41014 Sensors and Control for Mechatronic Systems

Lecture-2: Cameras

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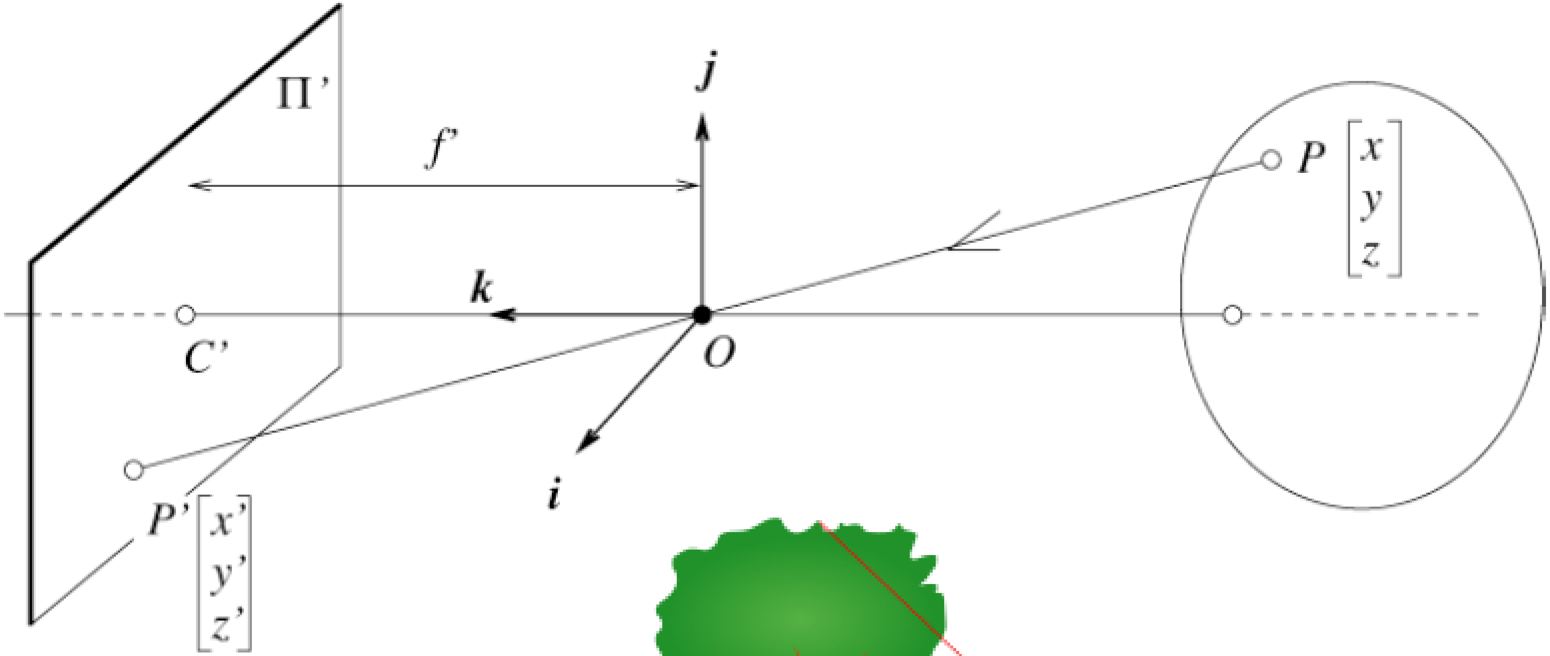
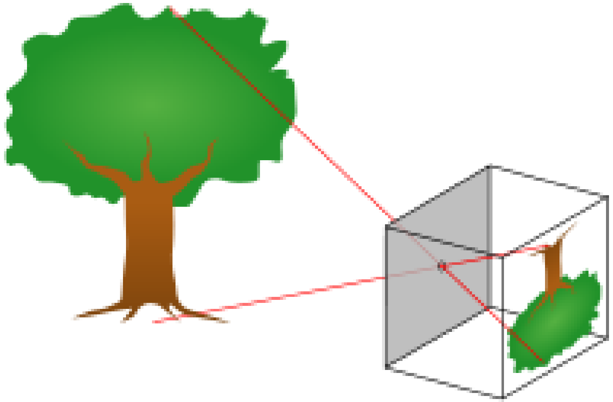
- **Single View Geometry**

