Image Denoising using Bilateral Filtering

Aim:

The probability of performing any task with null interference from noise is zero. Presence of noise leads to many disadvantages, so eliminating the noise plays a very crucial part in real world applications. The removal of noise in images and reconstructing the original image is known as Image denoising.

1. Our aim is to analyse Image denoising using bilateral filtering by varying its spatial and range parameters.
2. And compare its performance with other filters like median(non-linear) and mean filter(linear) using the psnr values and time complexity analysis.

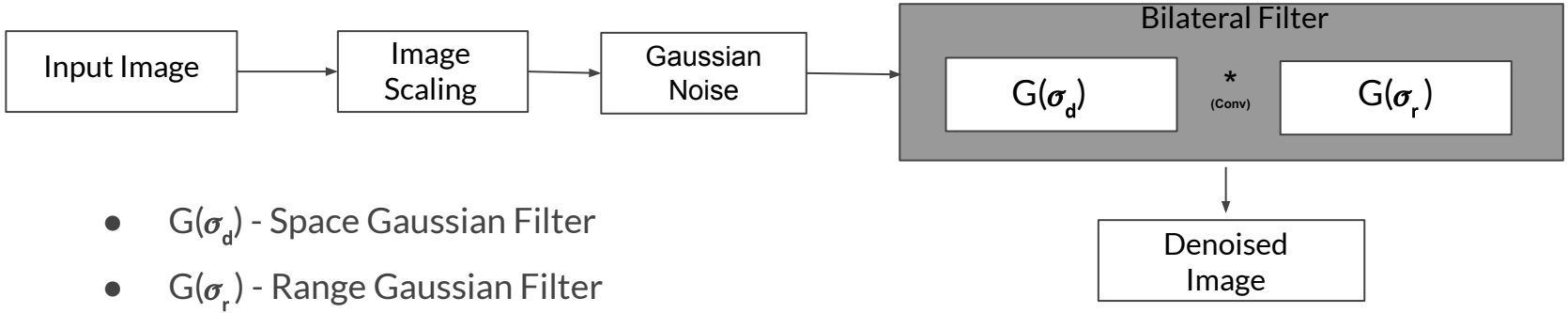
Setup parameters:

Input Image	Peppers.png
Input Type	RGB(color)
Gaussian Noise	0.1(Noise Density)
Impulsive Noise	0.1(Noise Density)
Mixed Noise	0.1 of Gaussian and Impulsive Noise

Fig.1

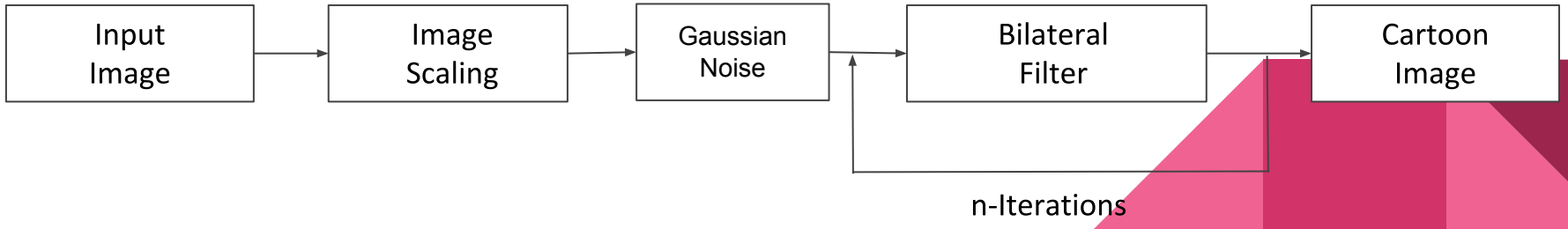
Block Diagrams:

