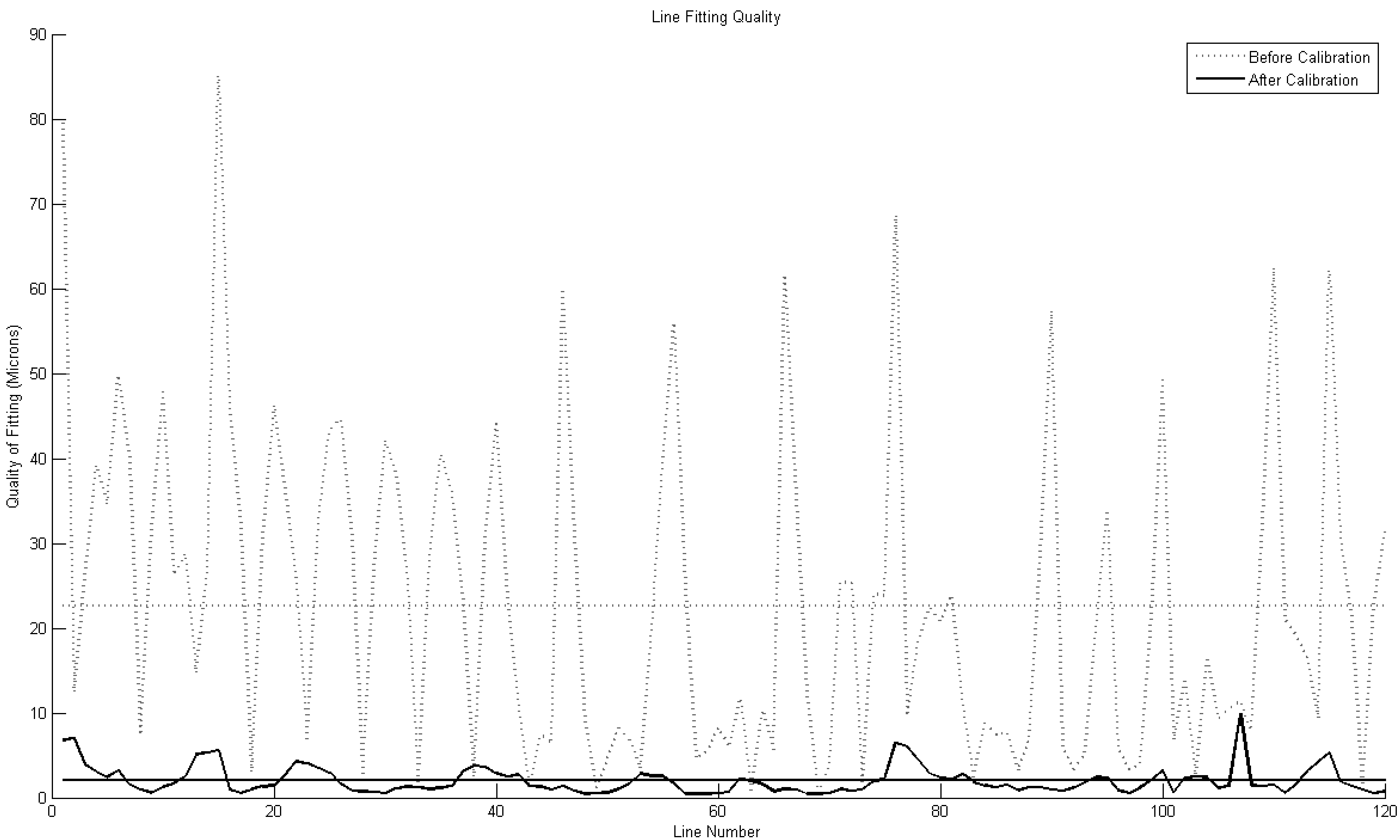
Before Removing Radial Lens Distortion



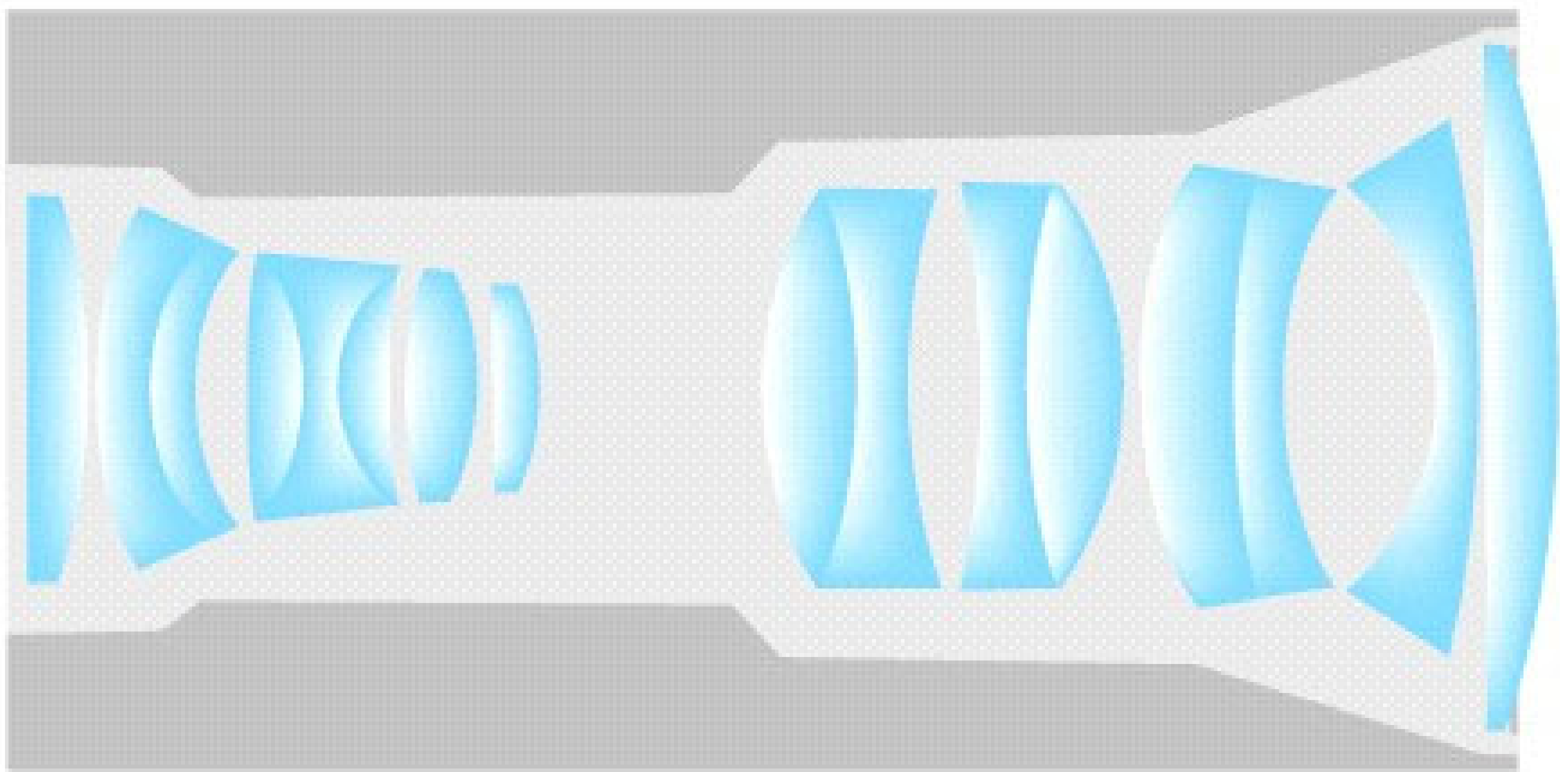
After Removing Radial Lens Distortion



Quality of Line Fitting



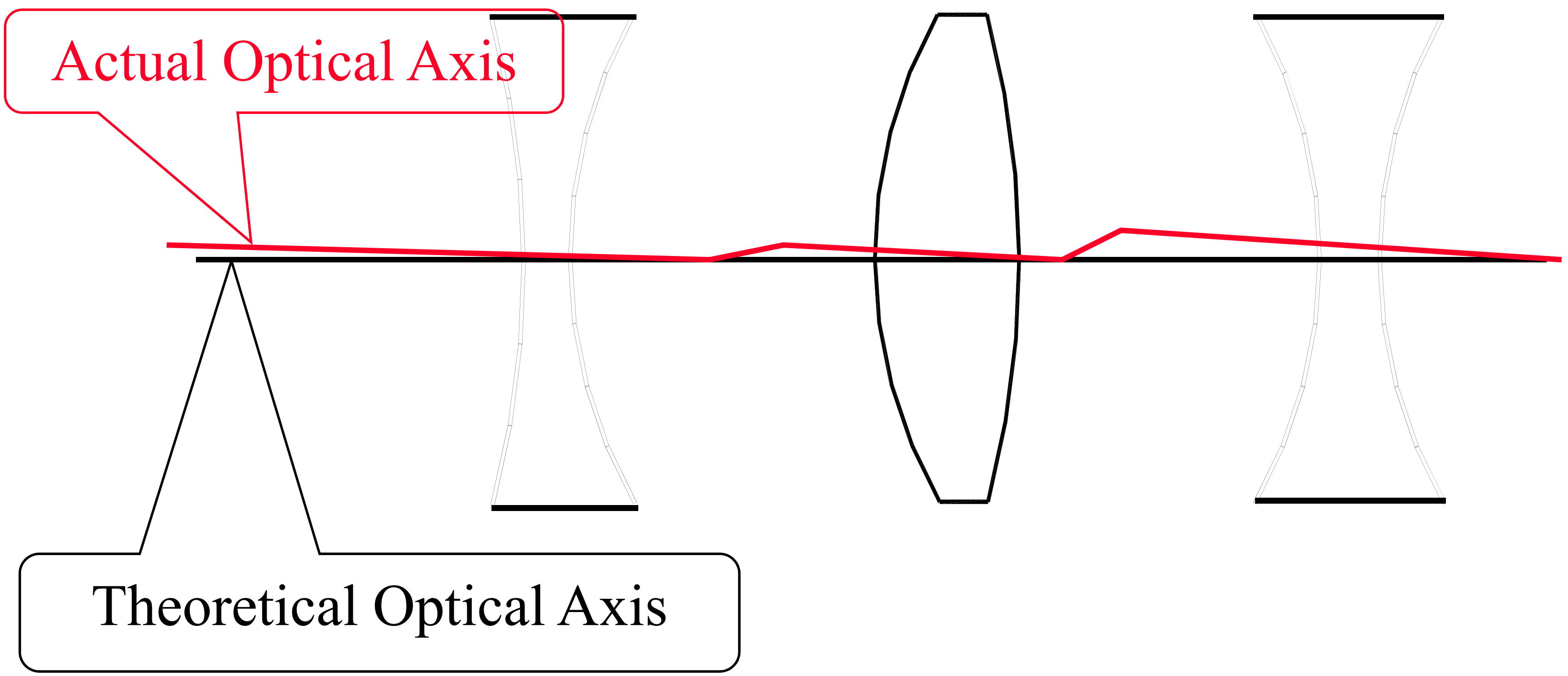
Lens Cone Assembly



