Salt and Pepper Noise Detection and removal by Tolerance based Selective Arithmetic Mean Filtering Technique for image restoration

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Summary

Removal of noises from the images is a critical issue in the field of digital image processing. This paper proposes a Tolerance based Arithmetic Mean Filtering Technique to remove salt and pepper noise from corrupted images. Arithmetic Mean filtering technique is modified by the introduction of two additional features. In the first phase, to calculate the Arithmetic Mean, only the unaffected pixels are considered. In the second phase, a Tolerance value has been used for the replacement of the pixels. This proposed technique provides much better results than that of the existing mean and median filtering techniques. The Peak Signal to Noise Ratio (PSNR) of the filtered image using the proposed technique is much higher than that of the filtered images obtained by the existing mean filtering techniques.

Key Word

*Tolerance Value, Tolerance Based Selective Arithmetic Mean Filtering Technique (**TSAMFT**), Peak Signal to Noise Ratio (**PSNR**), Arithmetic Mean Filtering (**AMF**), Mean Square Error (**MSE**).*

1. Introduction

Noise is any undesired information that contaminates an image. Noise [10] appears in an image from a variety of sources. The Salt and Pepper type noise is typically caused by malfunctioning of the pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process. For the images corrupted by Salt and Pepper noise [10], the noisy pixels can take only the maximum and the minimum values in the dynamic range.

To recover the image from its noise there exits many filtering techniques [1, 3, 10] which are application oriented. Some filtering techniques have better performance than the others according to noise category. The working procedure of the existing mean filtering technique is very simple. For the existing mean filtering technique [3, 10] one pixel is taken at a time and a sub window is considered around that pixel. Then mean is calculated using the pixel values of that sub window. Then the considered pixel is replaced with that mean. In this way, all the mean filtering techniques work.

There are some problems associated with the existing mean filtering techniques. The PSNR of the filtered images obtained by these two filtering techniques are actually lower than that of the corrupted images. So these two techniques actually decrease the quality of the noisy images rather than improving the quality.

The Arithmetic Mean Filtering Technique can successfully remove Salt and Pepper noise from the distorted image but in this case the filtered image suffers the blurring effect. For the mean filtering techniques each pixel is considered to calculate the mean and also every pixel is replaced by that calculated mean. So affected pixels are considered to calculate the mean and unaffected pixels are also replaced by this calculated mean. This undesirable feature prevents the mean filtering techniques from providing higher PSNR or better quality image.

To overcome this problem, some preventive measures must be ensured so that the affected pixels are not considered while calculating the mean and the uneffected pixels are not replaced at all. In the proposed approach these two features have been considered. These two features ensure that the affected pixels are not considered during the calculation of mean and the unaffected pixels are not changed.

2. Image Processing Terminologies

Some important features and terminologies that are related with these paper and image processing are given below-

2.1 Probability Density Function (PDF)

The PDF of (Bipolar) Impulse noise is given by

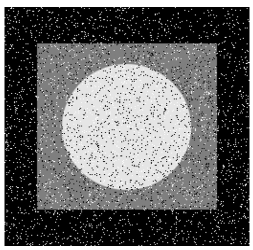
$$p(z) = \begin{cases} p_a & \text{for } z = a \\ p_b & \text{for } z = b \\ 0 & \text{otherwise} \end{cases}$$

Manuscript received May 5, 2008
Manuscript revised May 20, 2008

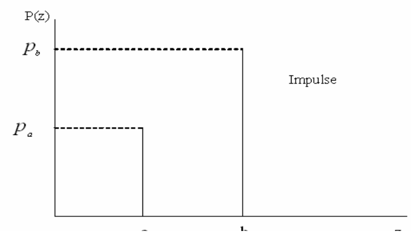
if b>a, gray-level **b** appears as a light dot in the image. Conversely, level **a** appears like a dark dot. If either p_a or p_b is zero, the impulse noise is called unipolar.

If in any case, the probability is zero and especially if they are approximately equal, impulse noise values resemble Salt and Pepper granules randomly distributed over the image. For this reason, bipolar noise or impulse noise is also called Salt and Pepper (Shot and Spike) noise.

