Digital Image Processing
Assignment-4 Report

Question 1: Image Denoising

Summary

Image denoising is a critical preprocessing step in image analysis to remove noise while preserving important features. In this assignment, we utilized the bilateral filter and Gaussian smoothing to denoise a noisy image. The parameters for each method were fine-tuned to achieve optimal results. Additionally, the Laplace filter was applied to the original image, the denoised images (from the bilateral and Gaussian filters), to observe how edge information was preserved or lost.

Results

The following images shows the results of implementation for denoising and edge enhancement using the Laplace filter. The comparison highlights the differences in how the bilateral and Gaussian filters process the noisy image.

Figure 1: Results of image denoising. (a) Original noisy image patch, (b) Bilateral filtered image patch, (c) Gaussian smoothed image patch.

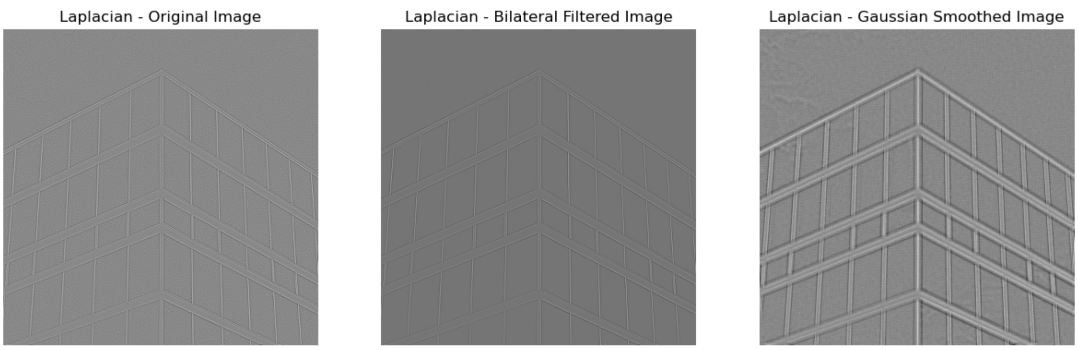

Figure 2: Results of Laplacian filtering. (a) Laplacian on original image, (b) Laplacian on bilateral filtered image, (c) Laplacian on Gaussian smoothed image.

Inferences

1. **Preservation of Edges:** The bilateral filter effectively denoised the image while preserving sharp edges. This is because the bilateral filter considers both spatial closeness and intensity similarity, enabling it to smooth regions of similar intensity while retaining edge information.

2. **Gaussian Smoothing:** The Gaussian filter, while reducing noise, blurred the edges significantly, causing edge details to be lost. This was evident in the output, where edges became thicker and less defined.

3. **Application of the Laplace Filter:** When the Laplace filter was applied:

   - The bilateral filtered image produced sharper and well-defined edges, demonstrating the superior edge-preserving capabilities of the bilateral filter.
   - The Gaussian smoothed image resulted in thicker and less distinct edges, reflecting the loss of fine details due to the blurring effect of the Gaussian filter.

4. **Why Bilateral Filtering is Preferred:** The bilateral filter is highly effective for denoising tasks where edge preservation is crucial. Its ability to smooth noise without compromising edge sharpness makes it ideal for applications such as medical imaging, object detection, and computer vision tasks requiring detailed structural integrity.

Question 2: Hough Transform

Hough Transform

2.a Implementation of Hough Transform

We implemented the Hough Transform for circle detection, assuming the radius of the circles is known. Below are the results for different scenarios analyzed during the assignment.

Scenario 1: Basic Circle Detection

Synthetic Image: We first tested the Hough Transform on a synthetic image with known circle parameters. The results are shown in Figure 3.