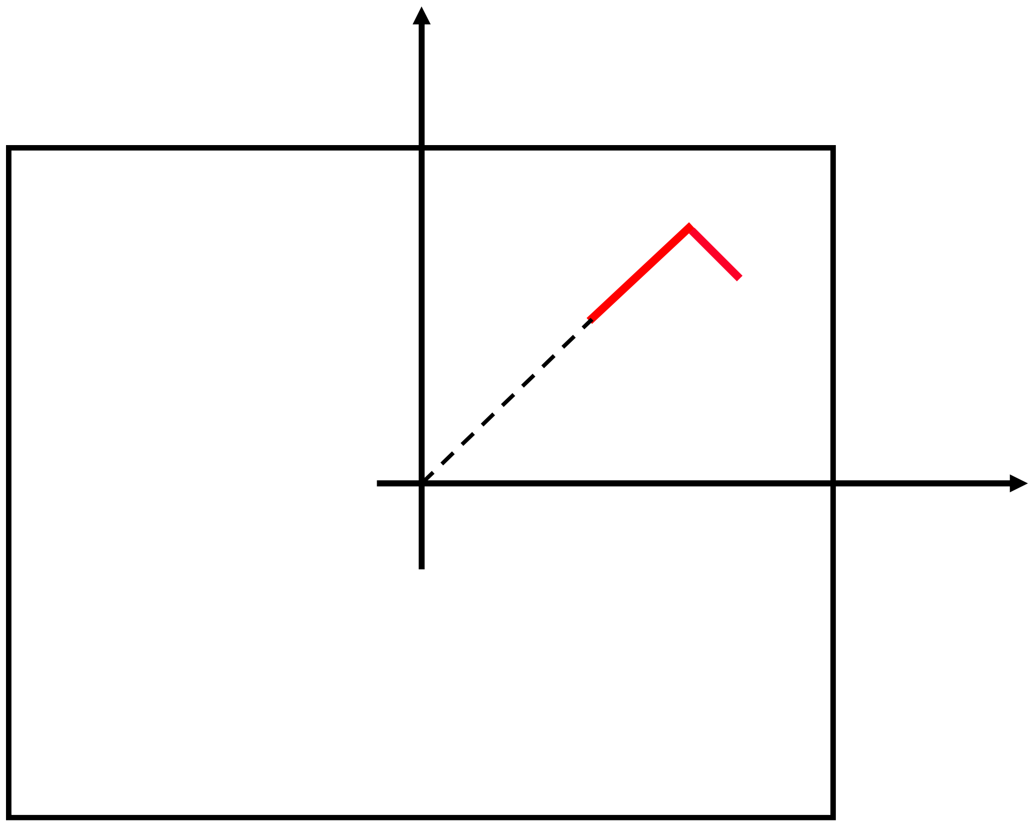
De-centering Lens Distortion

- De-centering lens distortion is caused by misalignment of the components of the lens system.
- De-centering lens distortion has two components:
  - Radial component, and
  - Tangential component.

