Image Processing

Project Overview

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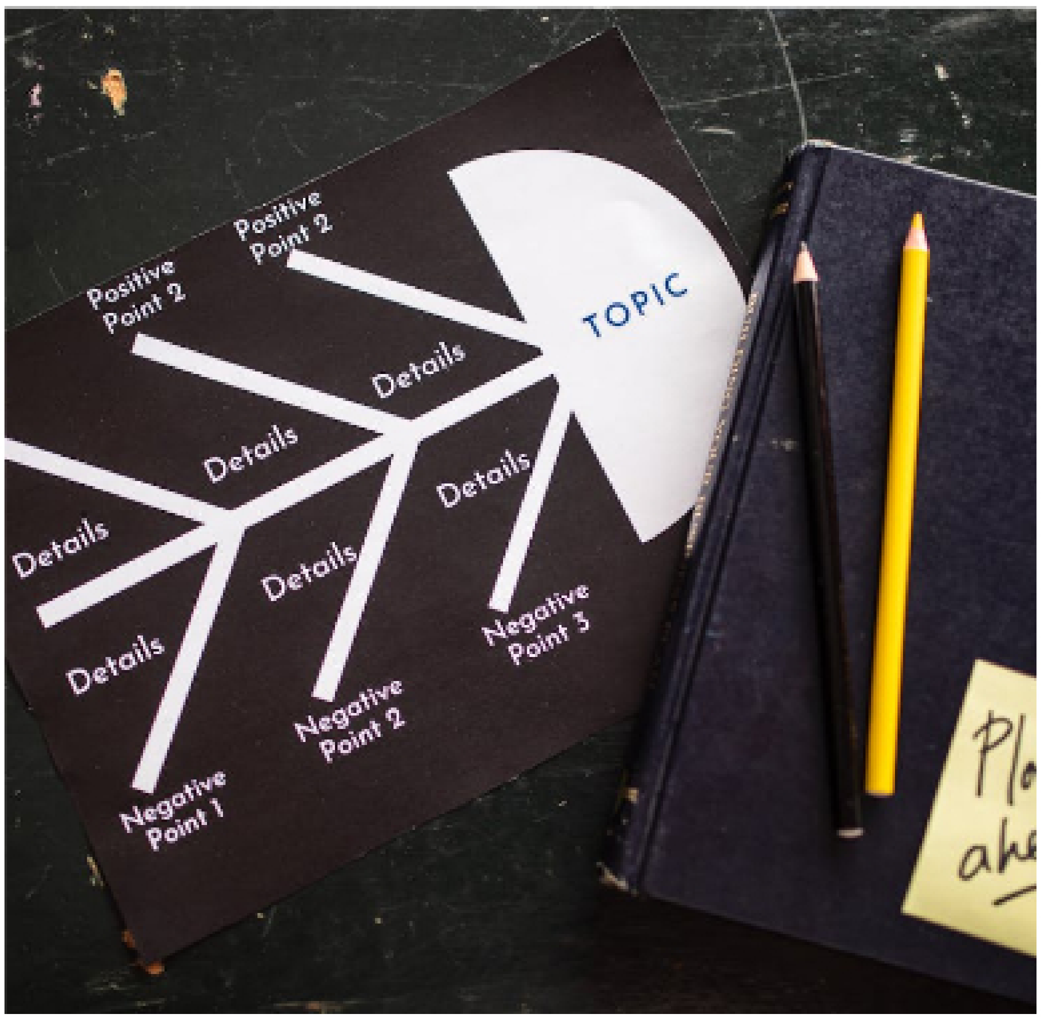
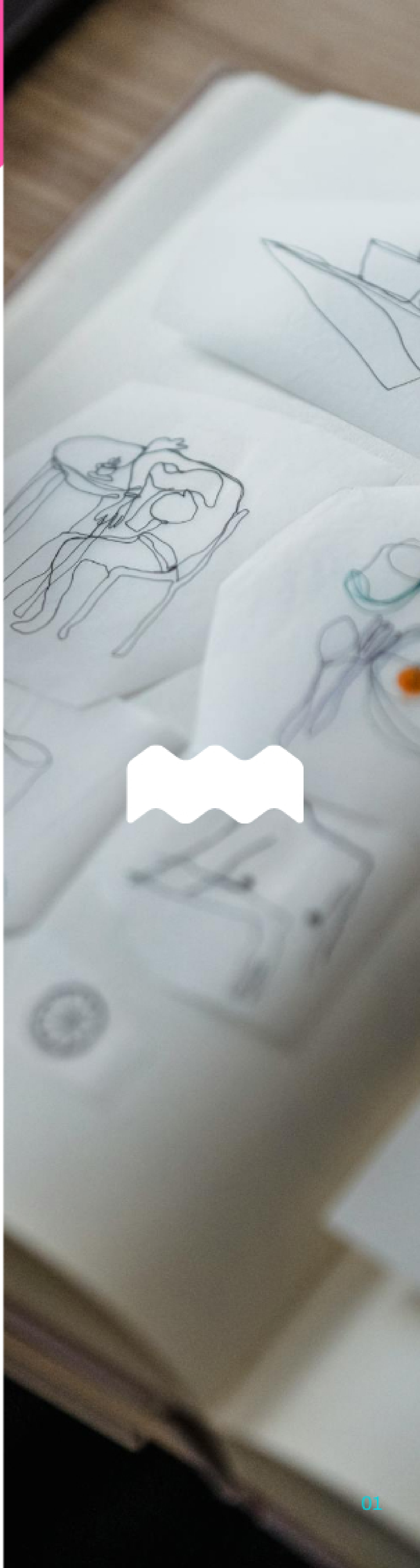


