Effectiveness of Filtering Methods for Denoising Salt and Pepper Noise

1 Introduction

Salt and pepper noise introduces random black and white pixels into an image. Various filtering techniques are available to mitigate this noise, but each has distinct strengths and weaknesses. In this document, we discuss the effectiveness of **Median**, **Gaussian**, **Average**, **Mixed** (Median + Gaussian), and **Bilateral** filters, based on the Peak Signal-to-Noise Ratio (PSNR) values obtained from the denoising process.

2 Filtering Techniques

2.1 Median Filter

The **Median filter** is a non-linear filtering technique that replaces each pixel's value with the median value of its surrounding pixels. It is particularly effective for removing **salt and pepper noise** because it preserves edges while removing outliers.

2.2 Gaussian Filter

The **Gaussian filter** is a linear smoothing filter that averages pixel values using a Gaussian kernel. While it is effective for reducing **random noise**, it struggles with salt and pepper noise due to its smoothing nature, which blurs sharp features.

2.3 Average Filter

The **Average filter** (mean filter) replaces each pixel with the mean of its surrounding pixels. It is simple, but it can result in significant blurring, especially around edges, making it less effective for removing salt and pepper noise.

2.4 Mixed Filter (Median + Gaussian)

The **Mixed filter** combines the strengths of both the Median and Gaussian filters. The Median filter removes the salt and pepper noise, while the Gaussian

filter further smooths the image and reduces any small-scale noise left behind.

2.5 Bilateral Filter

The **Bilateral filter** is an edge-preserving and noise-reducing filter that smooths images while maintaining sharp edges. It combines two important properties:

1. **Spatial Proximity**: Pixels that are close to the center pixel influence the smoothing more.
2. **Photometric Similarity**: Pixels with similar intensity values to the center pixel are given higher weight.

This makes bilateral filtering highly effective for removing noise while preserving edges, which is particularly useful for images with **salt and pepper noise**.

3 Performance Comparison

The table below presents the PSNR values for each filter across varying noise densities (30%, 50%, 70%, and 90%) for the three test images.

Noise Level	Filter	House Image	Livingroom Image	Mandrill Image
5*30%	Median	39.40	33.11	33.14
	Gaussian	28.51	28.52	28.50
	Average	28.92	28.45	28.44
	Mixed	37.77	32.20	32.22
	Bilateral	30.83	29.87	29.88
5*50%	Median	36.84	32.26	32.25
	Gaussian	28.16	28.18	28.18
	Average	28.33	28.19	28.18
	Mixed	33.62	31.04	31.01
	Bilateral	29.11	29.21	29.88
5*70%	Median	34.69	31.46	31.48
	Gaussian	28.04	28.05	28.05
	Average	28.11	28.06	28.04
	Mixed	30.83	29.78	29.80
	Bilateral	28.25	28.73	29.88
5*90%	Median	32.95	30.73	30.73
	Gaussian	27.98	27.97	27.96
	Average	28.01	27.98	27.97
	Mixed	29.26	28.90	28.91
	Bilateral	27.82	28.39	29.88

Table 1: PSNR Values for Different Filters at Varying Noise Levels (30%, 50%, 70%, 90%) for House, Livingroom, and Mandrill Images.

4 Conclusion

For salt and pepper noise, the **Median filter** remains the most effective, achieving the highest PSNR values across all noise levels. The **Mixed filtering** approach provides a balanced solution, combining robust noise removal with smoother results. The **Bilateral filter**, while slightly less effective in terms of PSNR, excels at preserving edges and sharp details. The **Gaussian** and **Average filters**, while useful for other types of noise, are not as effective for salt and pepper noise, as indicated by their relatively lower PSNR values.