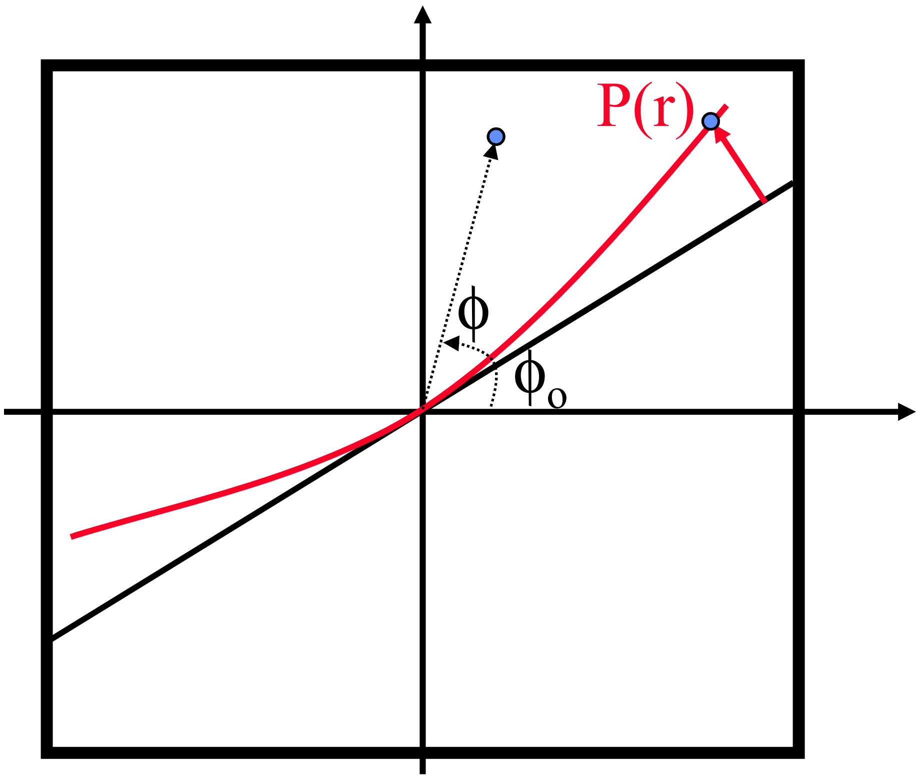
De-centering Lens Distortion



De-centering Lens Distortion



De-centering Lens Distortion



$$P(r) = J_1 r^2 + J_2 r^4 + \ldots\ldots\ldots$$

$$\Delta r = 3\ P(r)\ \sin(\phi - \phi_o)$$

$$\Delta t = P(r)\ \cos(\phi - \phi_o)$$

- P (r) is the profile along the axis with the maximum tangential distortion.
- ϕ_o is the direction of the axis with the maximum tangential distortion.

De-centering Lens Distortion

$$\Delta x_{Decentering\ Lens\ Distortion} = (1 + p_3 r^2)\{p_1(r^2 + 2\bar{x}^2) + 2 p_2 \bar{x}\ \bar{y}\ \}$$

$$\Delta y_{Decentering\ Lens\ Distortion} = (1 + p_3 r^2)\{2 p_1 \bar{x}\ \bar{y}\ + p_2(r^2 + 2\bar{y}^2)\}$$

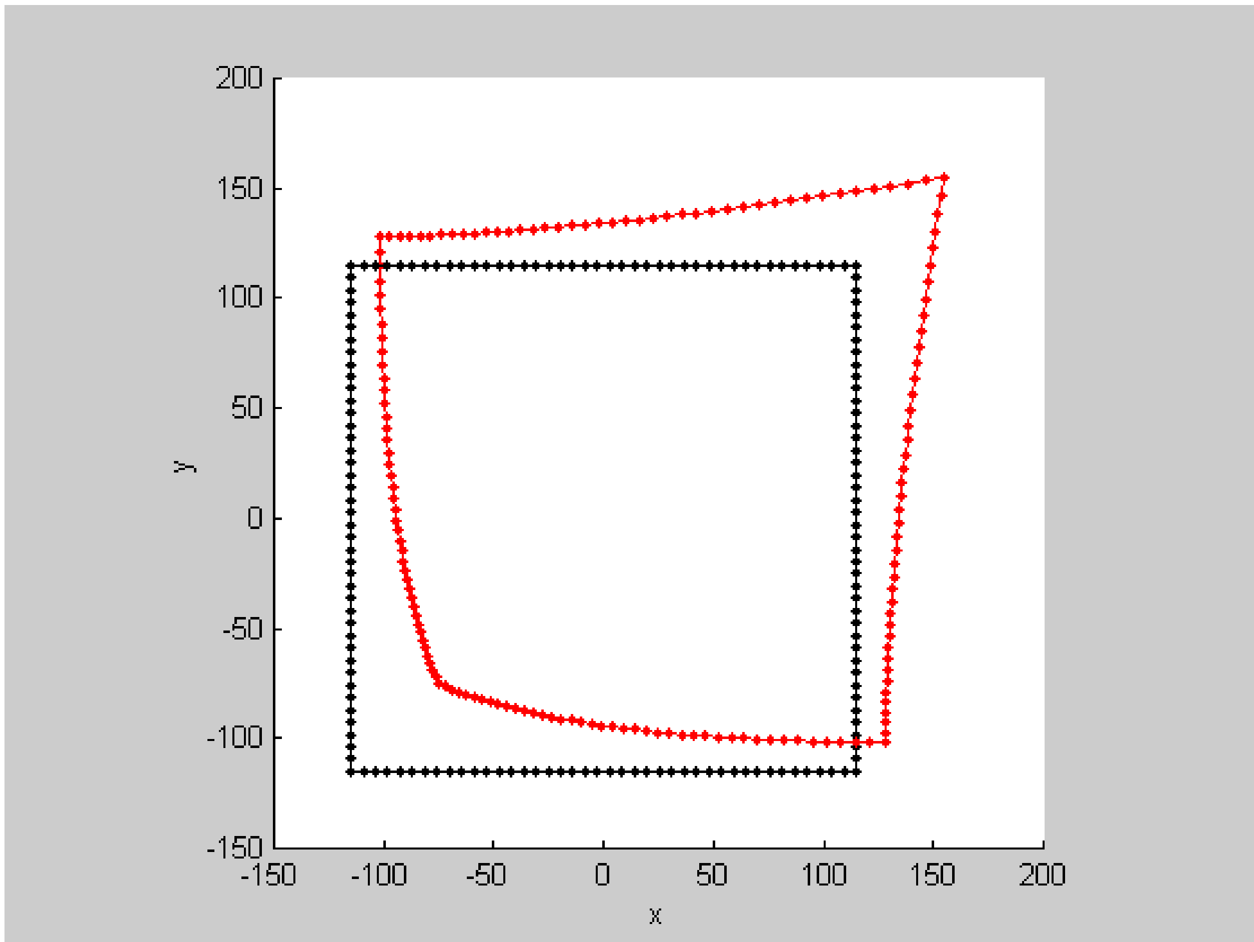
where: $r = \{(x - x_p)^2 + (y - y_p)^2\}^{0.5}$

$$\bar{x} = x - x_p$$

$$\bar{y} = y - y_p$$

- $p_1 = -J_1 \sin\phi_o$.
- $p_2 = J_1 \cos\phi_o$.
- $p_3 = J_2 / J_1$.