Bilateral Filtering Analysis

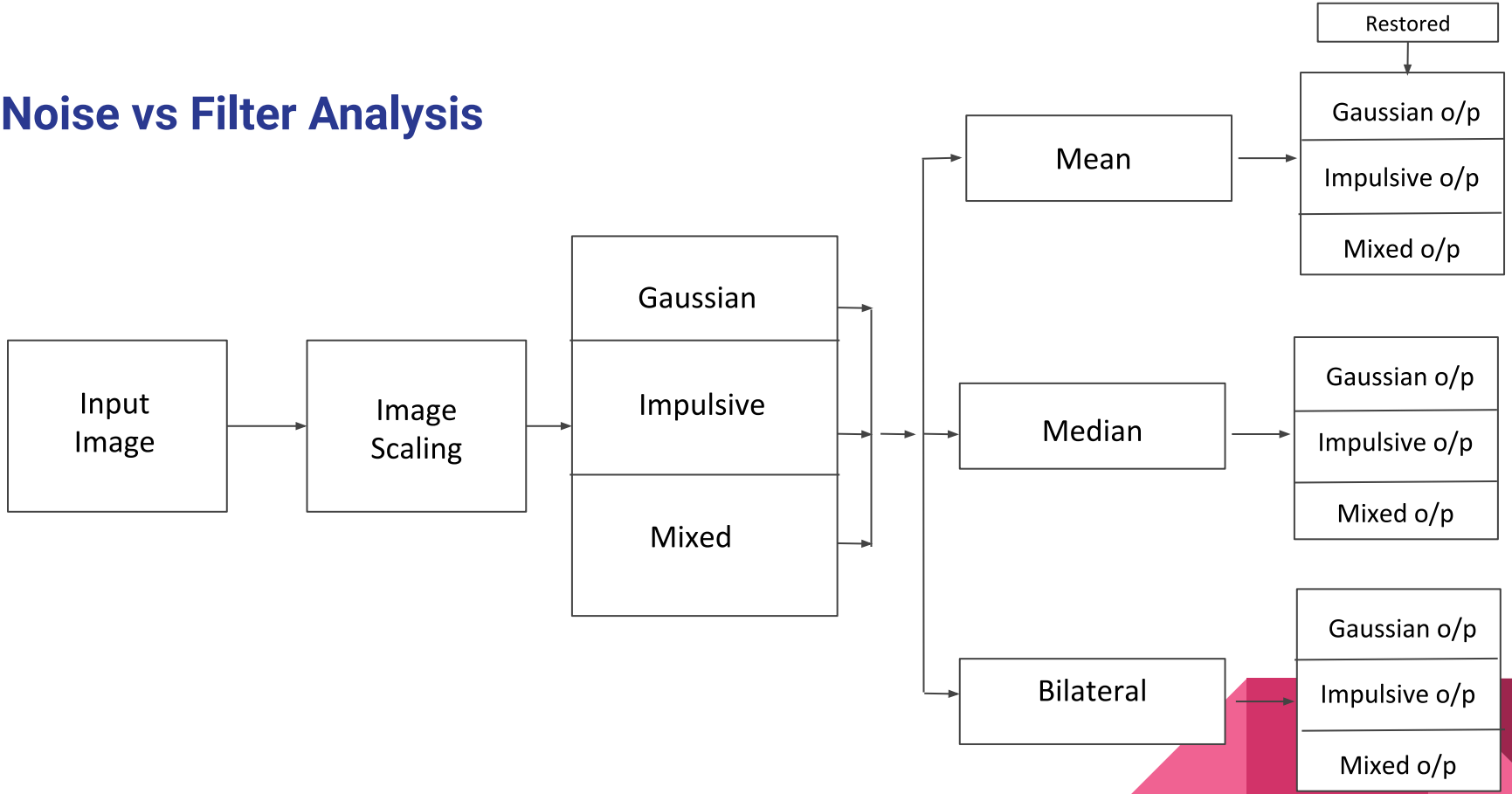


- $G(\sigma_d)$ - Space Gaussian Filter
- $G(\sigma_r)$ - Range Gaussian Filter

For Cartoon Image



Noise vs Filter Analysis



Observations:

Bilateral Filter analysis

1. This is the Gaussian noise affected original image.
2. This image is denoised using bilateral filter for different values of σ_r and σ_d .
3. Increasing the spatial parameters σ_d has a limited effect unless the range parameter σ_r is also increased. Although a large σ_r also produces smooth outputs,it tends to blur the edge

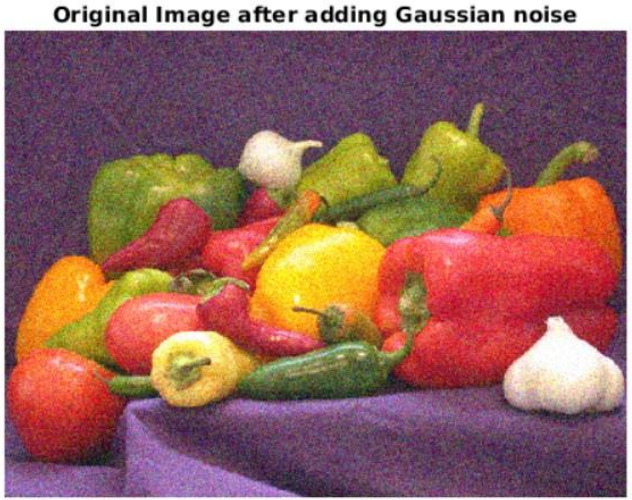


Fig.2

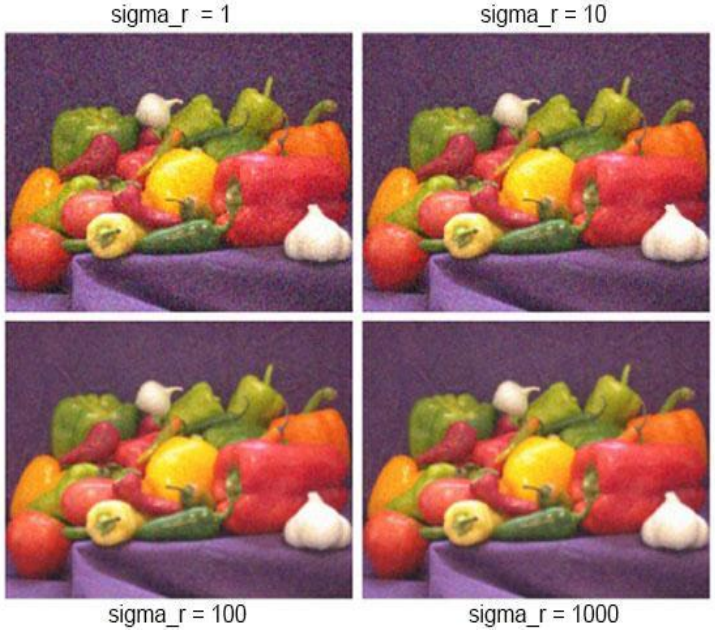

sigma_r = 1
sigma_r = 10
sigma_r = 100
sigma_r = 1000

Fig.3

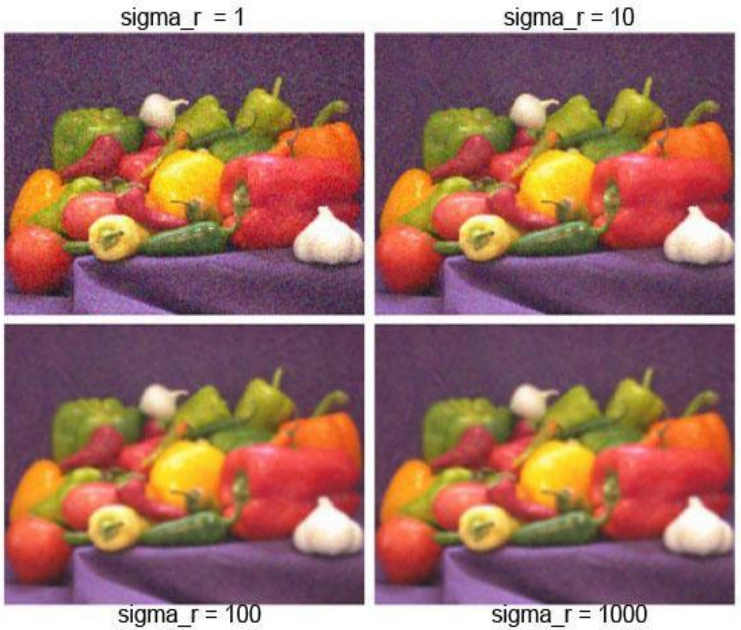

sigma_r = 1
sigma_r = 10
sigma_r = 100
sigma_r = 1000

Fig.4

1. From Fig.3, Fig.4, Fig.5 we can observe the changes in the reconstructed or denoised images.
2. Increase in σ_d resulted in increase of the amount of blurring of the output.
3. σ_r plays a key role in denoising and its range is limited to [0,100] because for $\sigma_r \geq 100$ there is no change in the output for any value of σ_d.