- **Pinhole model**





3. Cameras: Geometry

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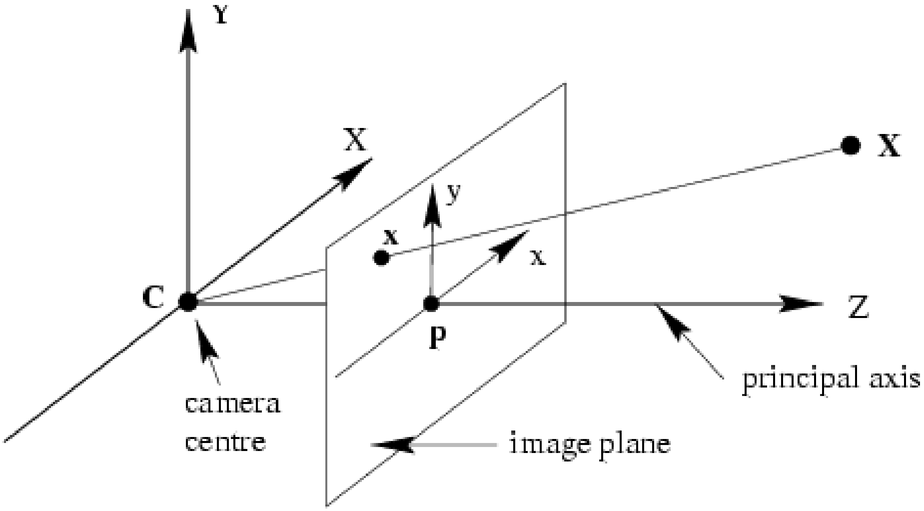
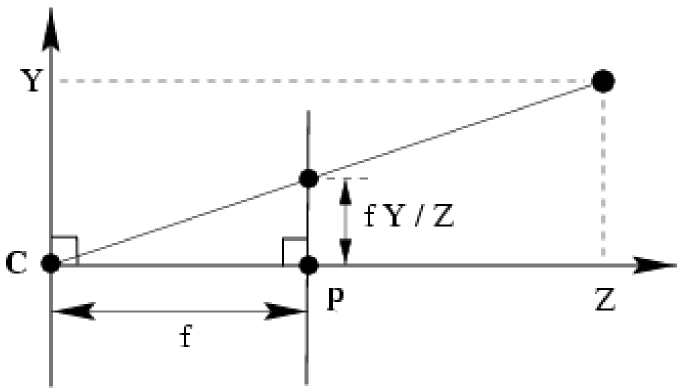
❖ Central projection





$$\mathrm{X} = [x, y, z]'$$

$$[x, y, z]' \rightarrow [f\frac{x}{z}, f\frac{y}{z}]' = \mathrm{x}$$

principle point, image plane, principal axis, camera centre

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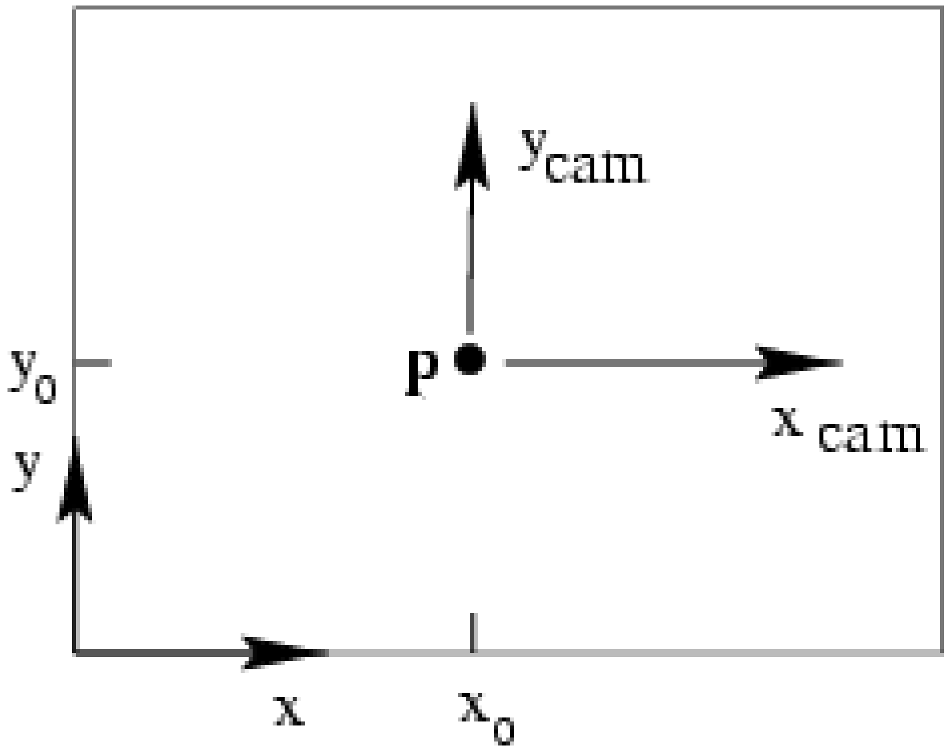
❖ **Central projection with principle point offset**