De-centering Lens Distortion

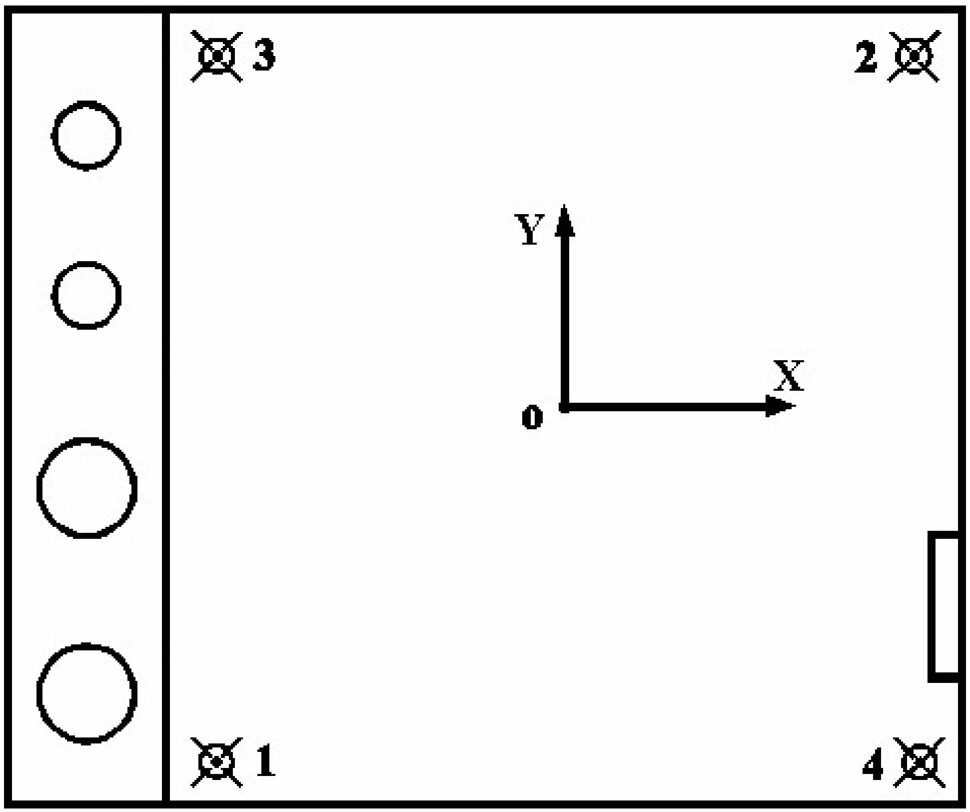


Without distortions — With distortions

Camera Calibration Certificate: Example

- Wild Heerbrugg Instruments Inc.
- Camera type: Wild RC10
- Identification number: 2061
- Lens: Wild 15 UAG I
- Identification Number: 6029
- Calibrated Focal Length: C = 153.167 mm
- Principal point coordinates in the Fiducial system:
  - x_p = 0.001 mm
  - y_p = -0.053 mm

Camera Calibration Certificate (CCC)



Fiducial Mark Coordinates (CCC)

ID	x-Coordinate mm	y-Coordinate mm
01	-105.999	-105.978
02	105.996	106.022
03	-106.018	106.021
04	105.988	-105.978

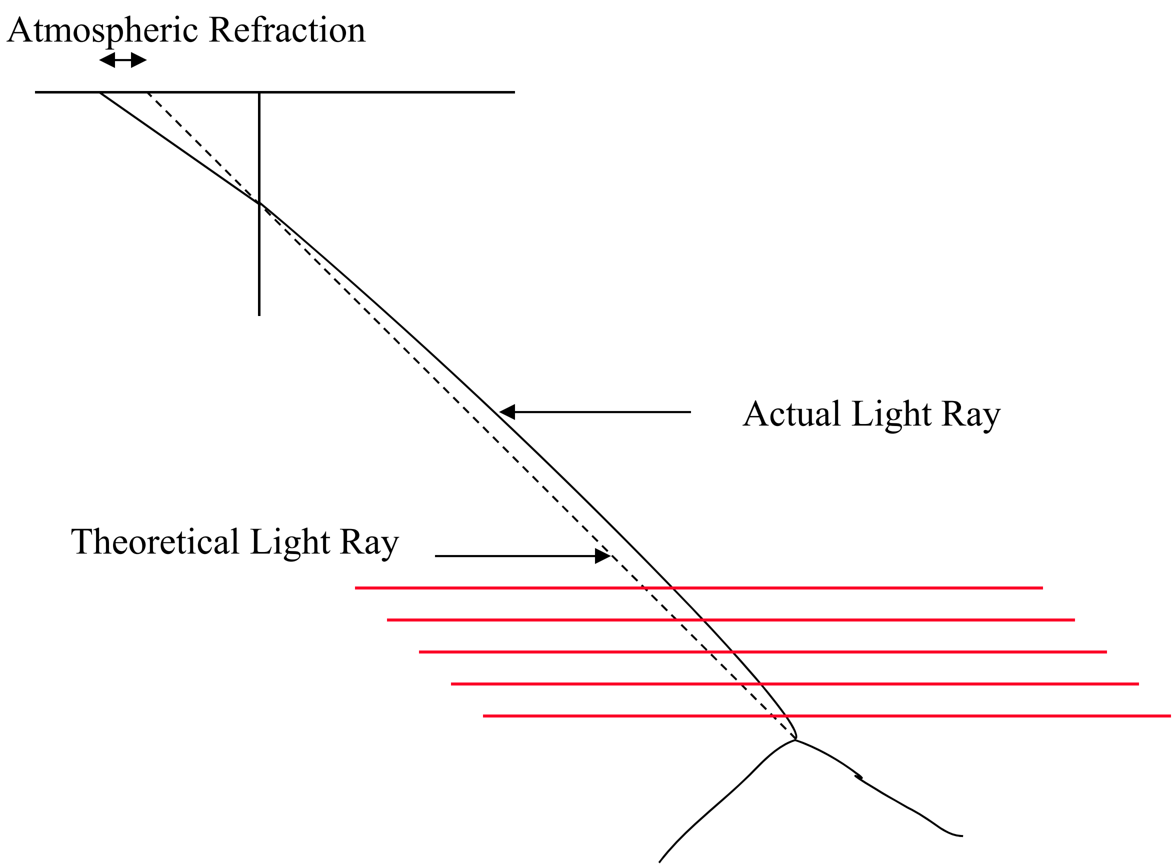
Camera Calibration Certificate

- Radial Lens Distortion Coefficients:
  - K_1 = 2.99778547E-08 mm^{-2}
  - K_2 = -3.15091119E-12 mm^{-4}
  - K_3 = 6.05776623E-17 mm^{-6}
- De-centering Lens Coefficients:
  - P_1 = 2.76490955E-07 mm^{-1}
  - P_2 = -1.06518601E-06 mm^{-1}

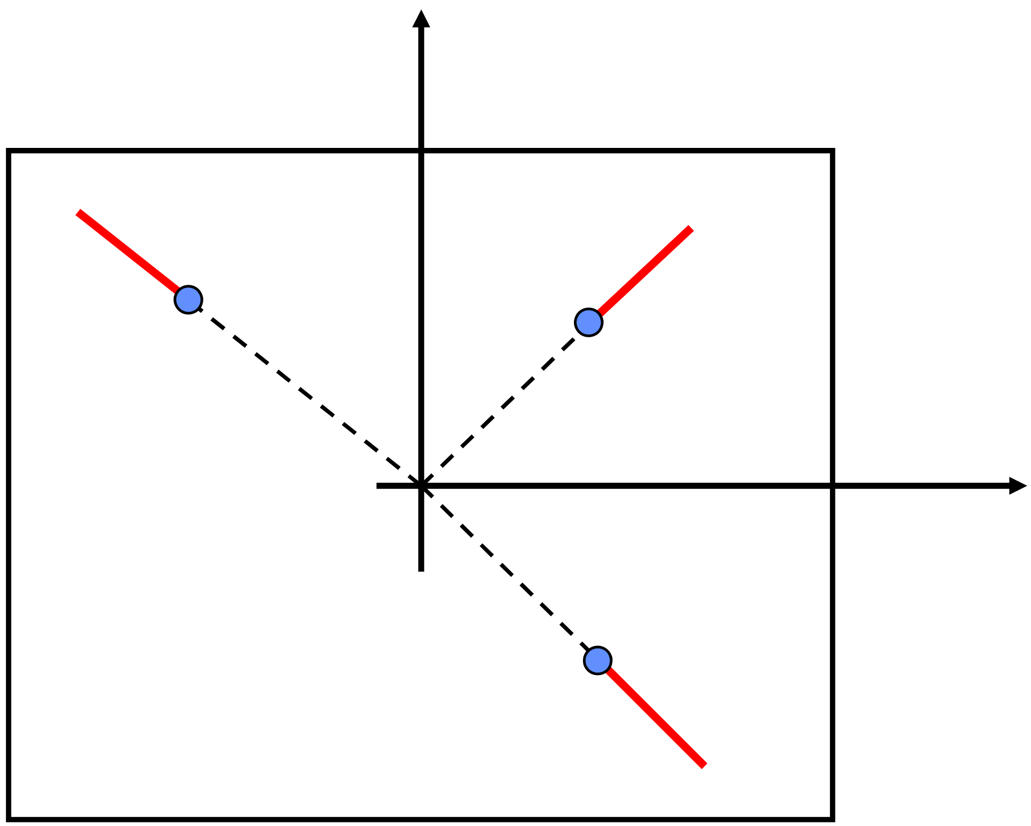
Atmospheric Refraction

- The light ray from the object point to the perspective center passes through layers with different temperature, pressure, and humidity.
- Each layer has its own refractive index.
- Consequently, the light ray will follow a curved not a straight path.
- The distortion occurs along the radial direction from the nadir point.
- It increases as the radial distance increases.