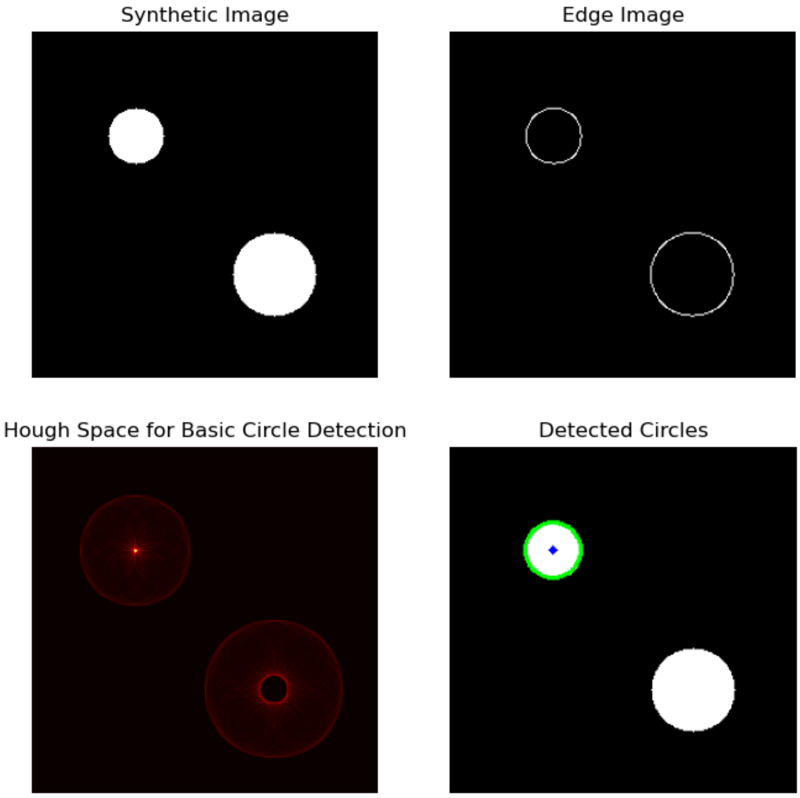

Figure 3: Hough Transform detecting a circle of given radius in a synthetic image.

We can see that the Hough Transform correctly detects the circle of the given radius.

Real Image: We used an image of coins to analyze the detection for various input radii. The results for radii 25, 30, and 19 are shown in Figure 4.

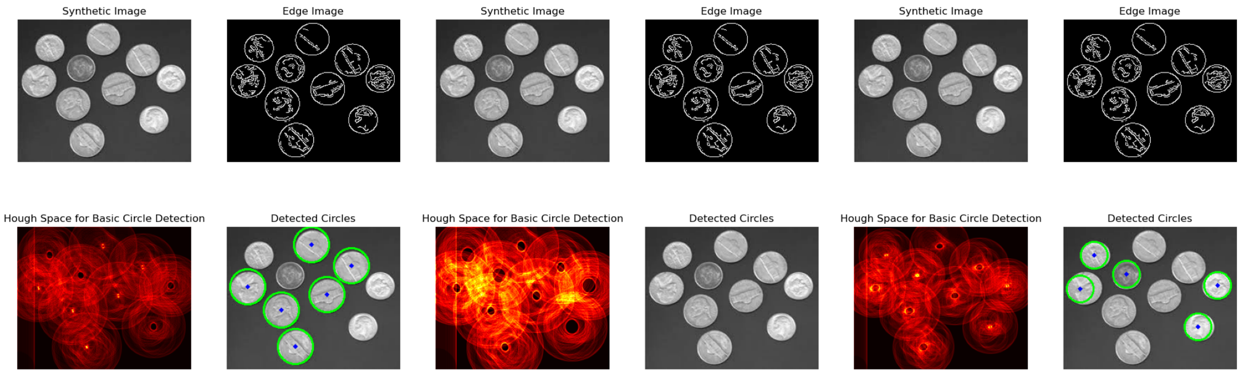

Figure 4: Circle detection in a real image of coins for radii 25 (left), 30 (center), and 19 (right).

From the results, we observe: - For radius 25 and 19, the circles are correctly detected. - For radius 30, no circles are detected. This indicates that the coin image contains circles with radii 25 and 19.

Scenario 2: Presence of Noise

We created synthetic images with circles and added Gaussian noise. Results for two levels of noise are shown in Figure 5.