Noise impulses can be either negative or positive. Impulse noise generally is digitized as extreme (pure black and white) values in an image. Hence the assumption usually is that **a** and **b** are "Saturated values", in the sense that they are equal to the minimum and maximum allowed values in the digitized image. As a result, negative impulses appear as black (Pepper) points in an image. For the same reason positive impulses appear as white (Salt) noises. For an 8 bit image this means that a=0 (black) and b=255 (white).



(a) Image affected by Salt and Pepper Noise



(b) PDF of the Impulse noise

Figure 1.Image with Salt and Pepper Noise and PDF

2.2 Peak Signal to Noise Ratio (PSNR)

The phrase **Peak Signal to Noise Ratio**, often abbreviated **PSNR**, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupted noise that affects the fidelity of its representation. As many signals have wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale. The PSNR is the most commonly used measure of quality of restored image. It is easily defined by the **Mean Squared Error** (**MSE**) which is for two $m\times n$ monochrome images *I* and *K*, where one of the images is restored image and the other is original image [8].

The MSE is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1} \| I(i,j) - K(i,j) \|^2$$

The PSNR is defined as:

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$

Here, MAX_I is the maximum pixel value of the image. When the pixels are represented using 8 bits per sample, this is 255.

3. Existing Mean Filtering Techniques

To recover the image from its noise there exits many mean filtering techniques which are application oriented. Some filtering techniques have better effects than the others according to noise category. Mean filtering techniques are described below

3.1 Arithmetic Mean Filtering (AMF) Technique

This is the simplest of the mean filtering techniques. Let S_{xy} represent the set of coordinates in a rectangular sub image window of size m × n centered at point (x, y). The AMF technique computes the average value of the corrupted image g(x, y) in the area defined by S_{xy}. The value of restored image ***f*** at any point (x, y) is simply the Arithmetic Mean computed using the pixels in the region defined by S_{xy}. We can express AMF by the equation

$$f(x,y) = \frac{1}{mn}\sum_{(s,t)\in S_{xy}} g(s,t)$$

3.2 Geometric Mean Filtering (GMF) Technique

For GMF technique each restored pixel is given by the product of the pixels in the sub image window, raised to the power 1/mn. A Geometric Mean Filter achieves smooth image comparable to the Arithmetic Mean Filter but it tends to lose less image quality during the process. GMF can be expressed by the expression given below

$$f(x,y) = \left[\prod_{(s,t)\in S_{xy}} g(s,t)\right]^{\frac{1}{mn}}$$

3.3 Harmonic Mean Filtering (HMF) Technique

The Harmonic Mean Filter [10] works well for Salt noise but fails for Pepper noise. It does well also with other types of noise like Gaussian noise. The HMF operation is given by the expression below

$$f(x,y) = \frac{mn}{\sum_{(s,t)\in S_{xy}} \frac{1}{g(s,t)}}$$

3.4 Median Filtering Technique

Median Filter [1] is an image filter that is more effective in situations where white spots and black spots appear on the image. For this technique the middle value of the m×n window is considered to replace the black and white pixels.

When white spots and black spots appear on the image, it becomes very difficult to guess which pixel is the affected one. Replacing those disturbing pixels with AMF, GMF and HMF are not sufficient because those pixels are replaced by a value which is not appropriate to the original one. We have seen over the distorted images that Median Filter has better influence than that of AMF, GMF and HMF, where AMF is the best among all the mean filtering techniques and HMF has the worst performance.

4. Proposed approach

To avoid the problems that are visible by the existing mean filtering techniques, we have developed an algorithm, which is a modification of AMF. Our proposed algorithm is described below:

4.1 Tolerance Based Selective Arithmetic Mean Filtering Technique (TSAMFT)

Salt and Pepper noise is considered as the extreme case among all types of noises. To recover the images affected by this noise, we have developed a technique called TSAMFT. In this technique our main concern is to use the Arithmetic Mean Filtering Technique efficiently to recover from Salt and Pepper noise. We know that for Salt and Pepper noise the pixel value of the noisy image is converted to 0 and 255. When we use Arithmetic Mean Filtering Technique we take 3 × 3 windows and find out the Arithmetic Mean and in this case all the 9 pixels of this 3 × 3 window are used to calculate the Arithmetic Mean. But to calculate mean using the extreme value, provide us with erroneous result in our technique. To avoid this effect we ignored the pixel of value 0 and 255 while calculating the mean. But it may be the case that the pixels of the 3× 3 window represent a black or white object. Hence the pixels are not affected by the noise rather the original values 0 and 255. To deal with this situation, we consider one pixel and a sub window of size 3×3 around that pixel and find out Arithmetic Mean from the pixels of the sub window ignoring the pixels with the maximum (255) and minimum (0) value. If the number of pixels is less than 3 out of 9 (window size m×n) adjacent pixels, we use the traditional Arithmetic Mean Filtering Technique. Otherwise we use the calculated mean found by this technique.

