Computer Vision Past Paper 2019 - 2020

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Question 1: Image Filtering:

a) Prewitt filtering:

(i) Write down the 3x3 horizontal Prewitt filter h_x and vertical Prewitt filter h_y

$$h_x = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix} \quad \text{and} \quad h_y = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

(ii) Perform convolution between the image and the filters. Write down the output.

$$h_x = \begin{bmatrix} -3 & -1 & 0 & 1 & 3 \\ -6 & -3 & 0 & 3 & 6 \\ -9 & -6 & 0 & 6 & 9 \\ -12 & -9 & 0 & 9 & 12 \\ -9 & -7 & 0 & 7 & 9 \end{bmatrix} \quad \text{and} \quad h_y = \begin{bmatrix} -3 & -5 & -6 & -5 & -3 \\ -2 & -4 & -6 & -4 & -2 \\ -2 & -4 & -6 & -4 & -2 \\ -2 & -4 & -6 & -4 & -2 \\ 5 & 9 & 12 & 9 & 5 \end{bmatrix}$$

(iii) Explain how the Prewitt filter h_x can be separated as two filters.

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

(iv) In certain computer vision tasks (e.g. Harris corner detection), to calculate the image gradient, Gaussian filtering is applied prior to Prewitt filtering. Explain the motivation for performing Gaussian filtering.

Gaussian filtering is applied to a image would blur an image which removes details and noise. By operating similarly to the mean filter, this filter removes the noise which would affect the performance of the edge detection filters like Prewitt Filter.

b) In certain computer vision tasks (e.g. Harris corner detection), to calculate the image gradient, Gaussian filtering is applied prior to Prewitt filtering. Explain the motivation for performing Gaussian filtering.

- To implement the kernel, how would you design the kernel size K?

$$[-\sigma * k, \sigma * k]$$

- Suppose the Gaussian kernel size is $K \times K$ and the input image size is $N \times N$, evaluate the computational complexity using the big O notation for two implementations respectively: direct 2D Gaussian filtering and separable filtering.
  - Direct 2D Gaussian

$$\text{Multiplications} : K^2N^2$$
$$\text{Summations} : N^2(K^2 - 1)$$
$$O(K^2N^2)$$

  - Separable 2D Gaussian

$$\text{Multiplications} : 2KN^2$$
$$\text{Summations} : N^2(2K - 1)$$
$$O(2KN^2)$$

Question 1B:

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