Homework 05
Spatial Filtering using `cv2.filter2D()`

Md. Al-Amin Babu
ID: 2110676134

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Objective

The purpose of this homework is to analyze the effect of spatial filtering on a grayscale image using OpenCV's `cv2.filter2D()` function. The filters are:

- Smoothing (Average) Filter
- Sobel Filter (X and Y)
- Prewitt Filter (X and Y)
- Laplace Filter

Method

A grayscale image was taken as input and resized. Different kernels (Smoothing, Sobel, Prewitt, and Laplace) were defined and applied using OpenCV's `cv2.filter2D()` function. The outputs were compared to observe the effect of each filter.

Code

Click here to view the full Python code on GitHub

Kernels Used

Smoothing (Average)

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

Sobel Filter

Sobel X:

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

Sobel Y:

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

Prewitt Filter

Prewitt X:

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

Prewitt Y:

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

Laplace Filter

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

Observations

- **Smoothing (Average):** Removes noise and produces a blurred image with reduced fine details.
- **Sobel X:** Strong detection of vertical edges.
- **Sobel Y:** Strong detection of horizontal edges.
- **Prewitt X:** Detects vertical edges but with softer transitions compared to Sobel.
- **Prewitt Y:** Detects horizontal edges with smoother intensity changes.
- **Laplace:** Highlights edges in all directions, emphasizing areas of rapid intensity change.

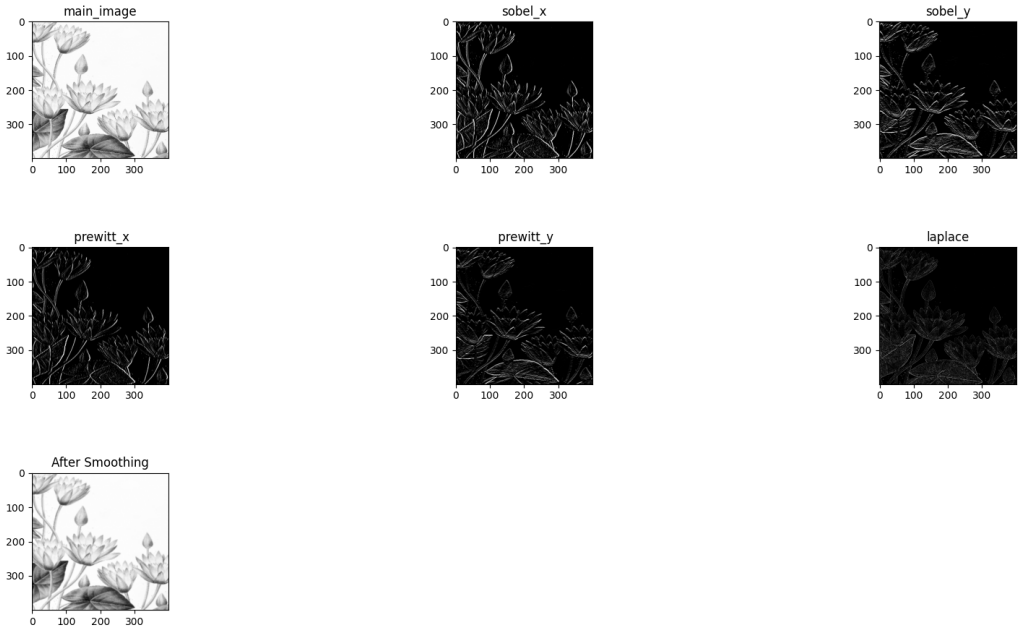

Figure 1: Results after applying Smoothing, Sobel (X, Y), Prewitt (X, Y), and Laplace filters on the grayscale image.

Conclusion

From this experiment, it is observed that different spatial filters serve different purposes in image processing:

- Smoothing reduces noise but sacrifices sharp details.
- Sobel and Prewitt filters are useful for directional edge detection.
- Laplace filter detects edges in all directions simultaneously, making it suitable for overall edge enhancement.

Thus, spatial filtering is an essential tool in feature extraction and image analysis, with the choice of filter depending on the specific application requirements.