Atmospheric Refraction



Atmospheric Refraction



Fiducial Center ≈ Nadir Point

Atmospheric Refraction

- $\Delta r = k\, r\, \{1 + r^2 / c^2\}$
- K is the atmospheric refraction coefficient.
- Image points are always displaced outwardly along the radial direction.
- Correction (Δr) is always negative.
- The above equation is only valid for almost vertical photography.

Atmospheric Refraction

$$k = 0.00241 \left\{ \frac{Z_o}{Z_o^2 - 6\,Z_o + 250} - \frac{Z^2}{Z_o(Z^2 - 6\,Z + 250)} \right\}$$

Where :

Z & Z_o are in Km above the sea level

$$\Delta x = k\;x\;(\frac{r^2}{c^2} + 1)$$

$$\Delta y = k\;y\;(\frac{r^2}{c^2} + 1)$$

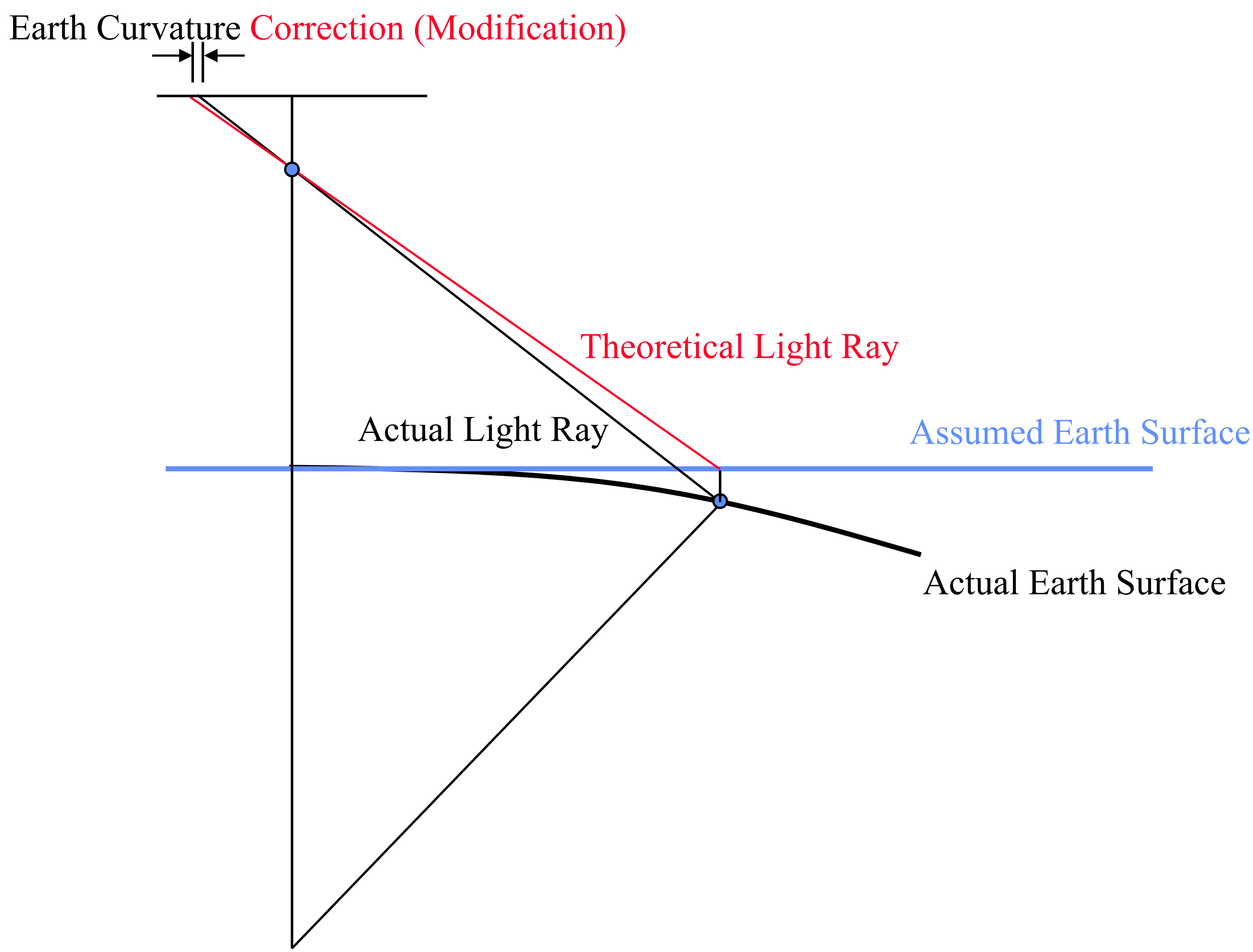
Earth Curvature

- It is not a problem with the image formation process (i.e., it is not a deviation from the assumed perspective geometry).
- It is a problem arising from the way we define the ground coordinate system.
- If the ground coordinates of the GCP are given relative to a true three-dimensional coordinate system, the curvature of the Earth's surface is already taken into account.

Earth Curvature

- If the GCP is given relative to a map coordinate system (e.g., state plane and orthometric height), we have a problem with small scale imagery.
  - The Earth surface as reconstructed from the imagery is a spheroid.
  - The Earth surface as defined by the GCP is flat.
- In this case, we have to distort the image coordinates in such a way that the Earth surface as reconstructed from the imagery is flat.

Earth Curvature



Earth Curvature

- If we are dealing with a single image, and if this image is a true vertical image,
- Then, the image coordinates can be changed to compensate for the effect of Earth curvature
- In effect, we get the points depicted in the image plane as if the Earth surface had been totally flat.