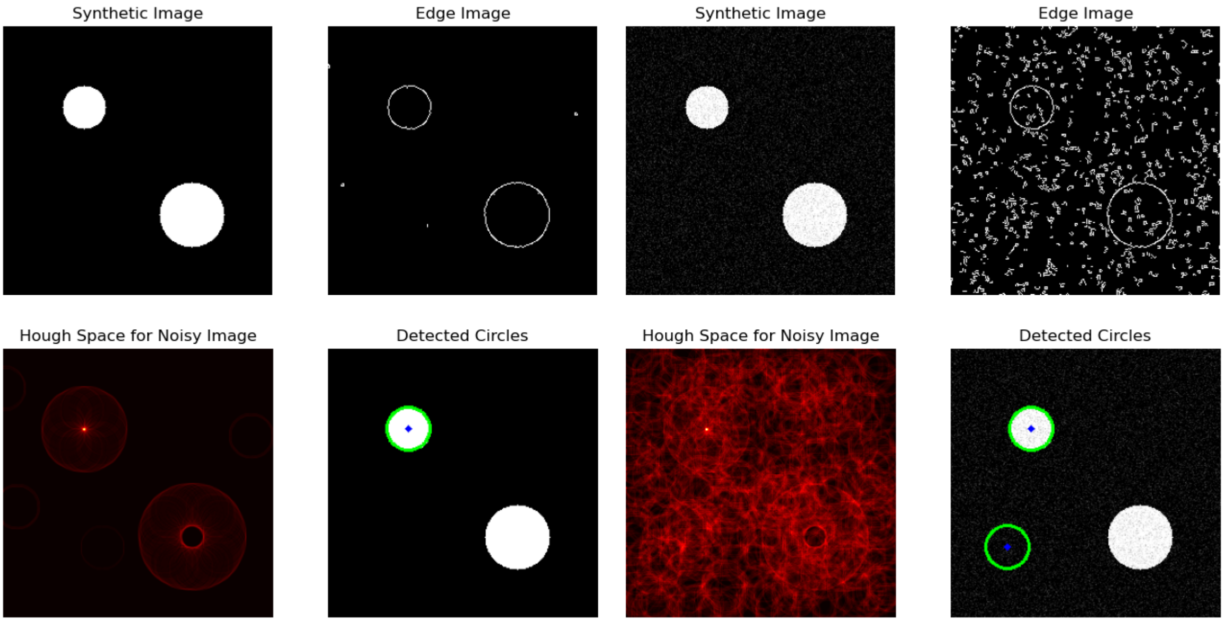

Figure 5: Effect of noise on Hough Transform: Low noise (left) and high noise (right).

Observations: - For low noise, the circle of the desired radius is accurately detected. - For high noise, false circles may be detected as noise interferes with the detection process.

Scenario 3: Giving Different Radius

We tested the Hough Transform by providing an incorrect radius. The results are shown in Figure 6.

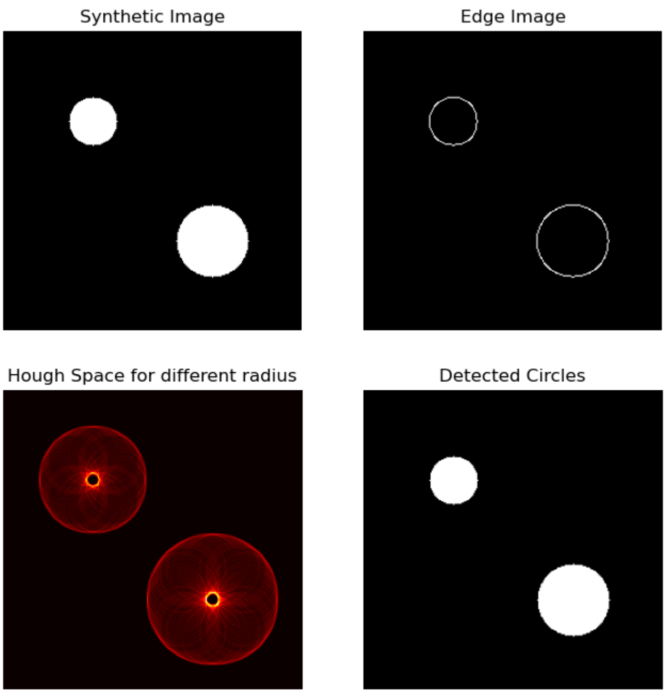

Figure 6: Hough Transform with an incorrect radius input.

Observation: When a radius different from the actual circle radius is provided, the Hough Transform fails to detect circles, as expected.

Scenario 4: Increasing Number of Circles, Including Partial Occlusion

We created two synthetic images with an increasing number of circles, including partially occluded circles. The results are shown in Figure 7.

