دانشگاه بوعلی سینا

Computer vision

Exercise 2

By:

Zahra Sharafian

Professor Hassan Khotanlou

Fall 2023

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Question 1

a)

Noise reduction is a process aimed at reducing or removing unwanted random variations or distortions in an image, known as noise. It can be caused by various factors such as sensor limitations, transmission interference, or environmental conditions.
The goal of noise reduction techniques is to enhance the visual quality of an image by suppressing or minimizing the impact of noise while preserving important image details. By reducing the noise, the image becomes cleaner, smoother, and more visually appealing.
There are different approaches to noise reduction. In this question we are using blurring filter.

The blurring process involves applying a blurring filter to the image. The filter modifies each pixel's value based on its surrounding pixels, causing adjacent pixel values to be blended together. This results in a loss of high-frequency information, such as fine details and edges, and creates a softer and more diffused appearance.

it's important to note that there is a trade-off between blurring and noise reduction. Increasing the size of the mask leads to a more noticeable blurring effect. This is because larger masks consider a greater number of neighboring pixels, resulting in a more intense smoothing effect. In this example, if we compare a 3x3 mask, a 5x5 mask, and a 7x7 mask, the 7x7 mask would indeed produce the highest level of blurring. This is because it considers a larger neighborhood of pixels when calculating the average value, leading to a stronger smoothing effect and more pronounced blurring in the resulting image.

In this example, the 3x3 and 5x5 masks performed better in noise reduction and preserved some level of image details. However, the 7x7 filter resulted in significant blurring of the image, causing a loss of fine details.

b)

A Laplacian mask is a mathematical filter used in image processing for edge detection and image sharpening. It is commonly used to enhance the high-frequency components of an image and highlight edges or details.
For image sharpening, the Laplacian mask is applied to the blurred or smoothed image to enhance the high-frequency components and emphasize edges. By subtracting the blurred image from the sharpened image, the details and edges become more pronounced, resulting in a sharpened appearance.

In this example Laplacian sharpening operation can help reduce the blurring effect. By enhancing the high-frequency components in the image, it brought back some of the lost details and increased the overall sharpness. The sharpened image is clearer and more defined compared to the original blurred image.

The sharpening operation does not directly address the original noise present in the image. In fact, it can potentially amplify the noise due to the enhancement of high-frequency components. So, when the original image has noise, the sharpened image might exhibit more noticeable noise artifacts.

c)

Repeated sharpening of an image may not necessarily improve image interpretation and can potentially introduce undesirable artifacts. While sharpening techniques can enhance the perceived sharpness and details in an image, excessive sharpening can lead to the amplification of noise and unnatural-looking edges.

in this example Repeated sharpening resulted in an over-sharpened appearance, causing the image to appear unrealistic.