$$\Delta r = H\, r^3 / 2\, R\, c^2$$

H flying height,

r radial distance from the principal point,

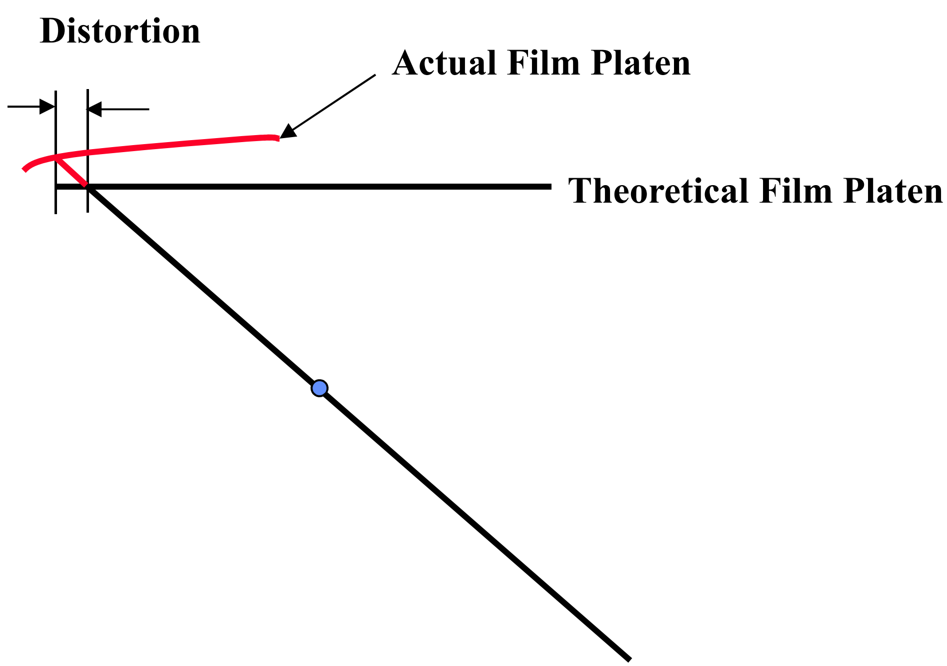
R radius of the Earth (6370 Km),

c principal distance

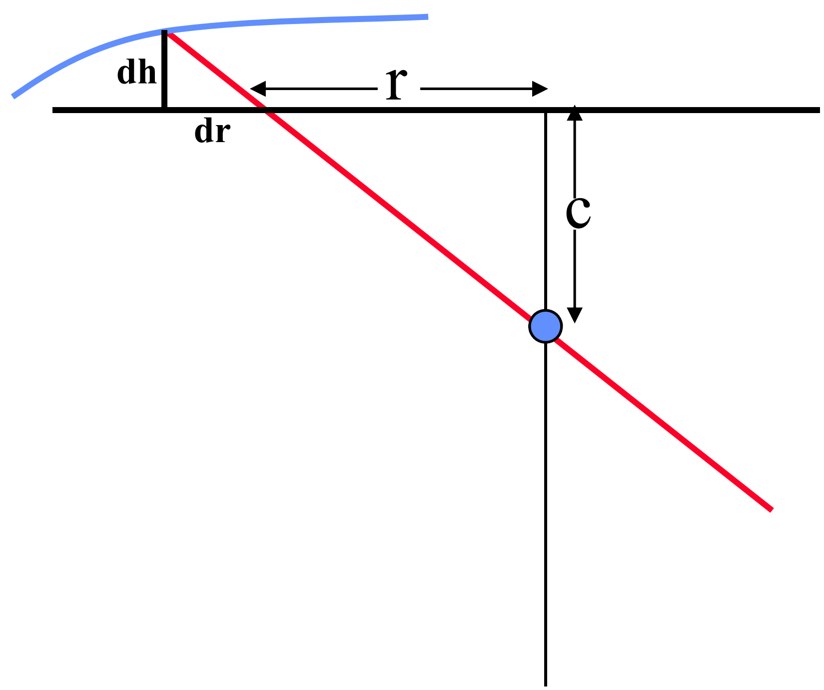
Earth Curvature

- Δr (correction) is always +ve.
- Nowadays, the GCPs are mainly provided by GPS which provides us with a true 3D (i.e., cartesian) coordinate system.
- Thus, we do not need to apply the earth curvature correction (modification).