In this technique we have also used a threshold called Tolerance. If the difference between the calculated Arithmetic Mean (excluding the pixels with gray level 0 or 255) and the intensity of the considered pixel is greater than the Tolerance, we replace the intensity of the considered pixel by the Arithmetic Mean. Otherwise the intensity of the considered pixel is unchanged.

4.2 Algorithm of TSAMFT

1. **For** each pixel *p* in the image **do**

    i. Take a sub window of size m×n arround that pixel.

    ii. Find out the Arithmetic Mean from the pixels of the sub window ignoring the pixels with the maximum (255) and minimum value (0).

    iii. If the number of pixels obtained after ignoring pixels of minimum and maximum value is greater than or equal to 1/3 rd of m×n then calculate the Arithmetic Mean Value with the selected pixels. Otherwise calculate Arithmetic Mean Value with all the pixels in the m×n sub window.

    iv. *Diff* = Difference between Arithmetic Mean and the intensity of *p*.

        a. **If** *Diff* ≥ Tolarence **then** replace Intensity of *p* by *AM*

        b. Otherwise leave the pixel value unchanged.

4.3 The significance of the Tolerance value

For Salt and Pepper noise the value of the distorted pixel is 0 or 255. So we find a significant difference between the mean and the value of the distorted pixel. Replacing only the distorted pixel will provide us with better result than replacing all the pixels. Our Tolerance value ensures that only the distorted pixels are replaced.

If we take Tolerance value 0, it will provide same result as Arithmetic Mean Filtering Technique. If we take small Tolerance value such as 5 or 10, then not only the distorted pixels but also the other pixels are replaced. If we increase the Tolerance value then for Salt and Pepper noise PSNR increases. If we take a very large Tolerance value (like 65 or greater than 65), some distorted pixels are not replaced which decreases the PSNR for Salt and Pepper noise.

From our experiments this technique produces a very good result for Salt and Pepper noise when the Tolerance value is 60. Considering a moderate Tolerance value such as 30 to 35, will provide better result than that of minimum Tolerance value (e.g. 5 to 10), but it will provide lower performance than taking high Tolerance value 60.

4.4 Significance of the Proposed Technique

For Salt and Pepper noise the PSNR obtained by the proposed technique is much higher than that of all other mean filtering techniques and the image is free from blurring effect. If we use a suitable Tolerance value like 60 or around 60, the best result is achieved. If we increase the Tolerance value from that level, the PSNR and image quality both will be decreased.

5. Simulation

5.1 PSNR Vs Tolerance Value

For the simulation purpose we have used Multimedia Education System (MTES), Microsoft Visual C++ and Adobe Photoshop. We have chosen Lena.jpg as the sample image, which is shown in figure 3. In our proposed approach, the PSNR of the filtered image varies with the Tolerance value. Whenever we take a smaller Tolerance value we obtain comparatively lower PSNR. The PSNR Value increases along with the increase of the Tolerance value up to a certain level. Then the PSNR decreases again. From table1 we can see, when the Tolerance value is 0 we get PSNR 24.5621 dB, PSNR value increases from that stage over the sample image. For the Tolerance value 60 we obtain the highest PSNR 25.4341. After that PSNR decreases again.