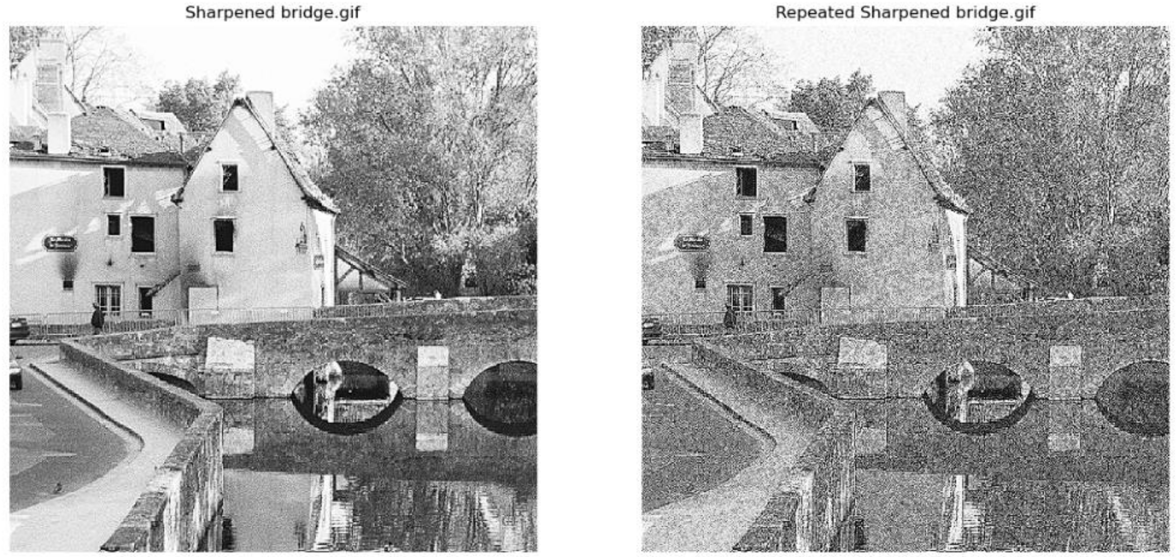

Figure 1 sharpened image and repeated sharpened image

It's important to strike a balance when applying sharpening techniques, considering the specific image characteristics, noise levels, and the intended purpose of the image interpretation.

Question 2

a)

Median filtering and averaging filtering are two commonly used techniques for noise reduction in image processing.

Median Filtering: Median filtering is a nonlinear filtering technique that replaces each pixel in an image with the median value of its neighboring pixels. It is particularly effective in reducing impulse or salt-and-pepper noise, where random pixels are corrupted with either very high or very low intensity values.

Averaging Filtering: Averaging filtering, also known as mean filtering, is a linear filtering technique that replaces each pixel in an image with the average value of its neighboring pixels. It is commonly used to reduce Gaussian noise, which is a type of random noise characterized by a bell-shaped distribution.

b)

The 'brain.png' image contains salt-and-pepper noise. Salt-and-pepper noise is a type of impulse noise where random pixels are affected by either very high or very low intensity values, resembling white and black specks in the image.

In this question, we applied three kernels of sizes 3x3, 5x5, and 7x7 for noise reduction using Averaging Filtering method. The image with 7x7 kernel size had less noise, but we also lost some image details.

In conclusion Averaging Filtering method is not suitable for removing salt-and-pepper noise. since salt-and-pepper noise affects individual pixels rather than entire regions, the Averaging Filtering method tends to produce blurred or smudged results when attempting to remove this type of noise. It may not effectively restore the original details and can result in loss of important image information.

c)

In this question, we applied three kernels of sizes 3x3, 5x5, and 7x7 for noise reduction using Median Filtering. The image with the 7x7 kernel showed better results compared to the other kernels. Additionally, it did not significantly lose a lot of details but noticeably reduced the noise.