Non Planar Film Platen



Non Planar Film Platen



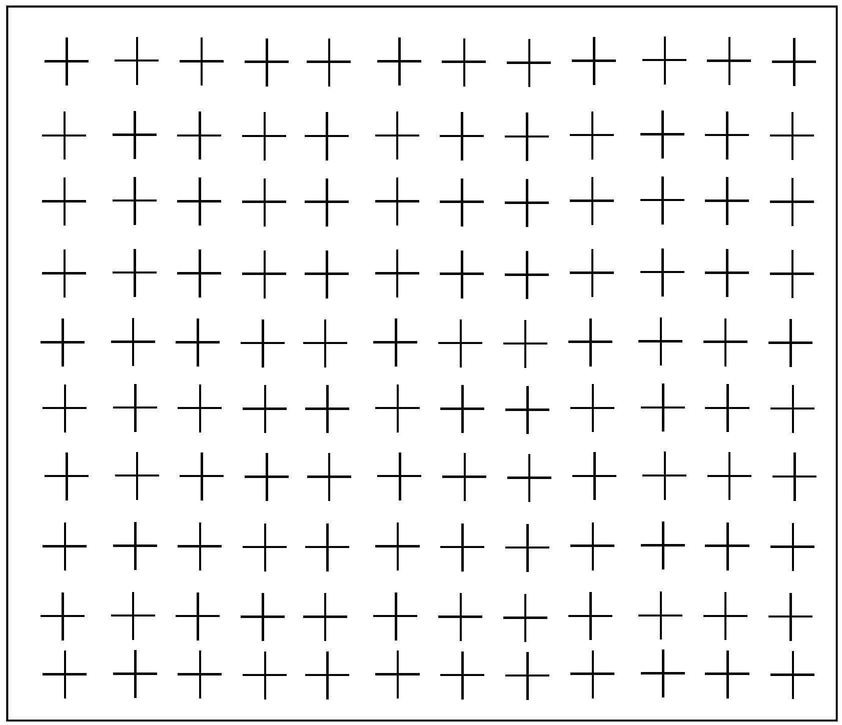
r/c = dr/dh

dr = dh * r/c

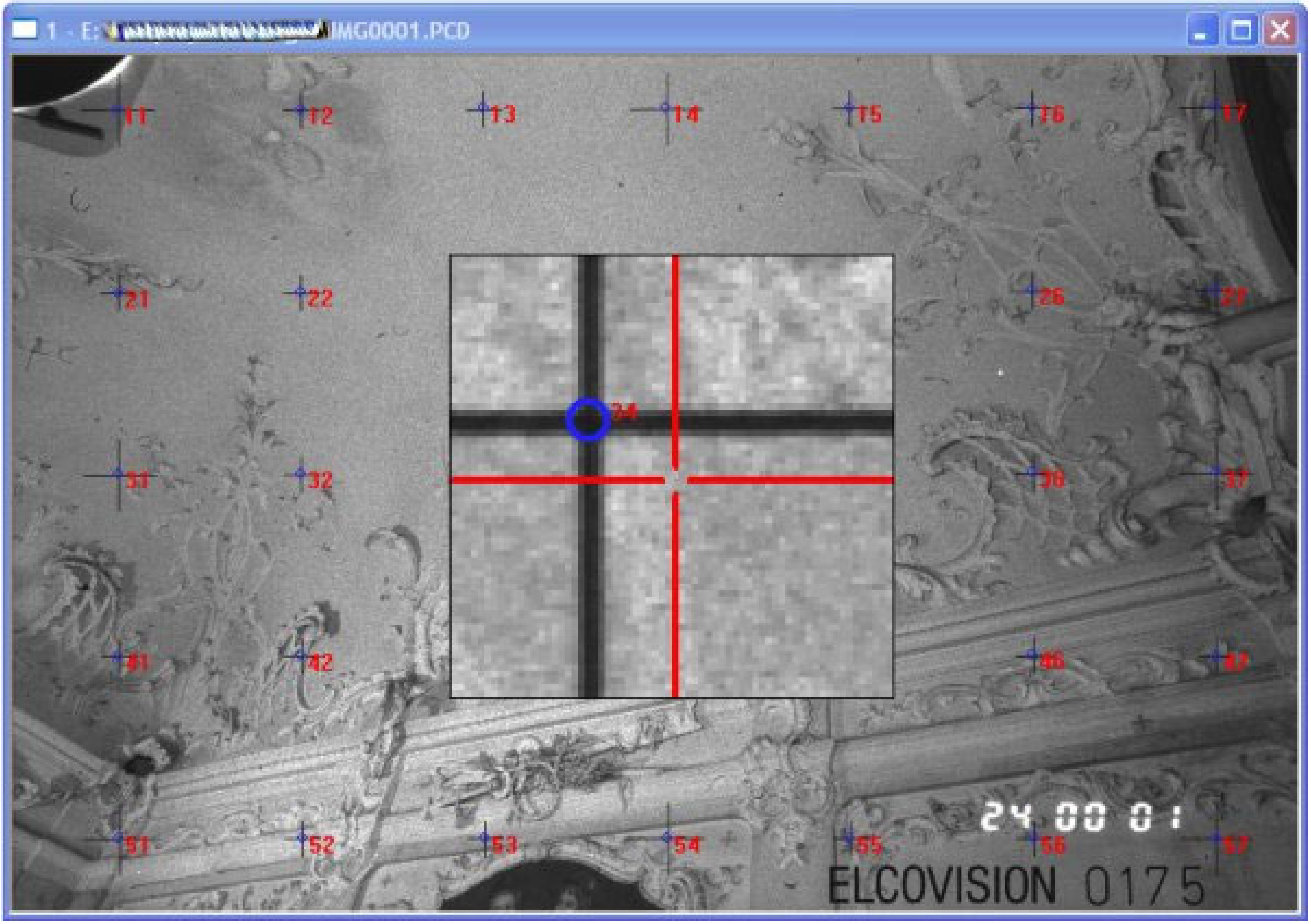
Non Planar Film Platen

- dh: The deviation of the film platen from a perfect plane.
- Using height gauges, dh can be measured and modeled by a high order polynomial.
- We can assure that the film is positioned tightly against the focal plane using either:
  - Glass plates (not recommended)
  - Suction mechanisms

Reseau Camera



Reseau Camera



http://www.elcovision.com/e_elco_reseau.html

Reseau Camera

http://www.elcovision.com/e_elco_reseau.html

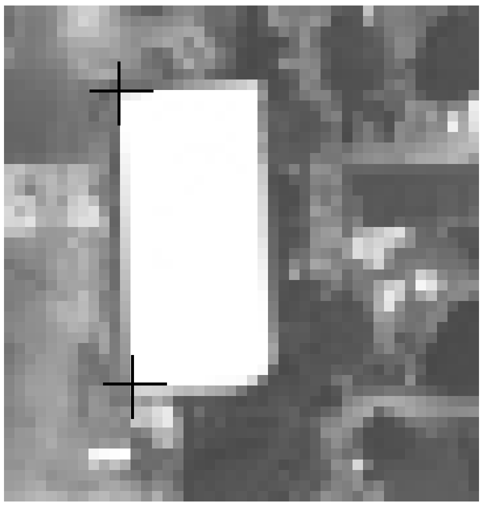
Reseau Camera

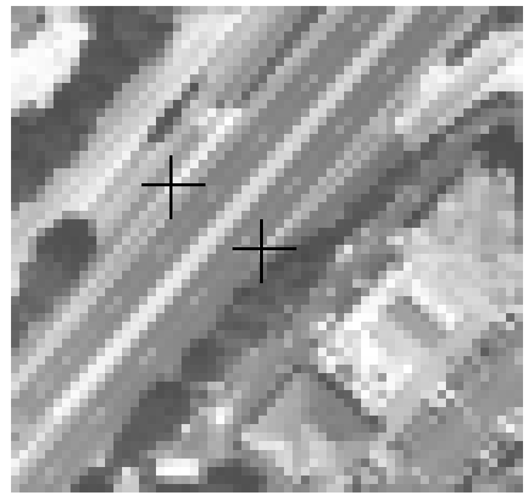
- Reseau: A raster of regularly spaced crosses marked on a glass plate in front of the film platen.
- The images of the crosses will appear on the final image.
- The image coordinates of the grid elements are available in the Camera Calibration Certificate (CCC).
- Comparing the image coordinates of the grid elements in both the image and the CCC, we can correct for the distortions that took place during film development.

Point Classification

- Points can be classified according to:
  - How do they appear in the imagery
    - Natural targets
    - Signalized targets
    - Artificial points
  - Their role in the adjustment
    - Control points
    - Check points
    - Tie points

