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IMAGE PROCESSING

Labwork 2: Point Processing, Image Filtering and Noise Removal

Part A. Pen and paper exercises:

Task A1: Given the following image *I*:

$$I = \begin{bmatrix} 104 & 100 & 108 \\ 99 & 106 & 98 \\ 95 & 90 & 85 \end{bmatrix}$$

- Apply the 3x3 averaging filter K_1 to the image *I*:

$$K_1 = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

- Apply the 3x3 weighted averaging filter K_2 to the image *I*:

$$K_2 = \frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

- Compare the two output values and explain which filters gives more importance to the center pixel.

Task A2: Given the following image *I*:

$$I = \begin{bmatrix} 12 & 13 & 14 \\ 15 & 255 & 16 \\ 14 & 13 & 12 \end{bmatrix}$$

- Apply a 3x3 median filter to the image *I* and compute the new center pixel value.

- From the output, explain why the median filter is effective for salt-and-pepper noise.

Task A3: Given the following image *I* and the point detection mask *K*:

$$I = \begin{bmatrix} 10 & 10 & 10 \\ 10 & 50 & 10 \\ 10 & 10 & 10 \end{bmatrix}$$

$$K = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

- Compute the output value at the center pixel.
- Then explain why this mask respond strongly to isolated bright points.

Task A4: Given the following image *J* and the Sobel kernels G_x, G_y

$$J = \begin{bmatrix} 10 & 10 & 10 \\ 20 & 20 & 20 \\ 100 & 100 & 100 \end{bmatrix}$$

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$G = \sqrt{G_x^2 + G_y^2}$$

- Compute G_x, G_y and the gradient magnitude *G*. Based on the values of G_x and G_y, determine whether the main edge in the image *J* in the horizontal or vertical. Explain your answer.

Task A5: Given the following image *J*:

$$J = \begin{bmatrix} 10 & 10 & 10 \\ 10 & 50 & 10 \\ 10 & 10 & 10 \end{bmatrix}$$

- Apply the Laplacian kernel *K* to the image *J*:

$$K = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

- Then compute the sharpened center pixel using:

$$g(x, y) = f(x, y) - \nabla^2 f(x, y)$$

Part B. Python/OpenCV Practice:

- Download one grayscale image from the Internet, or use your own grayscale image.

Task B1: Apply the three smoothing filters: averaging filter, Gaussian filter and median filter to the downloaded grayscale image. For each filter, using three kernel sizes: 3x3, 5x5, 9x9. Then,

- Display the original image and all filtered images.
- Compare the visual differences between the filtered images.
- Explain how the kernel size affects image details and blurring.

Task B2: Create three noisy versions of the grayscale image: image with Gaussian noise; image with salt-and-pepper noise; and image with periodic noise. Then,

- Display the original image and the three noisy images.
- Display the histogram of each original image and its corresponding noisy images.
- Explain on how each type of noise changes the image and its histogram.

Task B3: Apply the three smoothing filters (averaging, Gaussian, median) to each noisy image using the three kernel sizes 3x3, 5x5, 9x9, then complete the following result table:

Noise type	Best filter	Best kernel size	Explanation
Gaussian noise			
Salt-and-pepper noise			
Periodic noise			

Task B4: Apply the Laplacian filtering to the downloaded grayscale image, then:

- Display the original image, the Laplacian image and the sharpened image.
- Compare and explain the results before and after sharpening.

Task B5: Transform the original grayscale image and the periodic noisy image from the spatial domain to the frequency domain using the Fourier transform by doing the following steps:

- Compute the 2D Fourier transform of the original grayscale image.
- Shift the zero-frequency component to the center, then display the magnitude spectrum.
- Compare the Fourier spectrum of the original image and the periodic noisy image.

Task B6: Perform noise removal on the periodic noisy image using frequency-domain filtering by doing the following steps:

- Use the Fourier spectrum of the periodic noisy image.
- Choose a frequency-domain filter taught in the lectures to perform filtering. Explain your choice.
- Perform Inverse Fourier Transform to convert the filtered image from frequency domain back to spatial domain.
- Then display:
    - The periodic noisy image;
    - The Fourier spectrum before filtering;
    - The Fourier spectrum after filtering;
    - The restored image after inverse Fourier transform.