Module 7 : Robot vision I

Lecture 27 : Camera transformation and calibrations

Objectives

In this course you will learn the following

- Image Processing.
- Camera Calibration.
- Basic Concepts.
- Connectivity, Mixed Connectivity, M-distance.

Image Processing

$$C_k = (PCRT)W_k$$

$$x = \frac{\lambda\left(X - X_0\right)\cos\theta + \left(Y - Y_0\right)\sin\theta - r_1}{-\left(X - X_0\right)\sin\theta\sin\alpha + \left(Y - Y_0\right)\cos\theta\sin\alpha - \left(Z - Z_0\right)\cos\alpha + r_3 + \lambda}$$

$$y = \frac{\lambda\left\{-\left(X - X_0\right)\sin\theta\cos\alpha + \left(Y - Y_0\right)\cos\theta\cos\alpha + \left(Z - Z_0\right)\sin\alpha - r_2\right\}}{-\left(X - X_0\right)\sin\theta\sin\alpha + \left(Y - Y_0\right)\cos\theta\sin\alpha - \left(Z - Z_0\right)\cos\alpha + r_3 + \lambda}$$

Focal Length, λ = 35 mm Xo, Yo = 0, Zo = 1 m Pan, θ Tilt α = 135 deg r1 = 0.03 m r2 = r3 = 0.02 m

$$x = \frac{\lambda(-0.03)}{-1.53 + \lambda}$$

$$y = \frac{\lambda(-0.42)}{-1.53 + \lambda}$$

λ = 0.035 -> x = 0.7 mm and y = 9 mm

First camera coordinate systems coincidental (see Figure 27.1)

$$X_1 = \frac{x_1(\lambda - Z_1)}{\lambda}$$

$$X_0 = -B$$

$$X_2 = X_1 + B = \frac{x_2(\lambda - Z_2)}{\lambda}$$

$$Z_1 = Z_2 = Z \Rightarrow Z = \lambda - \frac{\lambda B}{x_2 - x_1}$$

$$X_1 = \frac{x_1 B}{x_2 - x_1}$$

$$Y_1 = \frac{y_1 B}{x_2 - x_1}$$

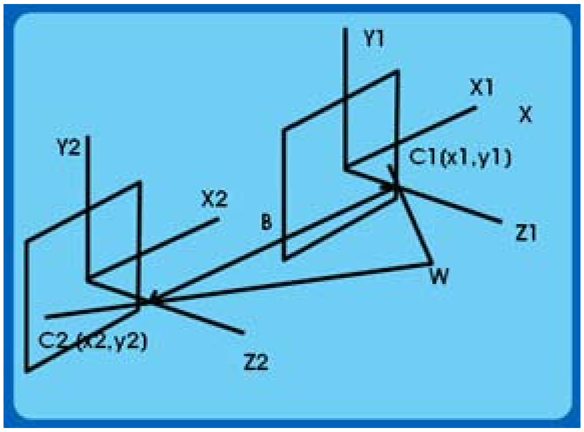


Figure 27.1 camera coordinate systems

Camera Calibration

$$\bar{C}_k = (PCRT)\bar{W}_k = A\bar{W}_k$$

$$\begin{Bmatrix} C_{k1} \\ C_{k2} \\ C_{k3} \\ C_{k4} \end{Bmatrix} = \begin{Bmatrix} xk \\ yk \\ zk \\ k \end{Bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{Bmatrix} x \\ y \\ z \\ 1 \end{Bmatrix}$$

$$x = \frac{C_{k1}}{C_{k4}}; y = \frac{C_{k3}}{C_{k4}}$$

$$xC_{k4} = a_{11}X + a_{12}Y + a_{13}Z + a_{14}$$

$$yC_{k4} = a_{21}X + a_{22}Y + a_{23}Z + a_{24}$$

$$C_{k4} = a_{41}X + a_{42}Y + a_{43}Z + a_{44}$$

$$a_{11}X + a_{12}Y + a_{13}Z + a_{14} - a_{41}Xx - a_{42}Yx - a_{43}Zx - a_{44}x = 0$$

$$a_{21}X + a_{22}Y + a_{23}Z + a_{24} - a_{41}Xy - a_{42}Yy - a_{43}Zy - a_{44}y = 0$$

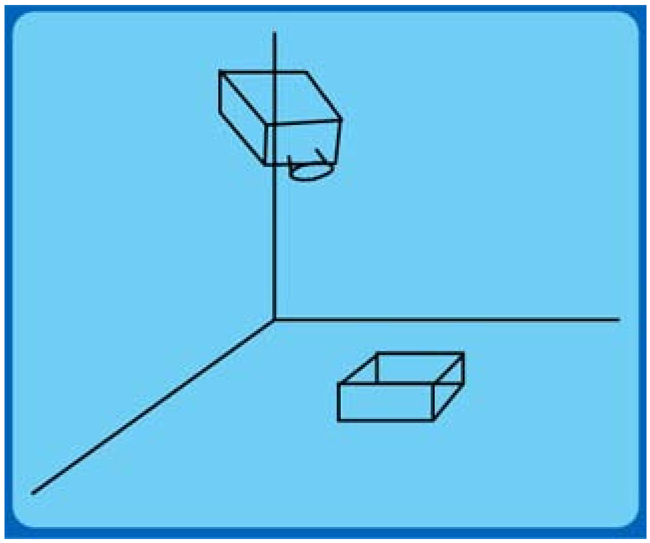


Figure 27.2 Camera & object

Image Processing

- Image f(x,y)
- Intensity at location (x,y)