$\left[p_x, p_y\right]'$ **is the coordinates of the principle point in image plane**

- **Central projection with principle point offset**

$$[x, y, z]' \rightarrow [f\frac{x}{z}, f\frac{y}{z}]' = \mathrm{x}$$

$$[x, y, z]' \rightarrow [f\frac{x}{z} + p_x, f\frac{y}{z} + p_y]' = \mathrm{x}$$

3. Cameras: Geometry

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❖ Central projection with principle point offset

$$\begin{bmatrix} fx + zp_x \\ fy + zp_y \\ z \end{bmatrix} = \begin{bmatrix} f & 0 & p_x & 0 \\ 0 & f & p_y & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$[p_x, p_y]'$ **is the coordinates of the principle points in image plane**

$$\mathrm{x} = \mathrm{K}[\mathrm{I}|0]\mathrm{X}_{\mathrm{cam}}$$

homogeneous

$$K = \begin{bmatrix} f & 0 & p_x \\ 0 & f & p_y \\ 0 & 0 & 1 \end{bmatrix}$$

K is camera calibration matrix; X_cam is in camera coordinate frame

3. Cameras: Geometry

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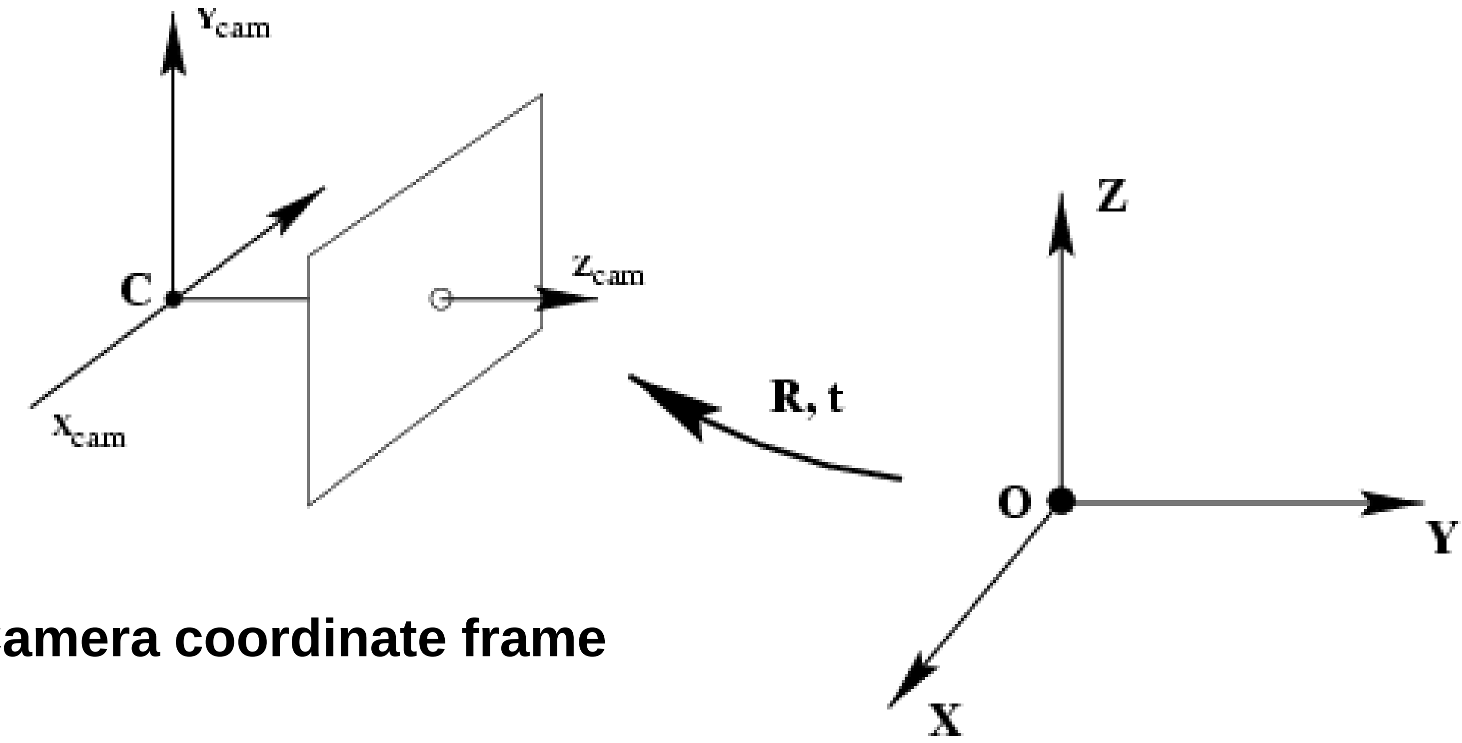
❖ Camera rotation and translation



