Part A: Image Filtering

Ans to the Ques No-01

Given $I = \begin{bmatrix} 7 & 4 & 1 \\ 8 & 5 & 2 \\ 9 & 6 & 3 \end{bmatrix}$ with $\bar{I} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 7 & 4 & 1 & 0 \\ 0 & 8 & 5 & 2 & 0 \\ 0 & 9 & 6 & 3 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

Formula

$$G(i,j) = \sum_{u=0}^{k-1} \sum_{v=0}^{l-1} F(u,v) \cdot \bar{I}(i+u, j+v)$$

Here $k = l = 3$

(a)

Given Filter $F = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

$G(0,0) = F \otimes I$

$$= \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} 0 & 0 & 0 \\ 0 & 7 & 4 \\ 0 & 8 & 5 \end{bmatrix}$$

$= (0\times0) + (0\times0) + (0\times0) + (0\times0) + (1\times7) + (0\times4)$
$(0\times0) + (0\times8) + (0\times5)$

$= 7$

$$G(0,1) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 7 & 4 & 1 \\ 8 & 5 & 2 \end{bmatrix}$$

$= 0+0+0+0+4+0+0+0+0+0$

$= 4$

$$G(0,2) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 4 & 1 & 0 \\ 5 & 2 & 0 \end{bmatrix}$$

$= 0+0+0+0+1+0+0+0+0$

$= 1$

$$G(1,0) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 7 & 4 \\ 0 & 8 & 5 \\ 0 & 9 & 6 \end{bmatrix} = 8$$

$$G(1,1) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 7 & 4 & 1 \\ 8 & 5 & 2 \\ 9 & 6 & 3 \end{bmatrix} = \cancel{8}5$$

$$G(1,2) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 4 & 1 & 0 \\ 5 & 2 & 0 \\ 6 & 3 & 0 \end{bmatrix} = 2$$

$$G(2,0) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 8 & 5 \\ 0 & 9 & 6 \\ 0 & 0 & 0 \end{bmatrix} = 9$$

$$G(2,1) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 8 & 5 & 2 \\ 9 & 6 & 3 \\ 0 & 0 & 0 \end{bmatrix} = \cancel{3}6$$

$$G(2,2) = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 5 & 2 & 0 \\ 6 & 3 & 0 \\ 0 & 0 & 0 \end{bmatrix} = 3$$

$$\therefore G = \begin{bmatrix} 7 & 4 & 1 \\ 8 & 5 & 2 \\ 9 & 6 & 3 \end{bmatrix}$$

(b)

$$F = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$G(0,0) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 7 & 4 \\ 0 & 8 & 5 \end{bmatrix} = 0$$

$$G(0,1) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 7 & 4 & 1 \\ 8 & 5 & 2 \end{bmatrix} = 0$$

$$G(0,2) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 4 & 1 & 0 \\ 5 & 2 & 0 \end{bmatrix} = 0$$

$$G(1,0) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 7 & 4 \\ 0 & 8 & 5 \\ 0 & 9 & 6 \end{bmatrix} = 0$$

$$G(1,1) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 7 & 4 & 1 \\ 8 & 5 & 2 \\ 9 & 6 & 3 \end{bmatrix} = 7$$

$$G(1,2) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 4 & 1 & 0 \\ 5 & 2 & 0 \\ 6 & 3 & 0 \end{bmatrix} = 4$$

$$G(2,0) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 8 & 5 \\ 0 & 9 & 6 \\ 0 & 0 & 0 \end{bmatrix} = 0$$

$$G(2,1) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 8 & 5 & 2 \\ 9 & 6 & 3 \\ 0 & 0 & 0 \end{bmatrix} = 8$$

$$G(2,2) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 5 & 2 & 0 \\ 6 & 3 & 0 \\ 0 & 0 & 0 \end{bmatrix} = 5$$

Now $G = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 7 & 4 \\ 0 & 8 & 5 \end{bmatrix}$