4. Since the image is not efficiently reconstructed, we use some other modified techniques like joint bilateral filtering, fuzzy bilateral filtering, adaptive bilateral filtering, guided filtering etc.

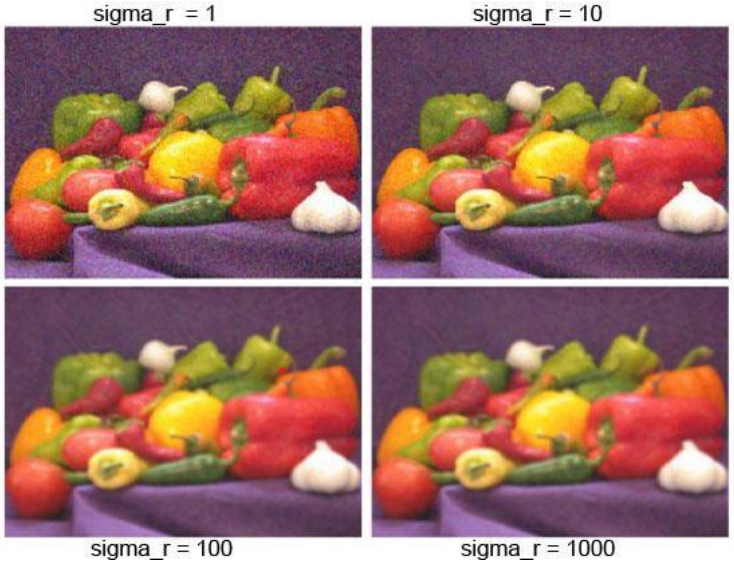


Fig.5

1. This bar plot gives the visualisation of the quality of the reconstructed images.
2. The best denoised image from the bar plot is for $\sigma_r \geq 100$.
3. The spatial parameter helps in smoothing the output without affecting the quality of the image and range parameter preserve edges and removes the introduced noise in the input image.

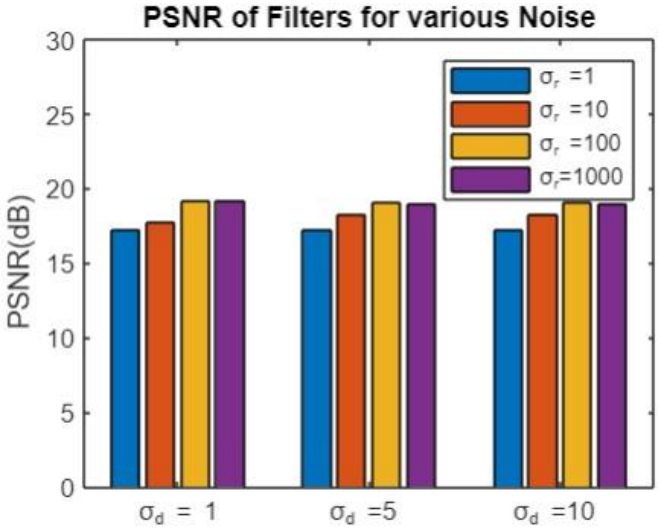


Fig.6

- The bilateral filter in its direct form can introduce several types of image artifacts:
- **Limitations:**

  i) **Staircase effect** – intensity of plateaus that lead to images appearing like cartoons.

  ii) **Gradient reversal** – introduction of false edges in the image.