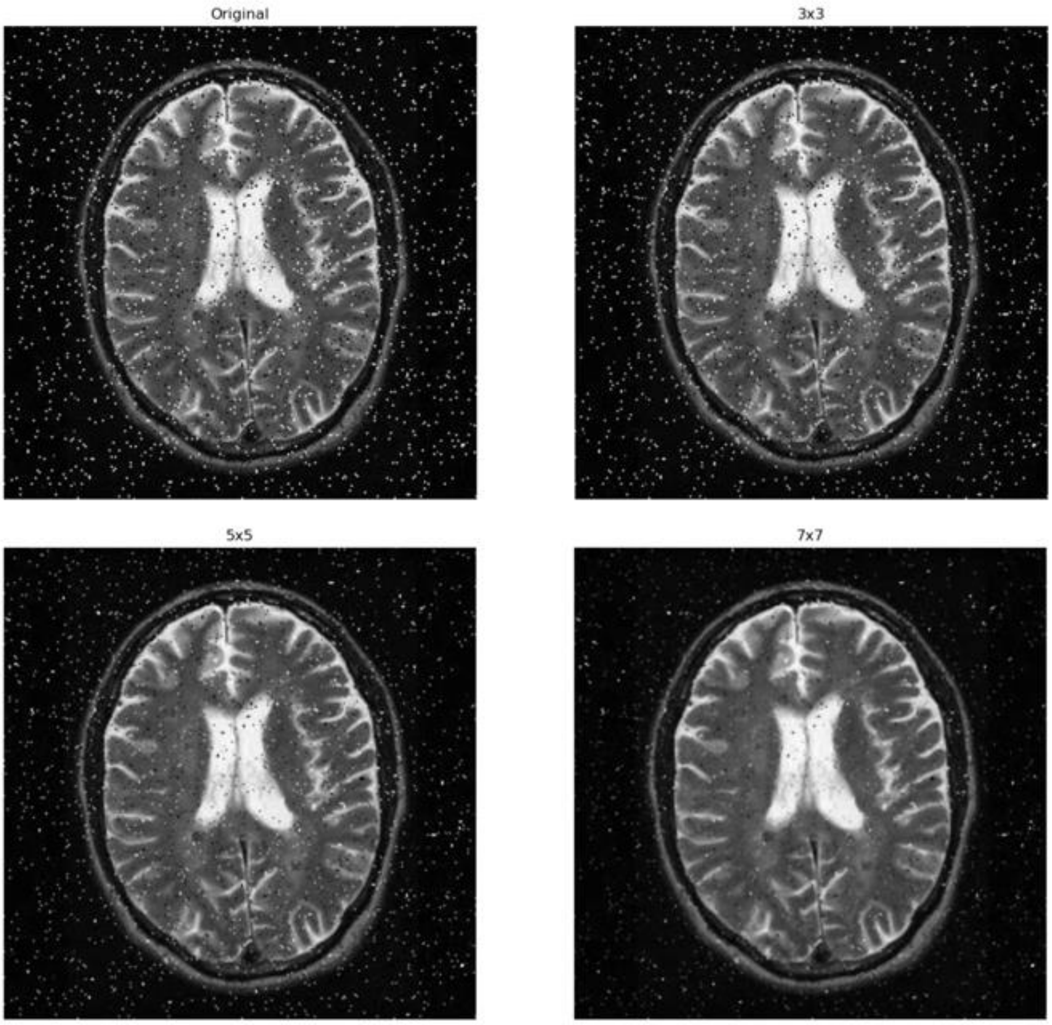

Figure 2 noise reduction using median filtering

In conclusion median filtering is highly suitable for salt-and-pepper noise reduction. It excels in removing outliers, preserves image details, and effectively eliminates impulse noise without significant blurring.

d)

1. Median Filtering:

   Advantages:

   - Effective Noise Removal: Median filtering is particularly effective in reducing impulse noise, such as salt and pepper noise. It replaces noisy pixels with the median value of their neighboring pixels, effectively eliminating outliers and reducing the impact of noise on the image.
   - Preservation of Image Details: Median filtering preserves image details and edges better than averaging filters. It does not blur the image significantly, making it suitable when maintaining image sharpness and preserving fine details is important.

   Disadvantages:

   - Limited Effectiveness for Other Types of Noise: While median filtering excels in reducing impulse noise, it may not be as effective for other types of noise, such as Gaussian noise. It is specifically designed for handling salt and pepper noise, and its performance may vary when applied to different noise types.
   - Smoothing of Textures: Median filtering can cause some smoothing of textures and fine-grained details in an image. This blurring effect may be undesirable in certain applications where preserving fine details is crucial.

2. Averaging Filtering:

   Advantages:

   - Simple Implementation: Averaging filtering, such as mean filtering, is straightforward to implement and computationally efficient. It involves calculating the average value of neighboring pixels, making it a simple and accessible technique for noise reduction.
   - Smoothing Effect: Averaging filters can effectively reduce random noise, including Gaussian noise, by smoothing out intensity variations. They are suitable for scenarios where reducing overall noise levels and achieving a more uniform appearance are desired.

