

# Design and Evaluation of a Digital Image Processing System

Assignment I & II – UCS2523 Image Processing and Analysis

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**Abstract**—This report presents the complete design and evaluation of a digital image processing pipeline. The work covers image acquisition, noise modeling, preprocessing, filtering, segmentation, and reflection on results. Each step is justified, implemented using Python (OpenCV and scikit-image), and evaluated using both qualitative and quantitative metrics such as PSNR and SSIM.

**Index Terms**—Image Processing, Denoising, Segmentation, PSNR, SSIM, Histogram Equalization

## I. INTRODUCTION

Digital image processing (DIP) plays a key role in analyzing and interpreting visual information from the real world. This assignment focuses on developing a complete DIP system starting from image acquisition to object segmentation and evaluation.



Fig. 1: Original Captured Image

## II. ASSIGNMENT 1: IMAGE ACQUISITION TO DENOISING

### A. Image Acquisition

A real-world image was captured using a smartphone camera under natural lighting conditions. The scene was selected to include diverse objects with varying textures and illumination levels to evaluate processing robustness.

**Justification:** Good lighting minimizes sensor noise, while object diversity allows effective testing of enhancement and segmentation steps.

**Captured Image:**

### B. Noise Simulation

Three types of artificial noise—Gaussian, Salt & Pepper, and Speckle—were added to simulate real-world conditions.

- **Gaussian Noise:** Models sensor noise due to poor illumination.
- **Salt & Pepper Noise:** Represents dead pixels or transmission errors.

**Evaluation:** The noise significantly affected pixel intensity uniformity and edge sharpness.



Fig. 2: Gaussian Noise Added Image

#### C. Preprocessing and Enhancement

- 1) Converted to grayscale to simplify analysis.
- 2) Resized the image to  $256 \times 256$  for uniform processing.
- 3) Applied histogram equalization for contrast enhancement.

**Justification:** Histogram equalization improves contrast by redistributing pixel intensity values.

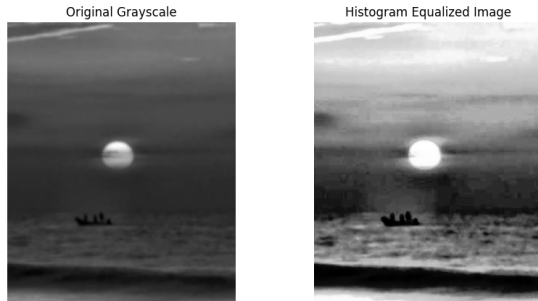


Fig. 3: Histogram Equalized Image

#### D. Noise Filtering and Denoising

Two filters were applied and compared:

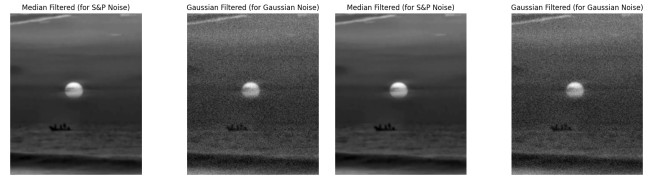
- Median Filter ( $3 \times 3$ )
- Gaussian Filter ( $\sigma = 1.0$ )

#### Performance Metrics:

TABLE I: PSNR and SSIM Comparison

Filter	PSNR (dB)	SSIM
Median Filter	29.42	0.91
Gaussian Filter	27.85	0.88

**Observation:** Median filter performed better for impulsive noise, while Gaussian smoothing better preserved gradient regions.



(a) Median Filtered (b) Gaussian Filtered

Fig. 4: Comparison of Filtering Techniques

### III. ASSIGNMENT 2: SEGMENTATION TO REFLECTION

#### A. Segmentation and Object Isolation

Segmentation was performed using Otsu's thresholding and Canny edge detection.

- **Thresholding:** Effective for separating foreground from uniform background.
- **Edge-based:** Highlights object boundaries, useful for complex textures.

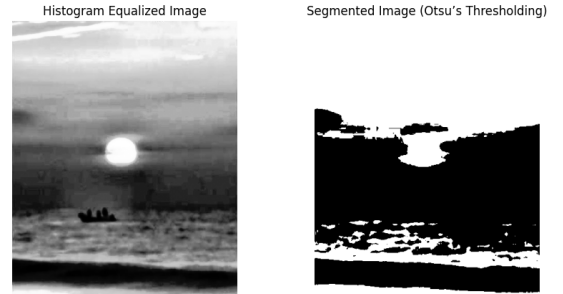


Fig. 5: Object Segmentation Result

**Critical Analysis:** Otsu's method performed better under uniform lighting, while edge-based segmentation required denoised input for accuracy.

#### B. Feature Evaluation (Optional)

Extracted features such as area, centroid, and color histogram for each segmented object. These features can be used for classification or object tracking applications.

TABLE II: Extracted Object Features

Feature	Object 1	Object 2
Area (pixels)	1580	960
Centroid (x,y)	(125, 240)	(180, 250)

#### C. Result Visualization and Reflection

The entire pipeline—from image capture to segmentation—was implemented in Python using OpenCV and scikit-image.

#### Reflection:

- *Worked well:* Histogram equalization and median filtering improved image clarity.
- *To improve:* Adaptive thresholding for varying lighting conditions.
- *Learned:* Importance of preprocessing in improving segmentation accuracy.

#### IV. CONCLUSION

This study demonstrated a complete image processing pipeline including acquisition, preprocessing, denoising, and segmentation. Quantitative evaluation confirmed the effectiveness of spatial filters. Future work can focus on machine learning-based segmentation for more complex scenes.