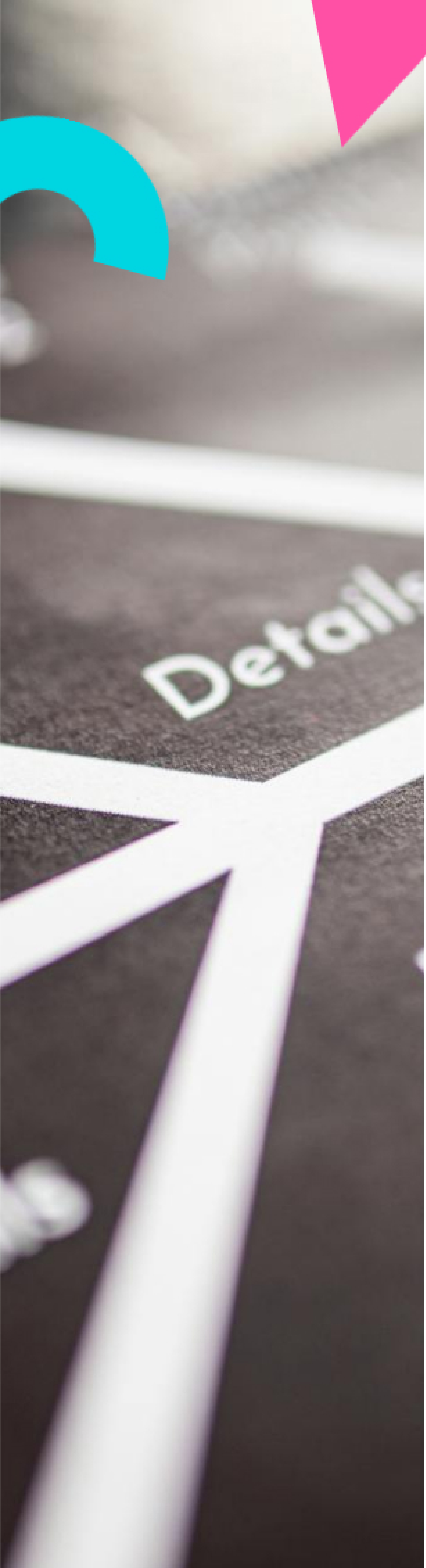
Abstract

Image noise removal is a critical step in image processing to enhance the quality of images corrupted by various types of noise.

This report investigates and implements multiple filtering techniques, including Median Filter, Average mean Filter, Arithmetic Mean Filter, Geometric Mean Filter, Harmonic Mean Filter, Contraharmonic Mean Filter, Adaptive Median Filter, Max and Min Filters, Midpoint Filter, and Alpha Trimmed Mean Filter.

The primary objective is to analyze their efficacy in reducing noise and improving visual quality and it depends on which filter user want to apply on the image to remove its noise in a good way .





Problem Definition

Images are frequently corrupted by noise during acquisition, transmission, or storage. Noise can degrade image quality and make subsequent image analysis or interpretation challenging.

Different types of noise, salt-and-pepper, and speckle noise, require different approaches to mitigate their effects. Noise removal filters are essential tools to restore image quality and ensure robust performance in downstream applications like object recognition and segmentation.

Methodology

Image Processing Techniques

1- Median Filter

Purpose:

The median filter is effective in removing salt-and-pepper noise (impulse noise) from images. It replaces each pixel value with the median of the neighboring pixel values, which helps to eliminate outlier pixel values that represent noise.

Implementation:

For each pixel in the image, its 3x3 neighborhood is extracted from the padded image. The median value of the neighborhood is computed. This median value is assigned to the corresponding pixel in the output (filtered) image.

2- Arithmetic Mean Filter

Purpose:

The arithmetic mean filter smoothens the image by replacing each pixel value with the average of its neighboring pixel values. This filter is effective against Gaussian noise but may blur image edges.

Implementation:

For each pixel, the mean of the pixel values in its 3x3 neighborhood is calculated. The computed mean value is assigned to the output image.