   Disadvantages:

   - Blurring of Image Details: Averaging filters can blur image details, including edges and textures, especially with larger kernel sizes. This blurring effect may result in a loss of sharpness and fine details in the image.

- Limited Effectiveness for Impulse Noise: Averaging filters are not as effective in handling impulse noise, such as salt and pepper noise. While they can reduce noise to some extent, they may not completely eliminate outliers and may not be the optimal choice for impulse noise reduction.

In summary, Median Filtering is advantageous for reducing impulse noise, preserving image details, and offering flexibility in kernel size. Averaging Filtering, on the other hand, is simple to implement, suitable for reducing random noise, and computationally efficient.

Question 3

a)

Sobel edge detection and Laplacian edge detection are methods used to find edges in images. The choice between them depends on what we want to achieve.
Sobel edge detection is suitable for getting accurate edge information and dealing with noisy images. It calculates the strength and direction of edges in different directions, giving us clear and precise edge locations.
Laplacian edge detection, on the other hand, is better for finding fine details and transitions in an image. It can detect smaller structures and both sharp edges and smooth transitions between colors.
In simple terms, Sobel is good for getting clear and accurate edges, while Laplacian is better for finding small details and transitions. The choice depends on what we want to focus on in our image.

b)

The code loads the 'Edge.jpg' image and applies the Sobel edge detection separately along the x and y dimensions using sobel from scipy.ndimage.

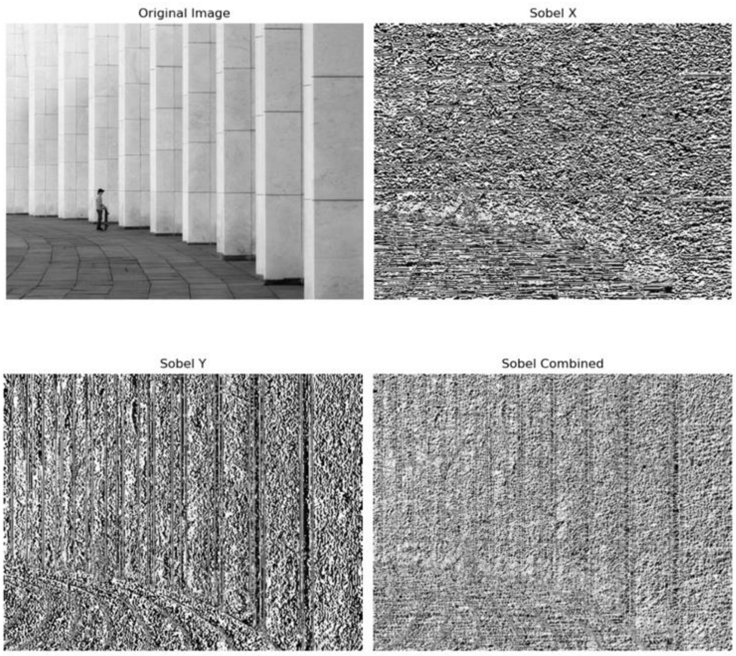

Figure 3 Sobel edge detector

c)

The code loads the 'Edge.jpg' image and applies the Laplacian edge detector using laplace from scipy.ndimage. It then calculates the magnitude of the Laplacian by taking its absolute value.

