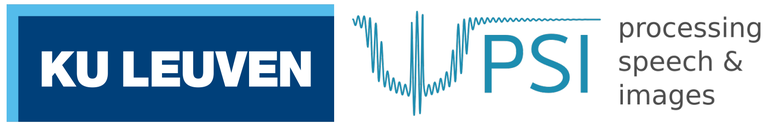
Image Analysis and Understanding: Exercises and Practicals 1

Feb 21, 2025 8:00 - 10:25



- Python basics

- Pinhole Camera Model

- Distortion (radial and tangential)

Pinhole Camera Model

$$sp = K[R|t]P'$$

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

3D point in world coordinate

Pinhole Camera Model

$$sp = K[R|t]P'$$

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \underbrace{\begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix}} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

Extrinsic parameters (camera pose)

R is rotation matrix

t is translation vector

Pinhole Camera Model

$$sp = K[R|t]P'$$

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \underbrace{\begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

Camera Intrinsic

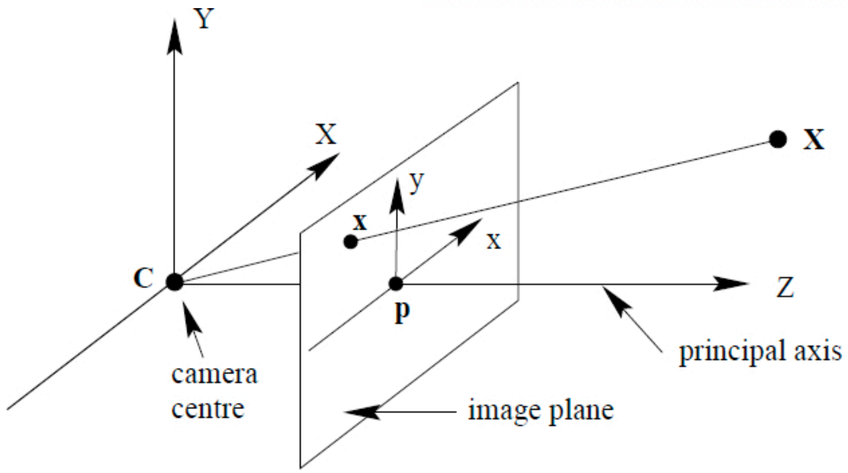
(c_x, c_y) is principal point (in pixel)

(f_x, f_y) is focal length (in pixel)

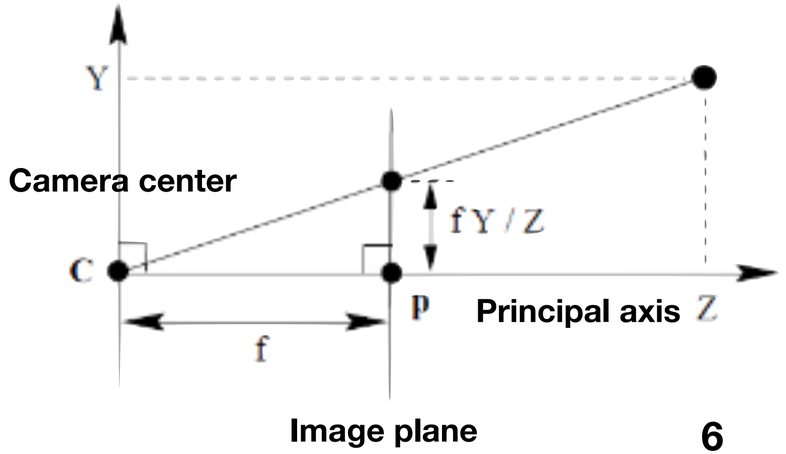
Pinhole Camera Model

$$sp = K[R|t]P'$$

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$



Example: only look at y component, in camera coordinate



Pinhole Camera Model

$$sp = K[R|t]P'$$

pixel coordinate

depth value

$$s \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

Pinhole Camera Model

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = R \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + t$$