5 Imagies

Figure 1: House

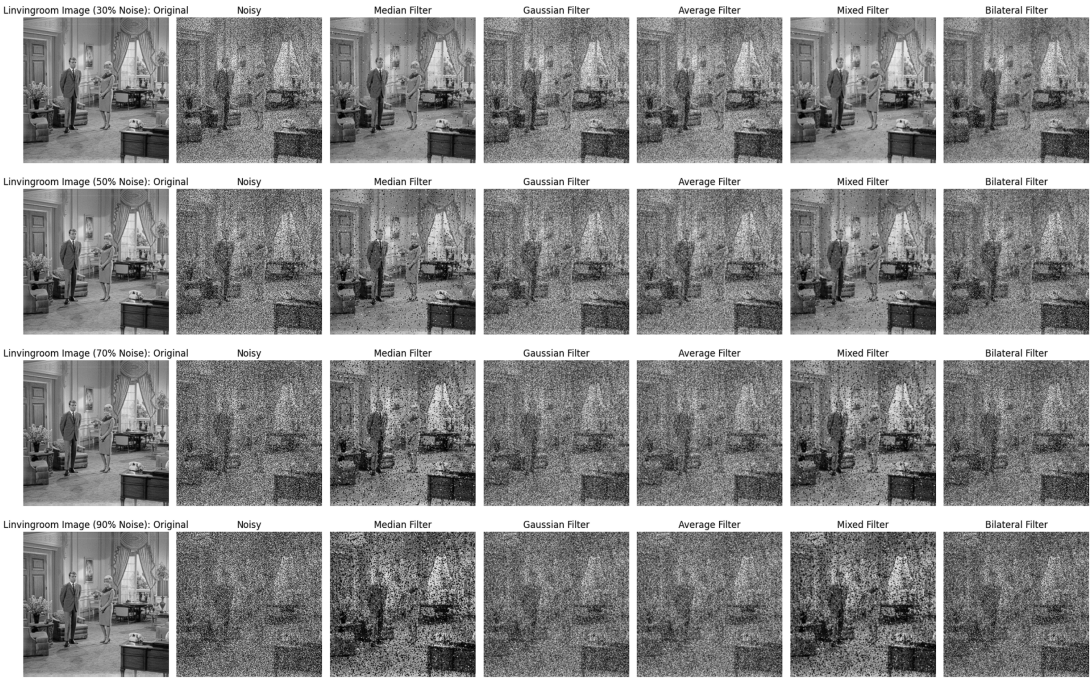

Figure 2: Livingroom

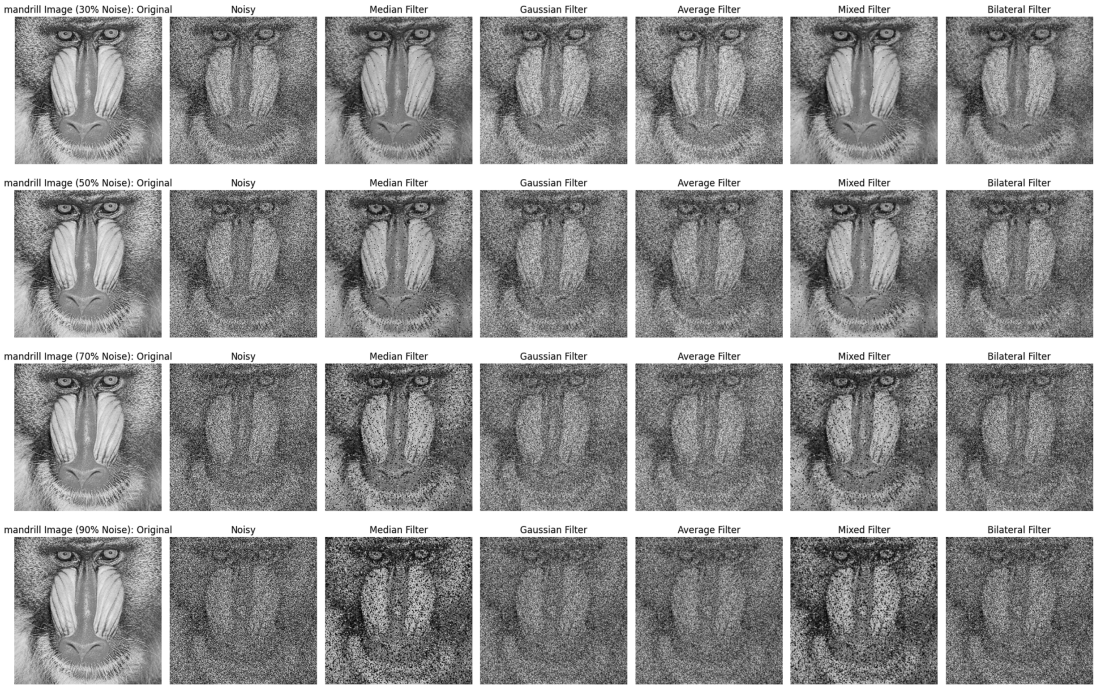

Figure 3: Mandrill