C

$$F = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

$$G(0,0) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 7 & 4 \\ 0 & 8 & 5 \end{bmatrix} = -8-5$$
$$= -13$$

$$G(0,1) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 7 & 4 & 1 \\ 8 & 5 & 2 \end{bmatrix} = -8-5-2$$
$$= -15$$

$$G(0,2) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 4 & 1 & 0 \\ 5 & 2 & 0 \end{bmatrix} = -5-2 = -7$$

$$G(1,0) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 0 & 7 & 4 \\ 0 & 8 & 5 \\ 0 & 9 & 6 \end{bmatrix} = 7+4-9-6$$
$$= -4$$

$$G(1,2) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 4 & 1 & 0 \\ 5 & 2 & 0 \\ 6 & 3 & 0 \end{bmatrix} = 4+1-6-3$$
$$= -4$$

$$G(2,0) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 0 & 8 & 5 \\ 0 & 9 & 6 \\ 0 & 0 & 0 \end{bmatrix} = 8+5 = 13$$

$$G(1,1) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 7 & 4 & 1 \\ 8 & 5 & 2 \\ 9 & 6 & 3 \end{bmatrix} = 7+4+1-9-6-3$$
$$= -6$$

$$G(2,1) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 8 & 5 & 2 \\ 0 & 6 & 3 \\ 0 & 0 & 0 \end{bmatrix} = 8+5+2 = 15$$

$$G(2,2) = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \begin{bmatrix} 5 & 2 & 0 \\ 6 & 3 & 0 \\ 0 & 0 & 0 \end{bmatrix} = 5+2 = 7$$

$$\cancel{G = \begin{bmatrix} -13 & -15 & -7 \\ -4 & -4 & -13 \\ 13 & 15 & 7 \end{bmatrix}} \quad \cancel{(\text{Ans})}$$

$$G = \begin{bmatrix} -13 & -15 & -7 \\ -4 & -6 & -4 \\ 13 & 15 & 7 \end{bmatrix} \quad (\text{Ans})$$

This Filter detects horizontal edges.

(d)

$$F' = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

$$G(0,0) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 0 & 7 & 4 \\ 0 & 8 & 5 \end{bmatrix} = 4+5 = 9$$

$$G(0,1) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 7 & 4 & 1 \\ 8 & 5 & 2 \end{bmatrix} = -7-8+1+2 = -12$$

$$G(0,2) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 \\ 4 & 1 & 0 \\ 5 & 2 & 0 \end{bmatrix} = -4-5 = -9$$

$$G(1,0) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 7 & 4 \\ 0 & 8 & 5 \\ 0 & 9 & 6 \end{bmatrix} = 4+5+6 = 15$$

$$G(1,1) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 7 & 4 & 1 \\ 8 & 5 & 2 \\ 9 & 6 & 3 \end{bmatrix} = -7-8-9+1+2+3$$
$$= -18$$

$$G(1,2) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 & 1 & 0 \\ 5 & 2 & 0 \\ 9 & 6 & 3 \end{bmatrix} = -4-5-9+3$$
$$= -15$$

$$G(2,0) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 9 & 8 & 5 \\ 8 & 9 & 6 \\ 0 & 0 & 0 \end{bmatrix} = 5+6 = 11$$

$$G(2,1) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 8 & 5 & 2 \\ 9 & 6 & 3 \\ 0 & 0 & 0 \end{bmatrix} = -8-9+2+3$$

$$= -12$$

$$G(2,2) = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 5 & 2 & 0 \\ 6 & 3 & 0 \\ 0 & 0 & 0 \end{bmatrix} = -5-6 = -11$$

$$G = \begin{bmatrix} 9 & -12 & -9 \\ 15 & -18 & -15 \\ 11 & -12 & -11 \end{bmatrix}$$

This filter ditect vertical edges where

'c' detect horizontal edges

(e)