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3- Geometric Mean Filter

Purpose:

The geometric mean filter reduces multiplicative noise and preserves image details better than the arithmetic mean filter.

Implementation:

The pixel values in the neighborhood are converted to a suitable numerical type (e.g., double) for accurate computation. The logarithm of each pixel value in the neighborhood is computed. The mean of these logarithms is calculated. The exponential of this mean gives the geometric mean. This geometric mean value is assigned to the output image.

4- Harmonic Mean Filter

Purpose:

The harmonic mean filter is effective for images with Gaussian noise and is especially good at reducing the effect of large pixel values (salt noise) while preserving low pixel values (pepper noise).

Implementation:

The reciprocal of each pixel value in the neighborhood is computed. The mean of these reciprocals is calculated. The reciprocal of this mean gives the harmonic mean. This value is used in the output image.

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5- Contraharmonic Mean Filter

Purpose:

The contraharmonic mean filter removes either salt noise or pepper noise, depending on the value of the order parameter Q.

For $Q > 0$, it reduces the effect of salt noise.

For $Q < 0$, it reduces the effect of pepper noise.

Implementation:

With Q set to -1, the filter targets pepper noise.

The numerator is computed as the sum of the pixel values raised to the power of $Q + 1$.

The denominator is computed as the sum of the pixel values raised to the power of Q.

The ratio of the numerator to the denominator gives the contraharmonic mean, which is assigned to the output image.

6- Midpoint Filter

Purpose:

The midpoint filter is useful for reducing uniform noise and works by averaging the maximum and minimum values within the neighborhood.

Implementation:

Within each neighborhood, the minimum and maximum pixel values are identified.

The midpoint is calculated by averaging these two values.

This midpoint value is assigned to the corresponding pixel in the output image.

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7-Max Filter

Purpose:
Removes pepper noise by replacing each pixel with the maximum value within its neighborhood, effectively eliminating low-intensity noise points.

Implementation:
For each neighborhood, the maximum pixel value is determined and assigned to the output image.

8- Min Filter

Purpose:
Removes salt noise by replacing each pixel with the minimum value within its neighborhood, effectively eliminating high-intensity noise points.

Implementation:
For each neighborhood, the minimum pixel value is determined and assigned to the output image.

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9- Average mean filter

Purpose:

After applying the various noise removal filters, a 9x9 mean filter is used to further smooth the image, reducing residual noise and minor variations.

Implementation:

A 9x9 averaging filter is created where each element has a value of 1/81 (since there are 81 elements in a 9x9 kernel).

The image is padded appropriately to handle the borders during convolution.

Convolution is performed manually by sliding the filter over the image and computing the sum of the element-wise multiplication at each position.

The resulting smoothed image is then generated.

10- Adaptive Median Filter

Purpose:

The adaptive median filter dynamically adjusts the size of the neighborhood used during filtering, making it effective for images with varying noise densities of salt-and-pepper noise.

Implementation:

Starting with an initial kernel size (e.g., 3x3), the filter examines the median value within the neighborhood.

If the median satisfies certain conditions regarding the minimum and maximum values in the neighborhood, the filter proceeds to decide whether to replace the current pixel with the median or keep it unchanged.

If the conditions are not met, the kernel size is increased (up to a maximum size) and the process is repeated.

This adaptive approach allows the filter to preserve image details while effectively removing noise.

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11- Alpha-Trimmed Mean Filter

Purpose:

The alpha-trimmed mean filter is a compromise between the mean and median filters. It is effective for images corrupted by mixed noise (both Gaussian and impulse noise).

Implementation:

The pixel values in the neighborhood are sorted.
A specified number (alpha) of the highest and lowest values are trimmed from the sorted list.
The mean of the remaining pixel values is computed and assigned to the output image.

12- Displaying the Results

Purpose:

To visually assess and compare the effectiveness of each filtering technique, the original and filtered images are displayed.

Implementation:

The original and all filtered images are displayed in a single figure window using subplots.
Each subplot is titled appropriately to indicate the filtering technique applied.
This arrangement facilitates side-by-side comparison of the results.

Conclusion

By implementing and analyzing various spatial domain filters in MATLAB, this study demonstrates the strengths and limitations of each technique in noise reduction for grayscale images. The median and adaptive median filters are particularly effective for impulse noise without significant loss of image detail. Mean-based filters, while useful against Gaussian noise, can smooth out important features and should be used judiciously.

The choice of filter depends on the type and level of noise present in the image and the importance of preserving edges and fine details. In practical applications, a combination of filters or adaptive techniques may be necessary to achieve optimal results.

The 9x9 mean filter used for smoothing underscores the trade-off between noise reduction and detail preservation. While it can effectively reduce residual noise, excessive smoothing can blur critical features.

Through manual implementation of these filters in MATLAB, a deeper understanding of their mechanisms and effects on images is achieved, providing valuable insights for image processing and analysis tasks.