- The cartoon effect is achieved by applying the bilateral filter iteratively.
- The resultant output is shown as in the Fig.7. It shows how the image is changing for each number of iterations.

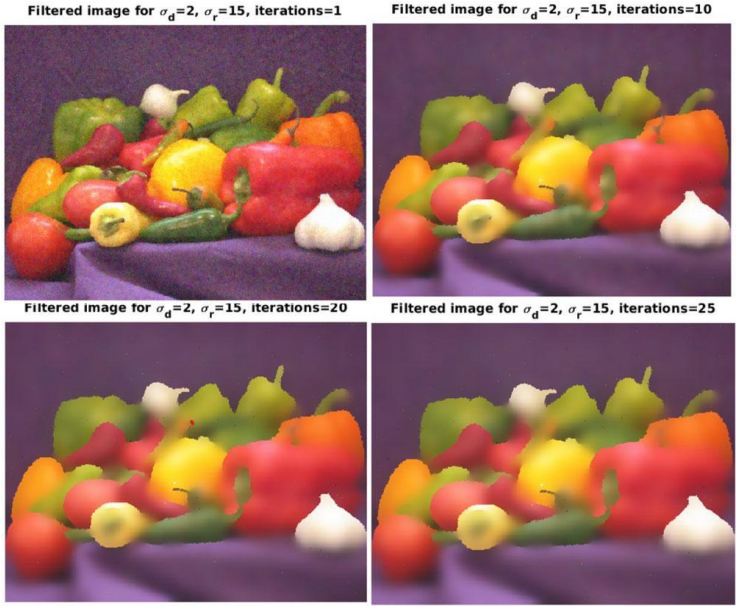


Fig.7

1. The PSNR value metrics shows the deviation(quality) of the cartoon image. As the iterations increased the PSNR value in decreased as shown in the plot Fig.8.
2. Iterating preserves the strong edges such as the borders (Fig.7) while removing the weaker details which results the output appearing like a cartoon image.

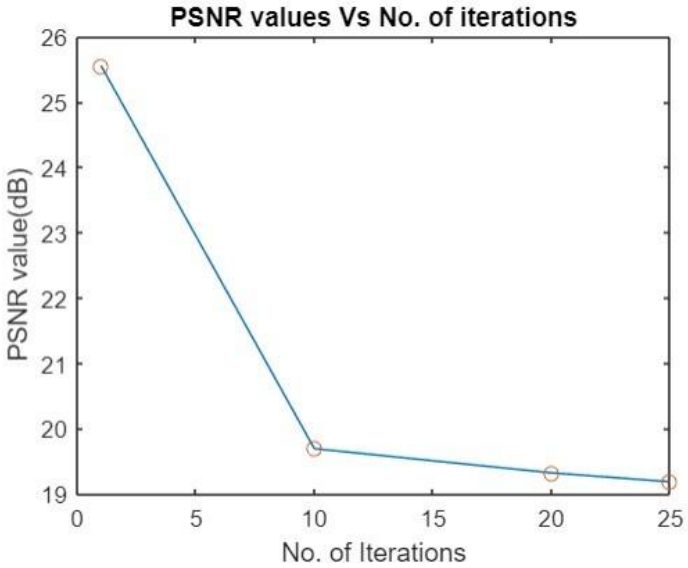


Fig.8

Noise vs Filter Analysis

1. As shown in the block diagram each noise affected image is passed through three filters and the output variations are observed.
2. From Fig.9 ,the first sub image is gaussian affected original image followed by the respective filters denoised image.
3. The linear filter example mean filter works very well towards gaussian noise and the non linear filter, median filter is one of simple and the most powerful filter known also works very well.
4. In Fig.10 mean filter ruined the edges of an image by blurring it to remove the noise, median filter removes only the noise without disturbing the edges which makes it the best filter to remove salt-pepper noise.

