

CSC420: Assignment 1

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Problem 1

1. The computational cost for $h * I$ when h is not separable is $O(n^2m^2)$.

This because each pixel in I gets computed for m^2 time, and there are n^2 pixels in total.

2. The computational cost for $h * I$ when h is not separable is $O(m^22n)$.

Problem 2

Canny Edge Detection Steps:

1. Filter the image with derivative of Gaussian in both horizontal and vertical directions.
 - The purpose of this is to smooth the image and remove the noise.
 - To do this, we apply Gaussian filter to convolve with the image.
2. Find the magnitude and direction for the gradients
 - The purpose of this is to find the possible edges
 - To do this, we apply edge detection filters (for example, Sobel) with different directions and convolve with the image.
3. Non-maximum suppression
 - Get rid of the spurious response from edge detection produced by noise.
 - To do this, we only take local maximum or minimum of the edges.
4. Linking and Thresholding
 - The purpose of this is to connect the unlinked edges.
 - To do this, define 2 thresholds low and high. We use the high threshold's results to start the edge curves and use low threshold's results to connect the unlinked edges.

Problem 3

Laplacian of Gaussian filters are symmetrical. It has the shape of 1. We can see that there is a decrease and then an increase going towards the center. This activates the edges because edges are composed of sudden change of pixel intensities.

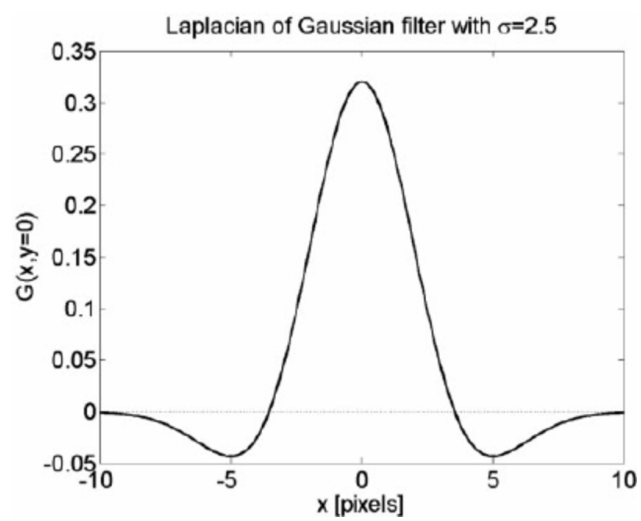


Figure 1: Laplacian of Gaussian with $\sigma = 2.5$

Problem 4

See code implementations in question_4.py.

1. See sample results in ???. The results are the grayscale image correlation and convolution with the sharpening filter

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 0 \end{bmatrix} - \frac{1}{9} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$



Figure 2: Result of my_correlation



Figure 3: Original image



Figure 4: Result of my_convolution

- 2.

Problem 5

See code implementations in question_5.py.

1. Separable Filters allow correlation and convolution operations to be performed at $2K$ operation cost instead of K^2 . This is because separable filters are able to be split into $1D$ horizontal and $1D$ vertical filters. The result of convolving the image with the 2 $1D$ filters is the same as convolving the image with the original separable filter.

This is achieved when when the Singular Value Decomposition has only one non-zero single value.

$$F = U\Sigma V^T = \sum_{i=0}^k \sigma_i u_i v_i^T$$

where $\sqrt{\sigma_1} \mathbf{u}_1$ and $\sqrt{\sigma_1} \mathbf{v}_1$ are the vertical and horizontal filters.

2. The Separable filter is $\frac{1}{16} \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$.

The output for the separable filter is

$$\begin{bmatrix} -0.25 \\ -0.5 \\ -0.25 \end{bmatrix}$$

$$\begin{bmatrix} -0.25 & -0.5 & -0.25 \end{bmatrix}$$

True

The Inseparable filter is $\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$.

The output for the separable filter is

False

Problem 6

See code implementations in question_6.py.

1. The image with noise is as follows



Figure 5: Result of add_rand_correlation



Figure 6: Original image

2. The recovered image is as follows. The chosen filter was the mean filter $\frac{1}{9} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$. This was chosen because averaging the pixels will reduce the effect of the noise and make the noisy pixel resemble the average of its neighbors.



Figure 7: add_rand_correlation



Figure 8: The recovered image



Figure 9: The original image

3. The image with salt and pepper noise is as bellow:



Figure 10: add_salt_and_pepper



Figure 11: The original image

4. Trying to recover salt and pepper noisy image does not yield a very good result: the output image is still noisy. The chosen filter is the median filter. This is achieved with OpenCV's *medianBlur* method. This works because salt and pepper noise is very extreme. The pixel has signal of either 1 or 0 (white or black). This affects the mean vastly, where as it does not really affect the median of the nearby pixels.

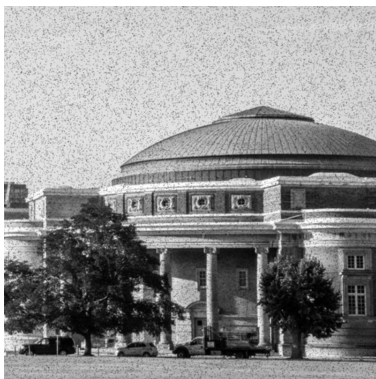


Figure 12: mean filter



Figure 13: median filter



Figure 14: The original image