Figure 3. Sample Image Lena.jpg

Table 1

Tolerance value	0	10	20	30	40	50	60	70	80
PSNR(dB)	24.5621	24.7207	24.8182	24.9193	25.1915	25.4009	25.4341	25.1909	24.5208

We see the changes of PSNR for different Tolerance values in the graph-

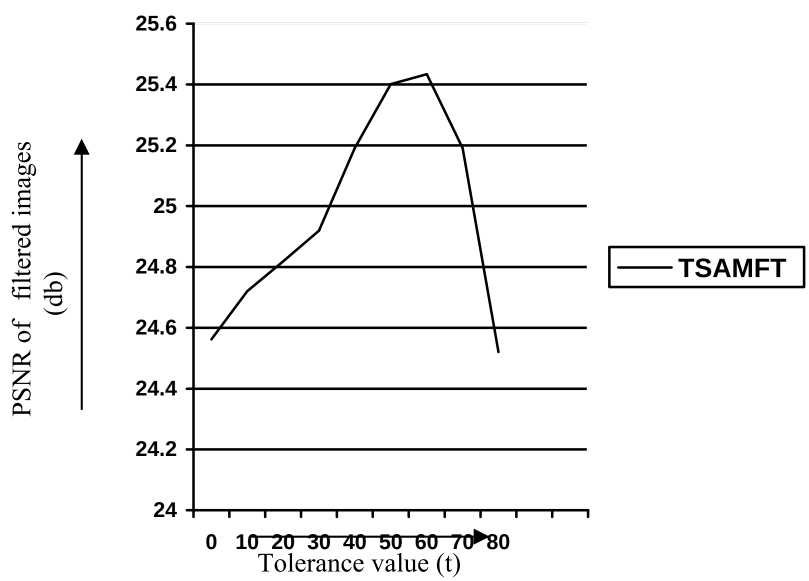


Figure 4. PSNR of filtered image Vs Tolerance value

From figure 4, we observe that if we increase the Tolerance value, the PSNR of the affected image will be increased. Ultimately the quality of the image will be increased. When the Tolerance value is 60 the PSNR is the highest, which means the image will be in super quality. But if the Tolerance value exceeds 60 the PSNR decreases as well as the quality of image decreases. In figure 3, we can see for Tolerance values of 70 to 80 the PSNR of the image decreases with a sharp edge. So we consider 60 as the upper limit of the Tolerance value.

5.2 Performance Analysis among the Filtering Techniques

In our paper we have considered PSNR, MSE and Visual perception as the criteria of comparison. If PSNR increases and MSE decreases, the noise will be reduced. So the filtering technique which provides

greater PSNR and less MSE reduces noise from the corrupted image.

From table 2, we find the PSNR of sample noisy image for different noise levels and also the PSNR of the filtered images for the comparison purpose. For example the PSNRs of the noisy images, are increased by Arithmetic Mean Filter but are decreased by the other two Mean Filtering techniques. It proves that Arithmetic Mean Filter is better than that of Geometric and Harmonic Mean Filtering techniques. But for the Tolerance value 60 of the proposed method, we achieve the highest PSNR of 32.0058db, which indicates the efficiency of the method.

Table 2

Image name	Noisy image (dB)	Existing Mean Filtering Techniques			TSAMFT (dB) (t=5)	TSAMFT (dB) (t=30)	TSAMFT (dB) (t=60) Recommended	TSAMFT (dB) (t=65)
		AMF (dB)	GMF (dB)	HMF (dB)				
Lena.jpg	10.6383	18.3413	8.3033	7.6201	20.50	20.8646	21.3147	21.184
	12.3941	20.4656	9.6533	8.7990	22.70	22.8959	23.3209	23.169
	15.18	23.5378	12.1248	11.0969	24.652	25.1114	25.2312	25.090
	16.1023	24.4312	11.1253	10.9820	26.675	27.3245	32.8769	31.093
	19.8139	27.7048	17.0313	15.8009	29.004	30.6055	34.8523	33.462