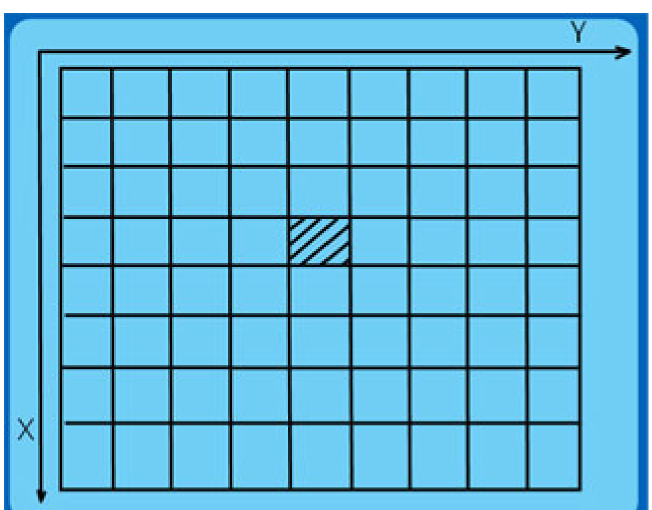


Figure 27.3 Pixel representation of intensity

Basic Concepts

Neighborhood of a pixel : N4(P)

4 Neighbors (x-1,y), (x,y-1), (x,y+1), (x+1,y)

Diagonal Neighborhood (x-1,y-1), (x+1,y-1), (x+1,y-1), (x+1,y+1)

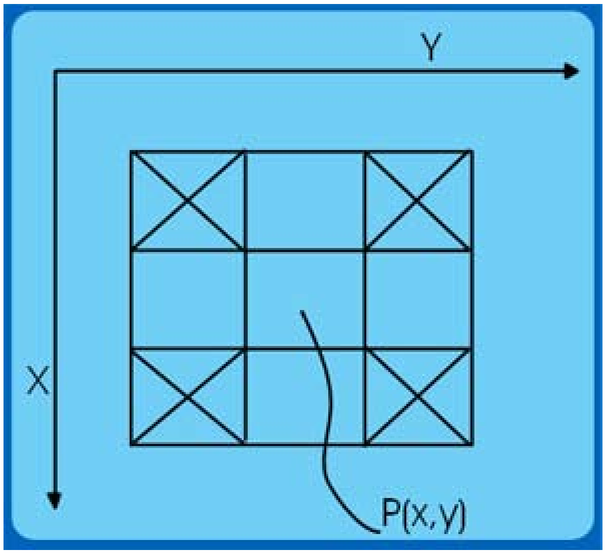


Figure 27.4 Image Processing

Connectivity

4- connectivity & 8-connectivity

Connected if the corresponding neighboring pixel has intensity value belonging to a specified set (depending on x,y)

- Mixed, m-connectivity: if
- q is in N_4 (P) OR
- q is in N_D (P) & there is no common N_4 of both p and q.

Mixed Connectivity

- Distance: Euclidean (D e)
- Distance based on N4 (city-block distance)
- N_4 (p,q) = 5 + 1 = 6
- Chessboard Distance D_8
- D_8 (p,q) = 5

$$De(p,q) = \sqrt{5^2+1} = \sqrt{26}$$

$$\sqrt{(x-u)^2+(y-v)^2} = De$$

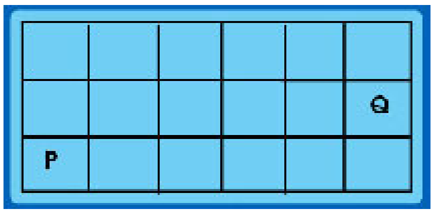
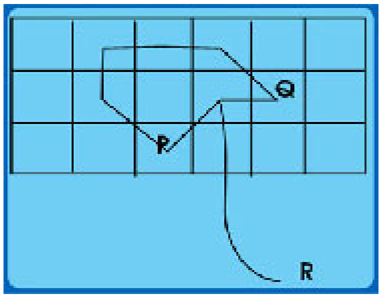


Figure 27.5 Connectivity

M-distance

E.g. D_m (p, q) = 5

If R is also connected D_m (p,q) = 2



Recap

In this course you have learnt the following

- Image Processing
- Camera Calibration
- Basic Concepts
- Connectivity, Mixed Connectivity, M-distance

Congratulations, you have finished Lecture 27. To view the next lecture select it from the left hand side menu of the page.