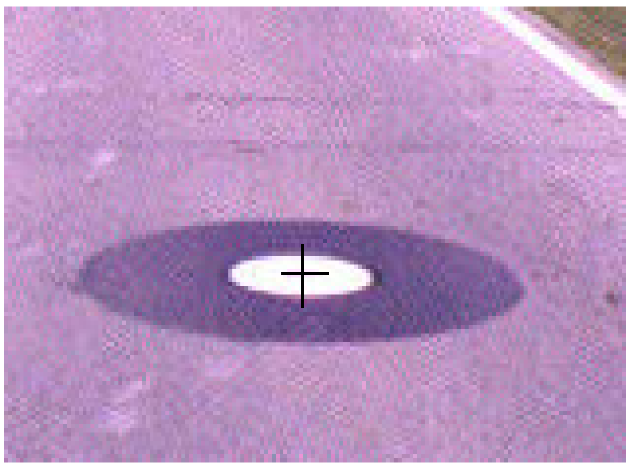
Natural Targets

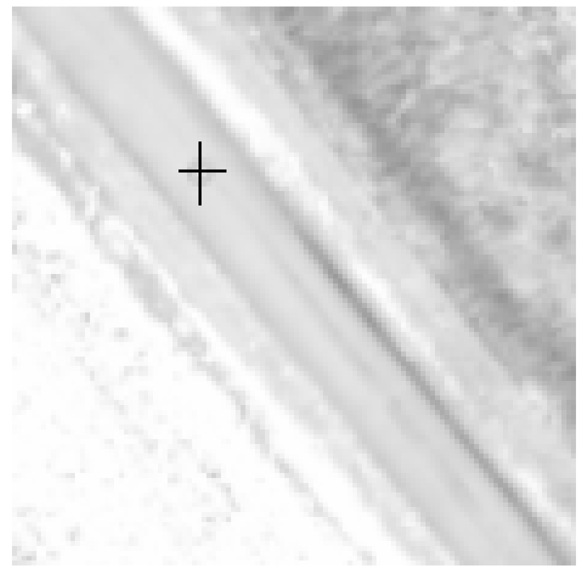




Artificial Points

Signalized Targets

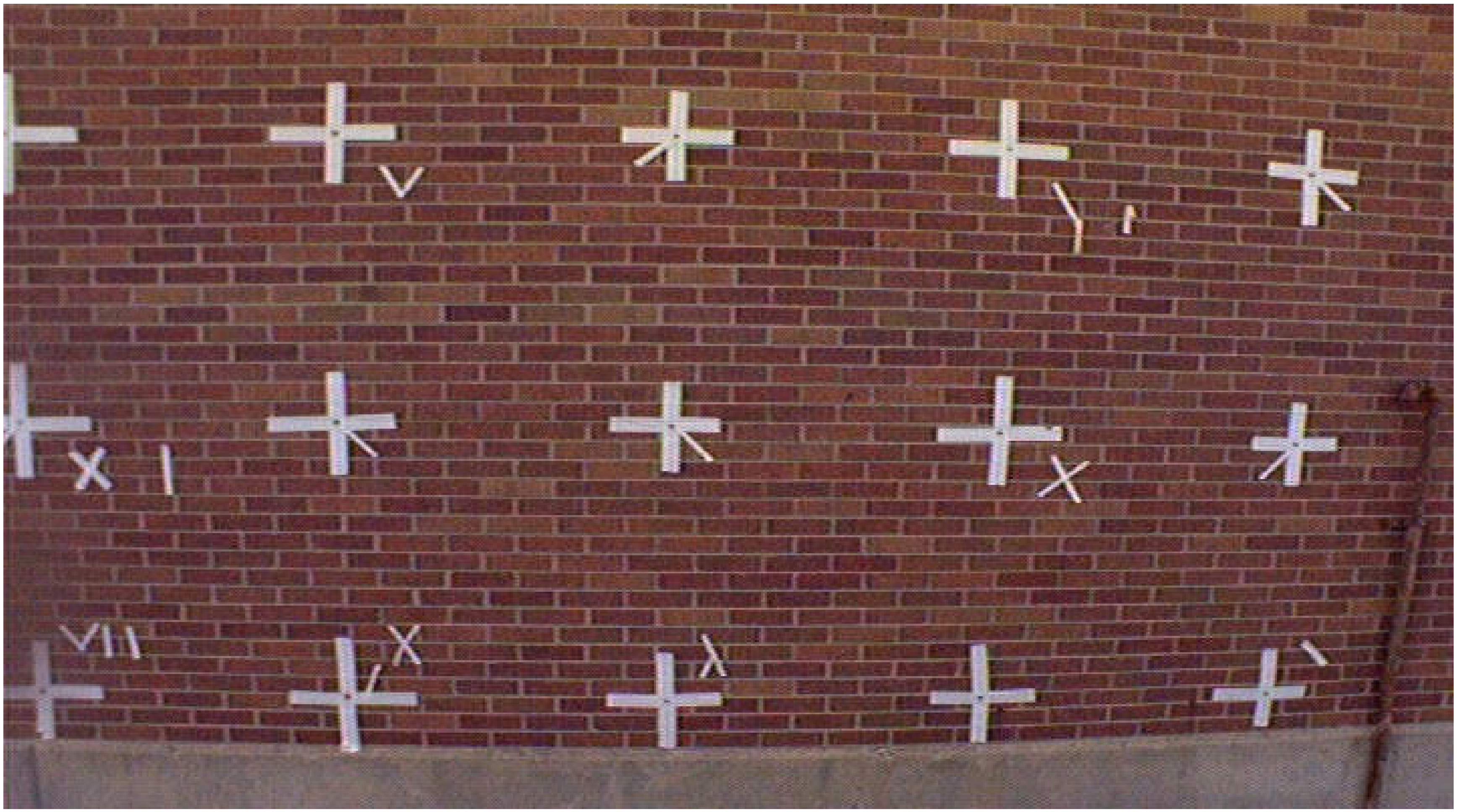




Signalized Targets

Signalized Targets: Preparation

Signalized Targets



Point Classification (II)

- Control Points:
  - points whose ground coordinates are available from geodetic measurements (e.g., GNSS).
  - They are used to define the datum during the bundle adjustment.
    - Origin (three parameters),
    - Orientation in space (three parameters), and
    - Scale (one parameter).
  - A minimum of three (more precisely $2\ ^{1}/_{3}$) non-collinear ground control points is needed to define the datum.

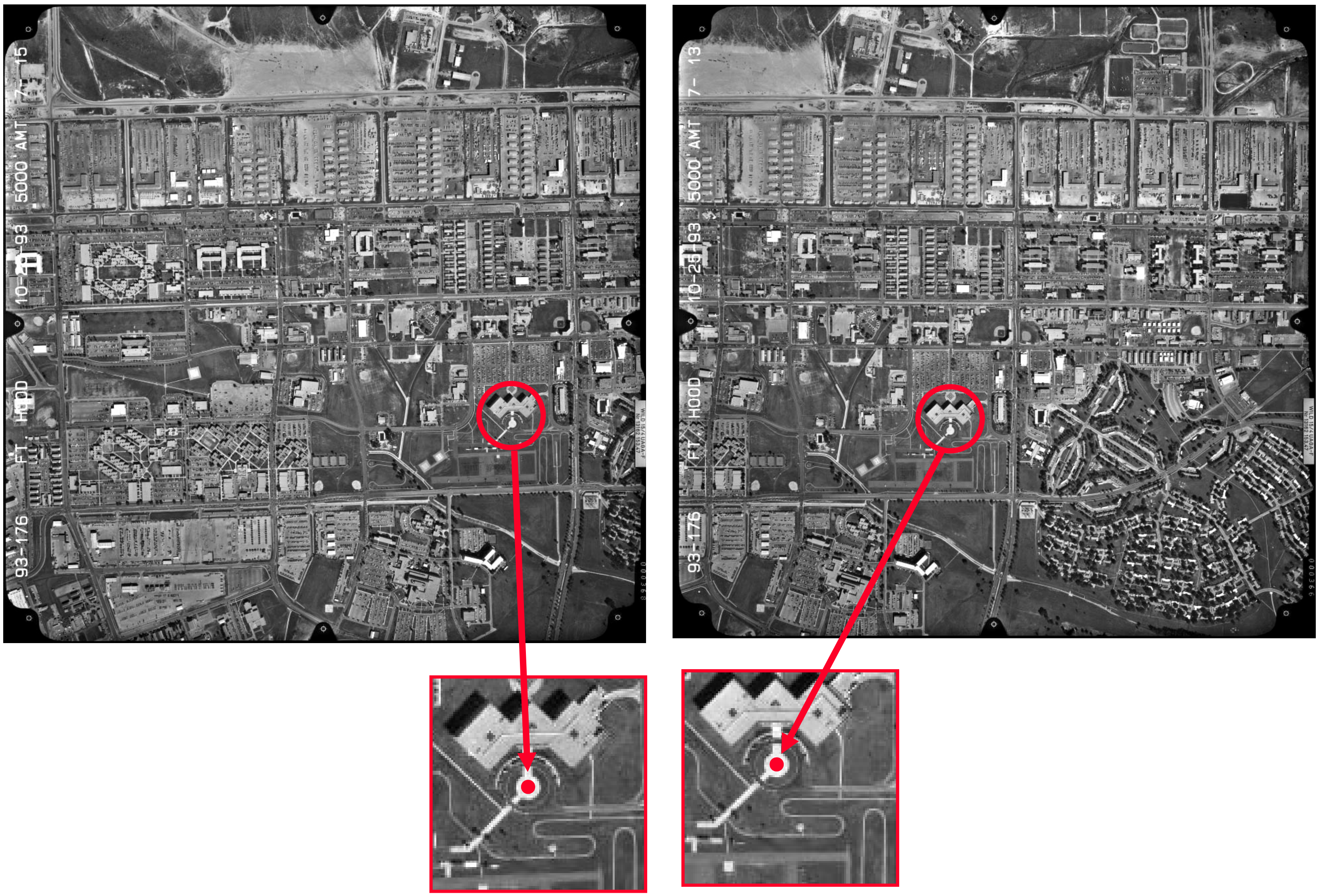
Ground Control Points: Collection

http://videoindustrial.files.wordpress.com/2011/09/gps.jpg

Point Classification (II)

- Tie Points:
  - Their function is to tie together overlapping images.
  - They should be well defined in the images.
  - Their ground coordinates are determined through photogrammetric adjustment.

Tie Points


93-176
FT. HOOD
10-20-93
5000' AMT
7- 15
93-176
FT. HOOD
10-20-93
5000' AMT
7- 13

Point Classification (II)

- Check Points:
  - Points whose ground coordinates are available from geodetic measurements.
  - In the photogrammetric adjustment, they are used as tie points.
  - By comparing the photogrammetric and geodetic coordinates, one can check the quality of the photogrammetric adjustment.