$$x' = x/z$$

$$y' = y/z$$

$$u = f_x * x' + c_x$$

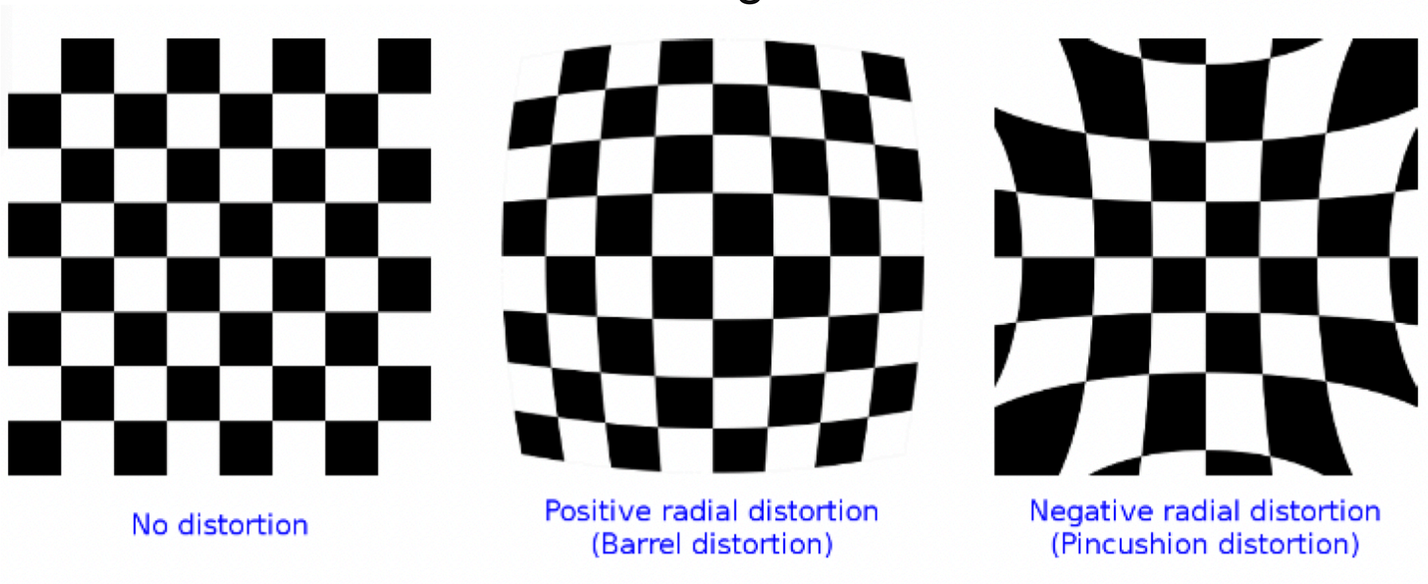
$$v = f_y * y' + c_y$$

The formula in the assignment materials can be interpreted as:

1. 3D world coordinate => 3D camera coordinate
2. 3D camera coordinate => **unit** 3D camera coordinate
3. Unit 3D camera coordinate => 2D pixel coordinate

Radial Distortion

Radial distortion causes straight lines to appear curved. This effect is more pronounced the further awa
point is from the center of the image.



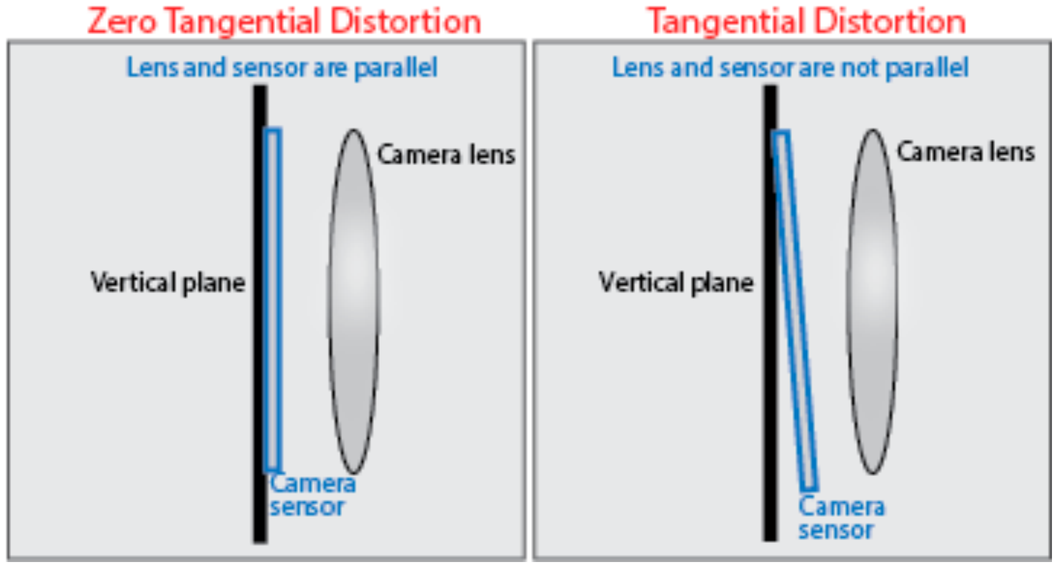
$$x'' = x'(1 + k_1 r^2 + k_2 r^4 + k_3 r^6)$$

$$y'' = y'(1 + k_1 r^2 + k_2 r^4 + k_3 r^6)$$

Note: $(x',\ y')$ $(x'',\ y'')$ are the **normalized** coordinates of a point

Tangential Distortion

Tangential distortion occurs when the lens is not aligned perfectly parallel to the imaging plane



$$x'' = 2p_1x'y' + p_2\left(r^2 + 2x'^2\right)$$

$$y'' = p_1\left(r^2 + 2y'^2\right) + 2p_2x'y'$$

Undistortion procedure

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = R \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} + t$$

1. World to camera coordinate

$$x' = x/z$$
$$y' = y/z$$

2. normalize to unit camera coordinate

$$x'' = x'(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) + 2p_1 x'y' + p_2 \left(r^2 + 2x'^2\right)$$
$$y'' = y'(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) + p_1 \left(r^2 + 2y'^2\right) + 2p_2 x'y'$$

3. Undistortion

Where $r^2 = x'^2 + y'^2$

$$u = f_x * x'' + c_x$$
$$v = f_y * y'' + c_y$$

4. Camera coordinate to pixel space