Fig.9

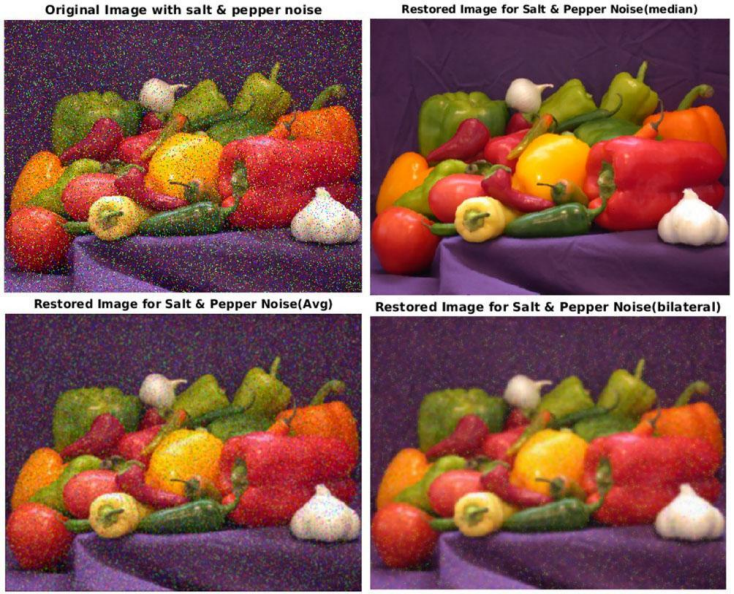

Original Image with salt & pepper noise
Restored Image for Salt & Pepper Noise(median)
Restored Image for Salt & Pepper Noise(Avg)
Restored Image for Salt & Pepper Noise(bilateral)

Fig.10

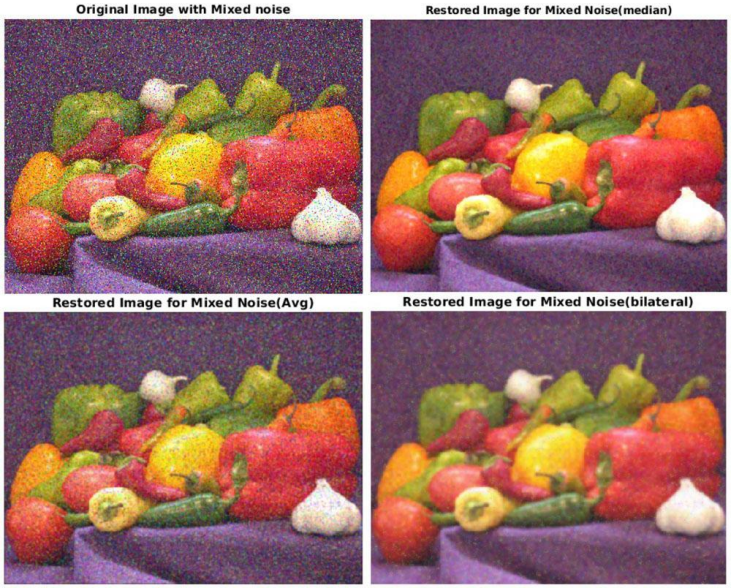

Original Image with Mixed noise
Restored Image for Mixed Noise(median)
Restored Image for Mixed Noise(Avg)
Restored Image for Mixed Noise(bilateral)

Fig.11

1. The bilateral filter is an application of the short time kernel for an edge preserving selective smoothing mechanism.To increase the quality of the denoised image,modifications are made to the bilateral filtering (SBF, JBF, FBF, MBF).

2. But the limitations of bilateral filter helps in the editing softwares(Adobe photoshop, GIMP) as surface blur tool, cartoon modifications etc.

3. Fig. 12 shows the PSNR values(quality of the image) of the denoised outputs.

4. Note that we have taken the bilateral filter parameters as $\sigma_d = 2, \sigma_r = 100$. So the quality results of bilateral filtering in the results(Fig.12) may vary if we change the parameters.