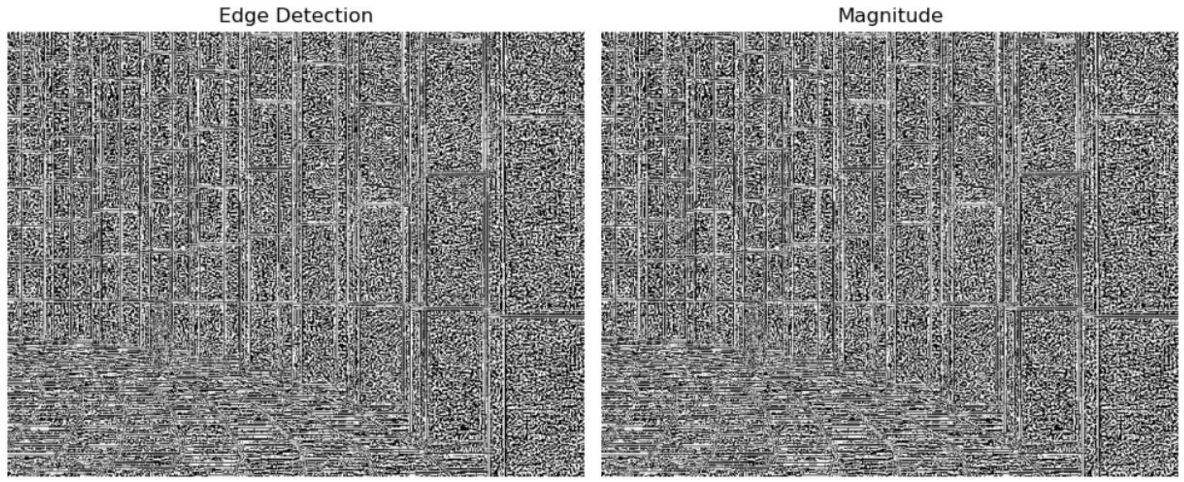

Figure 4 Edge Detection and Magnitude

d)

To determine which method works better, we need to consider the characteristics of the 'Edge.jpg' image and the specific requirements of the task. Here are some observations to consider:

- If the image contains sharp edges and smooth transitions, the Laplacian operator may capture them effectively.
- If the image has a significant amount of noise, the Sobel operator's noise reduction capabilities can be advantageous.
- If precise edge localization and accurate gradient estimation are important, the Sobel operator may be more suitable.
- If the task requires detecting both positive and negative edges, the Laplacian operator can provide this information.

Ultimately, the choice between Laplacian and Sobel operators depends on the specific features of the image and the desired edge detection requirements. The Laplacian operator provides better results for this image.

Question 4

a)

The Robert-Cross operator is a simple method used to detect edges in an image. It works by comparing the intensity differences between neighboring pixels.
To apply the Robert-Cross operator, we use two small 2x2 matrices. These matrices represent the gradients in the horizontal (Gx) and vertical (Gy) directions.
We slide these matrices over the image, calculating the differences between pixel intensities in the corresponding positions. These differences indicate how quickly the intensity changes in each direction.
By combining the horizontal and vertical gradient values, we get the overall gradient magnitude. Higher values represent stronger edges, while lower values indicate smoother areas.

b)

The Prewitt operator is an edge detection method that helps identify edges in an image. It works by calculating the gradient of the image intensity using two 3x3 kernels.
To apply the Prewitt operator, we convolve these kernels with the image. This involves placing the kernels on top of the image and performing element-wise multiplication and summation. This process is repeated for each pixel in the image.
The resulting values from the Gx operation indicate the rate of intensity change in the horizontal direction, while the values from the Gy operation represent the rate of intensity change in the vertical direction.
To obtain the overall gradient magnitude, we calculate the square root of the sum of squares of the Gx and Gy values.
The resulting gradient magnitude values represent the strength of the edges in the image. Higher values indicate stronger edges, while lower values indicate smoother areas.

c)

the original image, the results of the Robert-Cross operator, and the results of the Prewitt operator are displayed using 'plot_figure' function.

d)

To apply a high-boost filter to the images obtained after the Roberts cross-gradient and Prewitt operators, we can enhance the edges by boosting their intensities while leaving the rest of the image unchanged.

e)

The Roberts cross-gradient and Prewitt operators are both edge detection techniques used to identify and enhance edges in an image.