$F = \frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$

Now use only F except 1/16 multiplication for easy calculation —

$$G(0,0) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}\begin{bmatrix} 0 & 0 & 0 \\ 0 & 7 & 4 \\ 0 & 8 & 5 \end{bmatrix} = 28+8+16+5 = 57$$

$$G(0,1) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 1 \\ 1 & 2 & 1 \end{bmatrix}\begin{bmatrix} 0 & 0 & 0 \\ 7 & 4 & 1 \\ 8 & 5 & 2 \end{bmatrix} = 14+16+1+8+5+2 = 52$$

$$G(0,2) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 1 \\ 1 & 2 & 1 \end{bmatrix}\begin{bmatrix} 0 & 0 & 0 \\ 4 & 1 & 0 \\ 5 & 2 & 0 \end{bmatrix} = 8+4+5+4 = 21$$

$$G(1,0) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}\begin{bmatrix} 0 & 7 & 4 \\ 0 & 8 & 5 \\ 0 & 9 & 6 \end{bmatrix} = \{14+4+32+10+18+6 = \cancel{88}\ 84$$

$$G(1,1) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}\begin{bmatrix} 7 & 4 & 1 \\ 8 & 5 & 2 \\ 9 & 6 & 3 \end{bmatrix} = 7+14+1+16+20+4+9+12+3 = 80$$

$$G(1,2) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \begin{bmatrix} 4 & 1 & 0 \\ 8 & 7 & 0 \\ 9 & 6 & 3 \end{bmatrix} \quad 36$$

$$G(2,0) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \begin{bmatrix} 0 & 7 & 5 \\ 0 & 3 & 6 \\ 0 & 0 & 0 \end{bmatrix} = 67$$

$$G(2,1) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \begin{bmatrix} 8 & 6 & 2 \\ 9 & 6 & 3 \\ 0 & 0 & 0 \end{bmatrix} = 68$$

$$G(2,2) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \begin{bmatrix} 5 & 2 & 0 \\ 6 & 3 & 0 \\ 0 & 4 & 0 \end{bmatrix} = 33$$

$$G = 1/16 \begin{bmatrix} 57 & 52 & 21 \\ 84 & 50 & 36 \\ 67 & 68 & 33 \end{bmatrix}$$

Given filter is a Gaussian blur. This filter smooths the image by averaging close pixels with Gaussian weights, reducing noise and sharp transitions.

f

$$F = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Use $F = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$ for easy calculation

$$G(0,0) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} 0 & 0 & 0 \\ 0 & 7 & 4 \\ 0 & 8 & 5 \end{bmatrix} = 7+4+8+5 = 24$$

$$G(0,1) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} 0 & 0 & 0 \\ 7 & 4 & 1 \\ 8 & 5 & 2 \end{bmatrix} = 7+4+1+8+5+2 = 27$$

$$G(0,2) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} 0 & 0 & 0 \\ 4 & 1 & 0 \\ 5 & 2 & 0 \end{bmatrix} = \cancel{7} 4+1+5+2 = 12$$

$$G(1,0) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} 0 & 7 & 4 \\ 0 & 8 & 5 \\ 0 & 9 & 6 \end{bmatrix} = 7+4+8+5+9+6 = 39$$

$$G(1,1) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} 7 & 4 & 1 \\ 8 & 5 & 2 \\ 9 & 6 & 3 \end{bmatrix} = 7+4+1+8+5+2+9+6+3 = 45$$

$$G(1,2) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 4 & 1 & 0 \\ 5 & 2 & 0 \\ 9 & 6 & 3 \end{bmatrix} = 4+1+5+2+9+6+3 = 21$$

$$G(2,0) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 0 & 8 & 5 \\ 0 & 9 & 6 \\ 0 & 0 & 0 \end{bmatrix} = \cancel{6} 8+5+9+6 = 28$$

$$G(2,1) = \begin{bmatrix} 1 & 21 & 1 \\ 1 & 41 & 21 \\ 1 & 12 & 1 \end{bmatrix} \begin{bmatrix} 8 & 5 & 2 \\ 9 & 6 & 3 \\ 0 & 0 & 0 \end{bmatrix} = \cancel{68}\, 8+5+2+9+6+3 = 33$$

$$G(2,2) = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} 5 & 2 & 0 \\ 6 & 3 & 0 \\ 0 & 0 & 0 \end{bmatrix} = 5+2+6+3 = 16$$

$$G = \frac{1}{9} \begin{bmatrix} 24 & 27 & 12 \\ 39 & 45 & 21 \\ 28 & 33 & 16 \end{bmatrix}$$