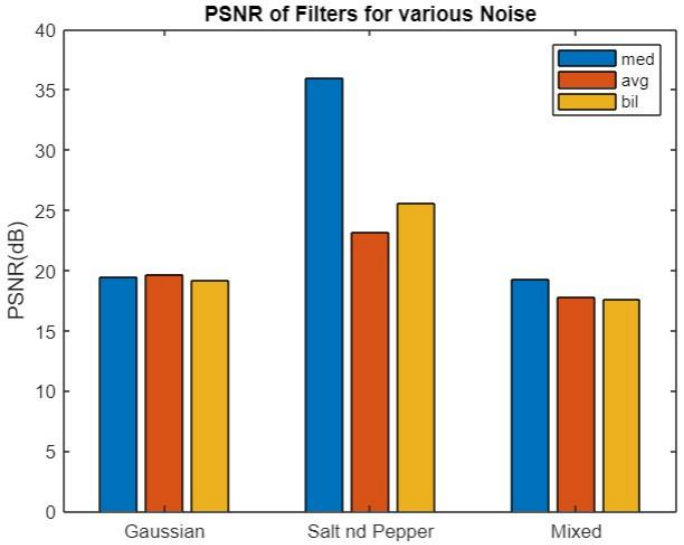


Fig.12

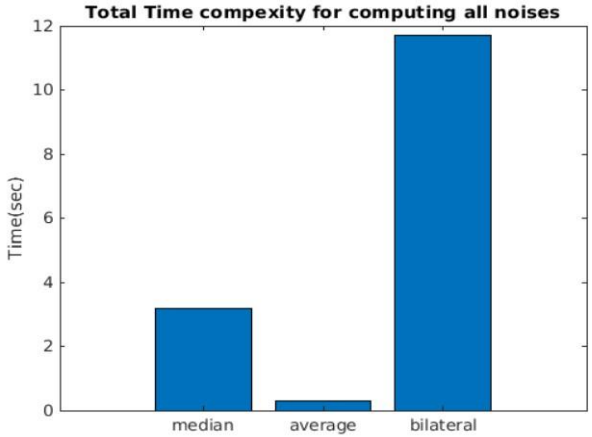


Fig.13

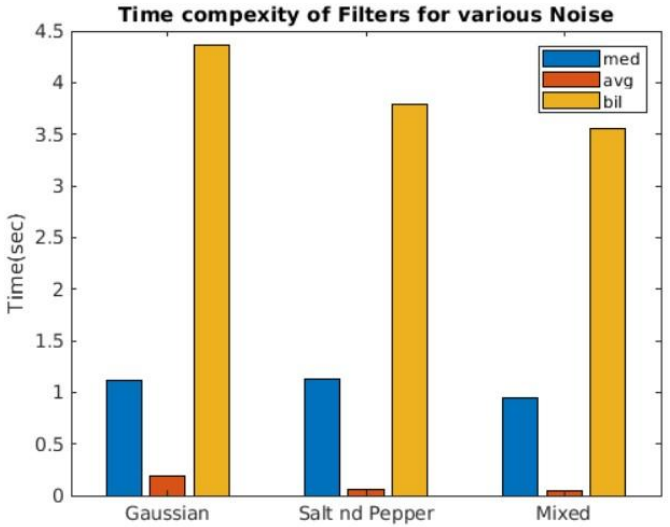


Fig.14

1. Fig.13, Fig.14 shows the time taken to complete the processes discussed till now.
2. It clearly shows bilateral filtering takes high computational time and mean filtering which is a simple averaging of filter, takes the least time.

Conclusion

- ➔ Bilateral Filtering is used in many real world applications
  - Image Denoising which plays key role in medical images, movie restoration etc.
  - Texture and Illumination Separation, Tone Mapping, Retinex, and Tone Management of an image to match the capacities of a given display or achieve photographic stylization.
  - Three-dimensional Fairing and in computer vision for autoencoders decoding, image compressions, Anomaly detection and many more.
- ➔ A clear and a basic visualisation analysis is done for image denoising using image bilateral filtering along with median filter and mean filter for Gaussian, Salt and Pepper, and Mixed noise for a color image.