Camera coordinate frame

World coordinate frame

Camera is on a moving vehicle. Object is in a global reference frame.

3. Cameras: Geometry

- **General camera projection**

$$
\begin{aligned}
\mathrm{x} &= \mathrm{K}[\mathrm{I} \mid 0]\mathrm{X}_{\mathrm{cam}} \\
&= \mathrm{K}[\mathrm{I} \mid 0]\begin{bmatrix} R & -R\bar{C} \\ 0 & 1 \end{bmatrix}\mathrm{X}
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{x} &= \mathrm{KR}[\mathrm{I} \mid -\bar{\mathrm{C}}]\mathrm{X} \\
&= \mathrm{PX}
\end{aligned}
$$

$$\mathrm{P} = \mathrm{KR}[\mathrm{I} \mid -\bar{\mathrm{C}}]$$

P is camera projection matrix

K: camera intrinsic parameters; R,C: camera extrinsic parameters

3. Cameras: Geometry

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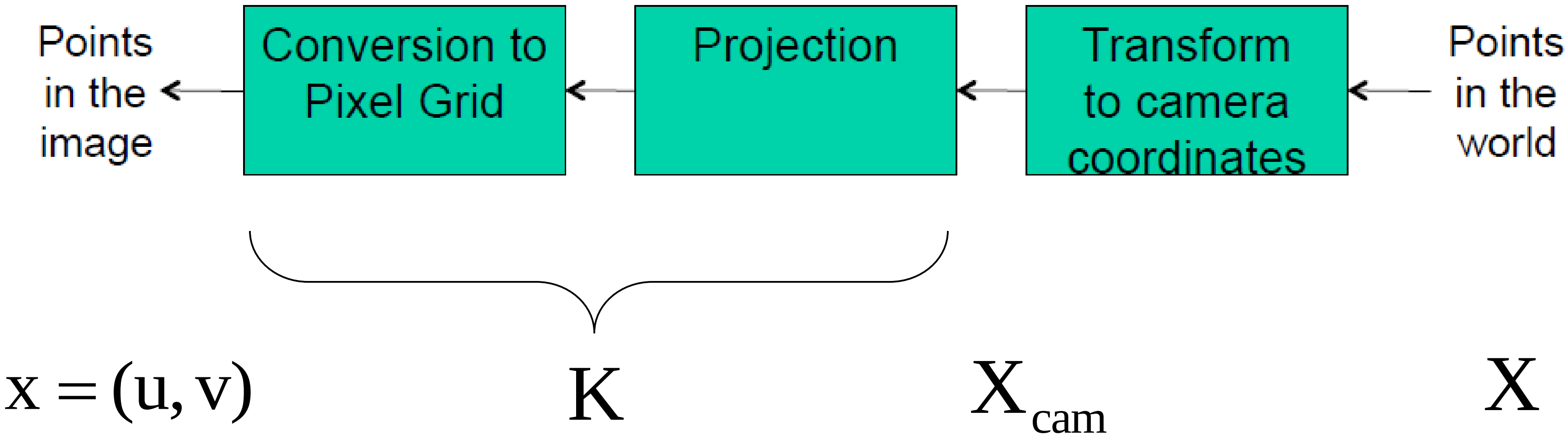
❖ The Projection "Chain"