In the results obtained from the Roberts cross-gradient operator, we observe that the edges appear to be thinner and more pronounced compared to the results obtained from the Prewitt operator. This is because the Roberts operator uses a simple 2x2 kernel to calculate gradients, resulting in a less complex and localized edge detection.
On the other hand, the Prewitt operator utilizes larger 3x3 kernels in both the x and y directions, capturing more information about the gradient changes in the image. As a result, the edges detected by the Prewitt operator tend to be wider and smoother compared to the Roberts operator.

Question 5

a)

In the given image, the bones of the skeleton are not clearly visible, and the image appears slightly blurry. To enhance this image we first load the "skeleton.png" image and convert it to grayscale. Then, we apply a Gaussian blur to the grayscale image to reduce noise and smooth out the edges.

Next, we use the Laplacian filter to detect the edges in the blurred image. To sharpen the image, we add the Laplacian-filtered image to the original grayscale image. This enhances the high-frequency components and restores the sharpness. Finally, we convert the sharpened image back to the BGR color space and display both the original and sharpened images.

The resulting image reveals more details and increases the visibility of the bones.

b)

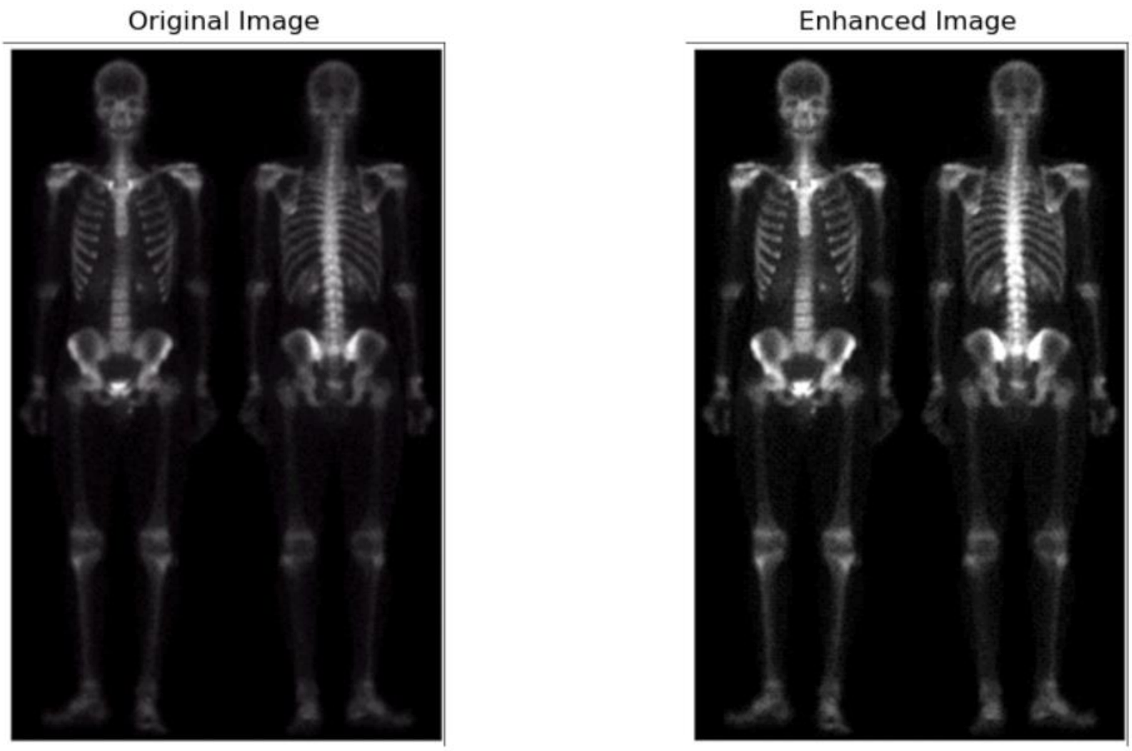

Figure 5 original image and enhanced image