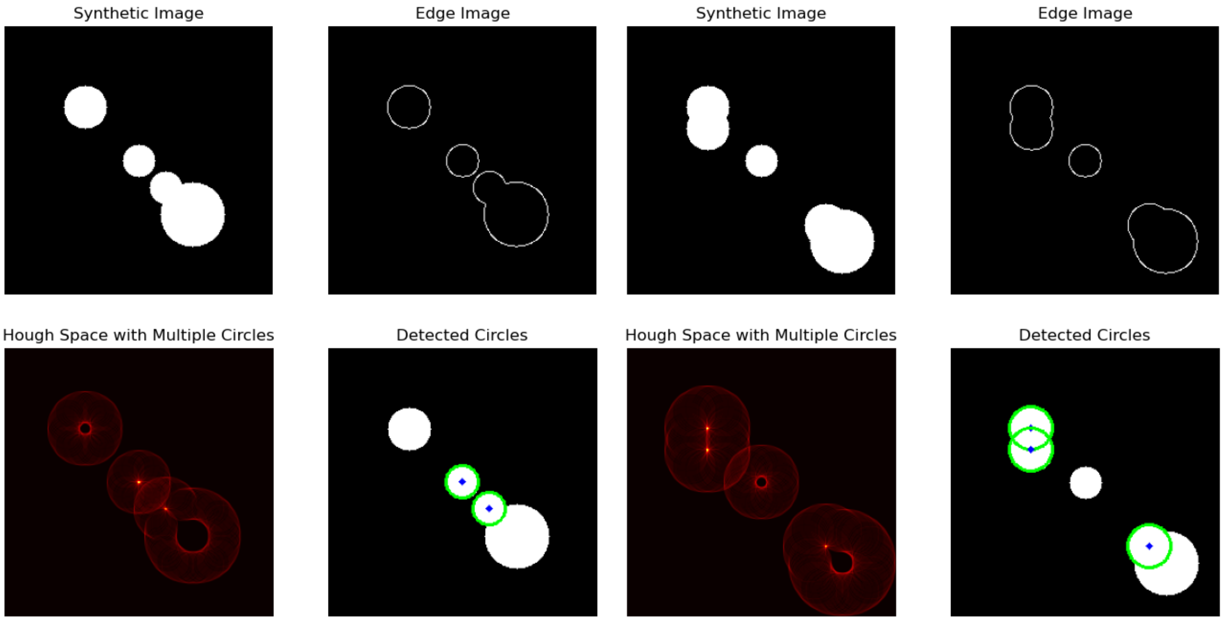

Figure 7: Effect of occlusion on Hough Transform: Partial occlusion (left) and significant occlusion (right).

Observations: - For partial occlusion, the Hough Transform successfully detects the circles. - However, significant occlusion (e.g., complete overlap of two circles) can negatively affect the detection accuracy.

2.b Edge Detection Analysis

In this subsection, we experimented with two different gradient-based edge detectors, Sobel and Prewitt filters, as the first step in the Hough Transform process. The results for detecting circles using these edge detectors are shown below:

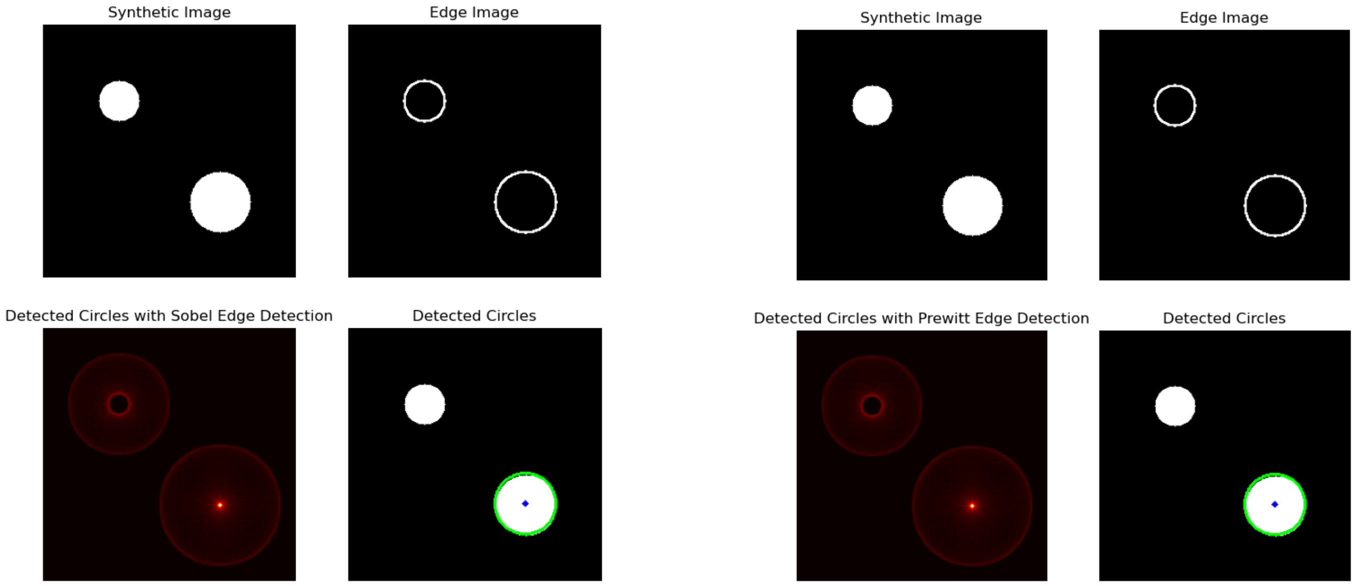

Figure 8: Results of circle detection using Sobel (left) and Prewitt (right) edge detectors.

Observations: Both Sobel and Prewitt edge detectors successfully identified the edges required for circle detection. The subsequent application of the Hough Transform correctly detected the circles, indicating that these gradient-based methods are effective for this task.