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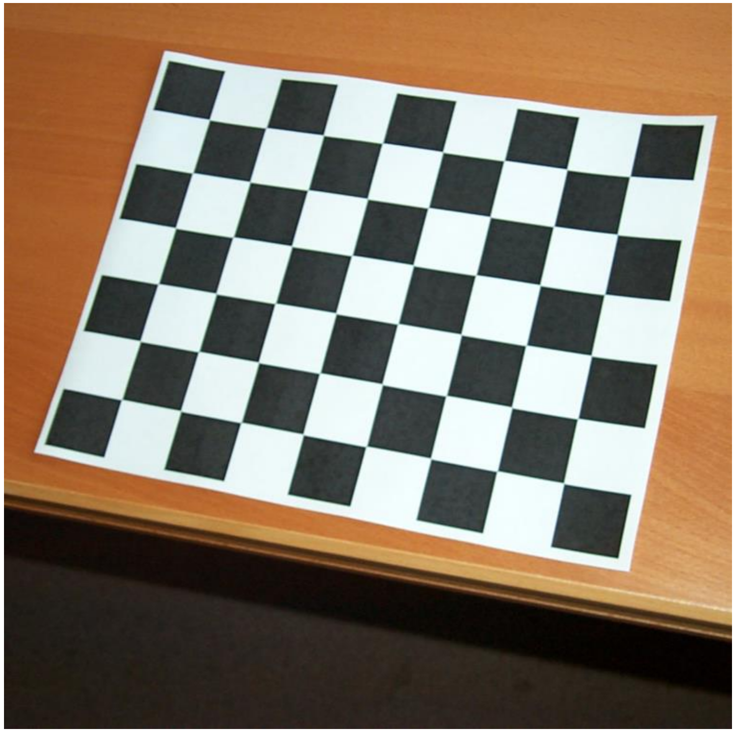
- **For more details about camera geometry, please refer to the Section “Single View Geometry” in book**

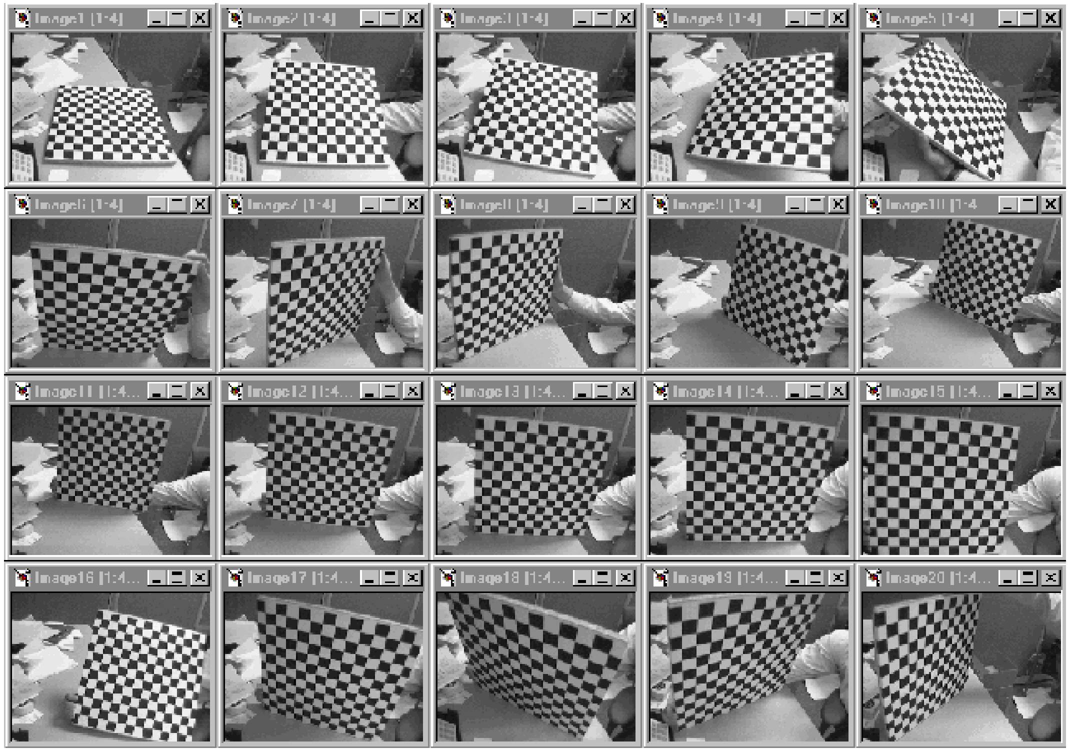
- ***Hartley, R., & Zisserman, A. (2003). Multiple view geometry in computer vision. Cambridge university press.***

4. Cameras: Calibration

Matlab implementation:

- http://www.vision.caltech.edu/bouguetj/calib_doc/index.html





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THANK YOU

Questions?

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