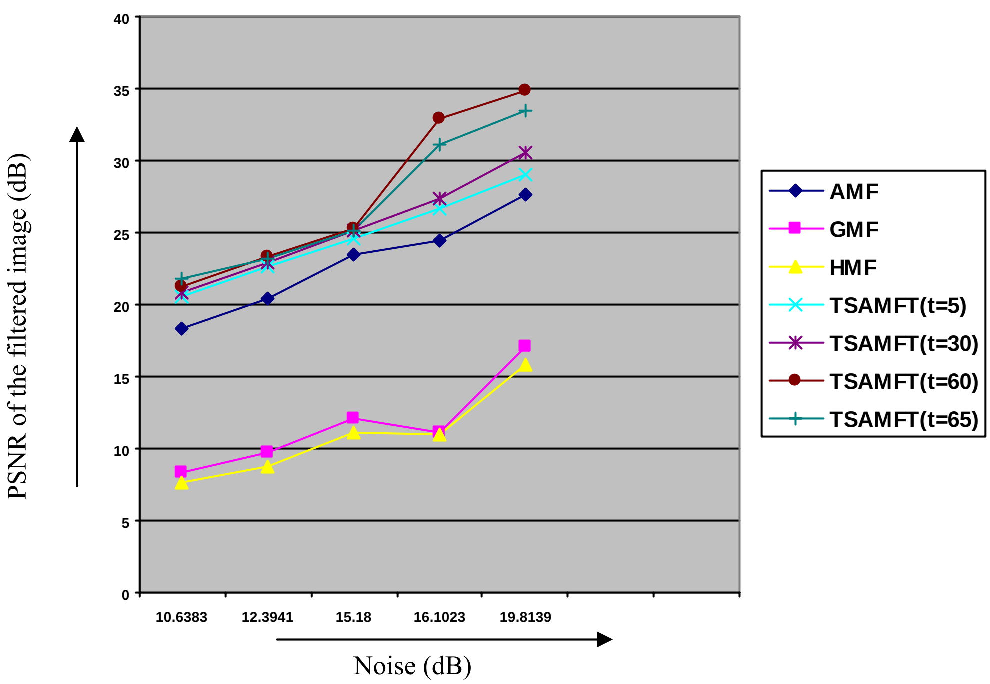


Figure 5.PSNR of filtered image Vs noise (Salt & Pepper noise) level by various techniques on image Lena.jpg

In figure 5, noise level is plotted in X axis and PSNR of filtered image is plotted in Y axis. For different noise levels we observe different PSNRs. From figure 5, it is clear that our proposed technique with Tolerance value (t) 60, provides the highest PSNR than that of others.

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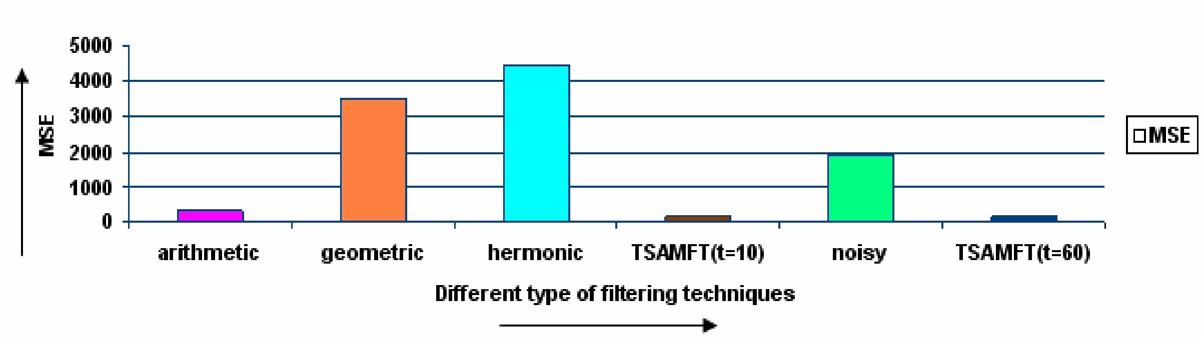

Figure 6. Mean Square Error of various techniques

In figure 6 MSE of different techniques is plotted. Here the smallest bar represents the lowest error. Here Arithmetic Mean Filtering Technique provides better result but our proposed technique (for Tolerance value t=60) provides the lowest error and the bar is smaller than that of Arithmetic Filtering Technique.

Figure 7. **Restoration of Lena image**. (a) Original image, (b) Corrupted image with Salt & pepper noise (16.1023 dB), (c) Image recovered by AMF technique (24.4312 dB), (d) Image recovered by GMF technique (11.1253 dB), (e) Image recovered by HMF Technique (10.9820 dB), (f) Image recovered by TSAMFT (t = 60) (34.8523dB)

In figure 7, we observe the effects of different filtering techniques on noisy Lena image. Here we can clearly identify that the mage recovered by **TSAMFT (t = 60)** is the closest to the original image and with highest PSNR. Hence from the visual perception the image looks extremely well.From the above shown figures, we can claim that our proposed **TSAMFT** is better than any other existing Mean Filtering Techniques.