"(f)" is an uniform (box) blur. Every neighbor contributes equally; It's tends to blur edges more and can look blocky. "(e)" is use center-weighted binomial/Gaussian weight - often yields smoother, more, natural denoising with less edge smearing

Problem - 2

ⓐ

Given $(i,j) = f^T t_{ij}$

Now $F = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

$f = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$ $f^T = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$

Now $G(0,0) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 7 \\ 4 \\ 0 \\ 8 \\ 5 \end{bmatrix} = 0$

$$G(0,1) = \cancel{[1\ 1}\ 0, 0$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 7 \\ 4 \\ 1 \\ 8 \\ 5 \\ 2 \end{bmatrix} = 0$$

$$G(0,2) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 4 \\ 1 \\ 0 \\ 5 \\ 2 \\ 0 \end{bmatrix} = 0$$

$$G(1,0) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 7 \\ 4 \\ 0 \\ 8 \\ 5 \\ 0 \\ 9 \\ 1 \end{bmatrix} = 0$$

$$G(1,1) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 7 \\ 4 \\ 1 \\ 8 \\ 5 \\ 2 \\ 9 \\ 6 \\ 3 \end{bmatrix} = 7$$

$$G(1,2) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 4 \\ 1 \\ 0 \\ 5 \\ 2 \\ 0 \\ 9 \\ 6 \\ 3 \end{bmatrix} = 4$$

$$G(2,0) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 2 \\ 8 \\ 5 \\ 0 \\ 9 \\ 6 \\ 0 \\ 0 \\ 0 \end{bmatrix} = 0$$

$$G(2,1) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 8 \\ 5 \\ 2 \\ 9 \\ 6 \\ 3 \\ 0 \\ 0 \\ 0 \end{bmatrix} = 8$$

$$G(2,2) = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 5 \\ 2 \\ 0 \\ 6 \\ 3 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = 5$$

$$\therefore G' = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 7 & 4 \\ 0 & 8 & 5 \end{bmatrix}$$

Which is same as ~~a~~ problem 1(b)

$\therefore$ we can write correllation as vector dot product

(showed)

Part B

Camera modeling

$P_c = (X, Y, Z) = (6m, 8m, -2m)$ (camera frame)

focal length $f = 35mm = 0.035m$

principal point $C = (2, 2)$ meters

pixel scals $k_x = k_y = 250$ pixels/meter

(a)

$$x = \frac{fX}{Z} \qquad y = \frac{fY}{Z}$$

$$x = \frac{0.035 \times 6}{-2} \qquad y = \frac{0.035 \times 8}{-2}$$

$$= -0.105m \qquad = -0.14m$$

$\therefore (x, y) = (-0.105, -0.14)$

(b)

$$\tilde{x} = x + c_x = -0.105 + 2$$
$$= 1.895m$$

$$\tilde{y} = y + c_y = -0.14 + 2$$
$$= 1.86$$

$\therefore (\tilde{x}, \tilde{y}) = (1.895, 1.86)$

(c)

$\tilde{x} = k_x x = 250 \times 1.895$

$= 473.75\ px$

$\tilde{y} = k_y y = 250 \times 1.86 = 465\ px$

$(\tilde{x}, \tilde{y}) = (473.75, 465)$

Code Link:
https://colab.research.google.com/drive/1DpVz_1-yj9QMDsx88QE-TlOmbpuK0FqX?usp=sharing