5.3 Performance Analysis between Median Filtering Technique and TSAMFT

Median Filtering Technique [1] is considered as a very good method to remove Salt and Pepper noise from the noisy images. Median Filtering Technique works better than that of the mean filtering techniques but it woks up to a certain amount of noise. From Table 3, when 10% noise is added to the image, Median Filter works better than our proposed technique. This is true up to 30% of noise. When noise is more than 30% our proposed technique works better than that of the Median Filtering Technique. The related graph is shown in figure 8.

Table 3

Image name	Noise (%)	Median Filter (dB)	TSAMFT(t=60) (dB)
Lena.jpg	10	29.721	25.2312
	20	26.9848	23.3209
	30	22.9517	21.3147
	40	18.8771	19.2773
	50	15.3610	17.3798
	60	12.6882	15.6069
	70	10.4650	13.9132
	80	8.5925	12.2890

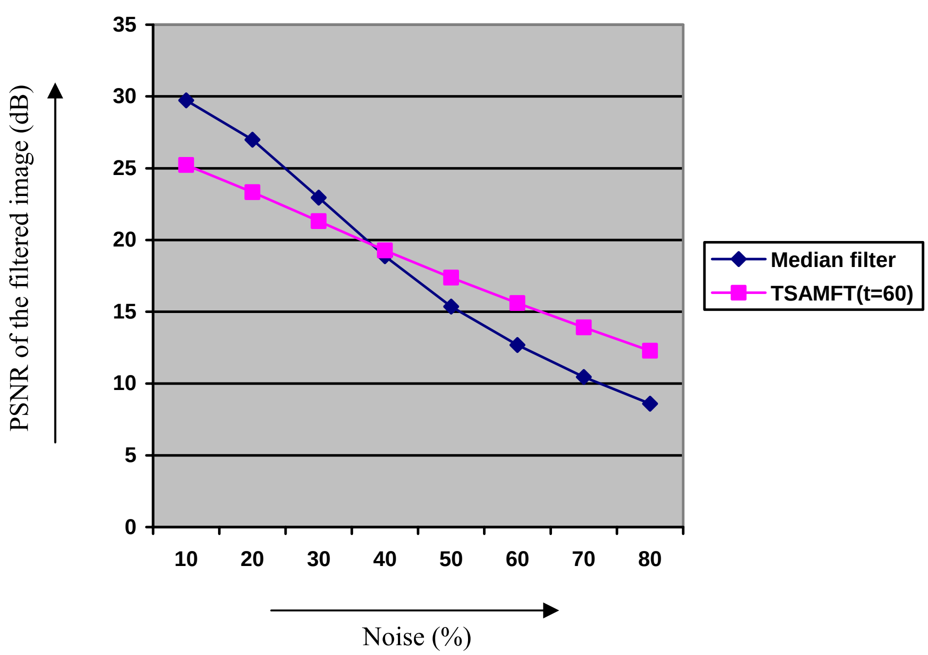

Figure 8. Noise (Salt & Pepper) (%) Vs PSNR of filtered image by Median Filter and TSAMFT

6. Conclusion and Future Plan

In this paper we have developed a new filtering technique, which is better than the existing Mean Filtering Techniques and in some cases Median Filtering Technique for Salt and Pepper noise. In our analysis we find that the Arithmetic Mean Filtering Technique works better than that of the Geometric and Harmonic Mean Filtering Techniques, while our proposed filtering technique works better than the Arithmetic Mean Filtering Technique. Here we introduce a new term Tolerance value. If we increase the Tolerance value, the PSNR and the quality of the image increase. This technique gives the best result when the Tolerance value is 60. Greater Tolerance value than this decreases both image quality and the PSNR. So we have defined a range of the Tolerance values. Finally we can say that our proposed technique can be effectively used to filter the images in the spatial domain. It performs better than that of the traditional filtering techniques and we hope that our effort will help to improve the future experiments over image processing and performance analysis. In future we will try to explore the effect of other filtering techniques over noisy image and upgrade them according to achieve the better performance.

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