Technium Vol. 3, Issue 9 pp.1-11 (2021)
ISSN: 2668-778X
www.techniumscience.com

A REVIEW PAPER: DIGITAL IMAGE FILTERING PROCESSING

Rana Riad K. Al-Taie*

Basma Jumaa Saleh**

Hiba A. Abu-Alsaad***

* Department of Computer Engineering/ Al-Mustansiriyah University/ Baghdad, Iraq
**Department of Computer Engineering/ Al-Mustansiriyah University/ Baghdad, Iraq
**Department of Computer Engineering/ Al-Mustansiriyah University/ Baghdad, Iraq

**eng.basmaj@uomustansiriyah.edu.iq Orcid: 0000-0003-2570-3901

***Eng.hibaakram@uomustansiriyah.edu.iq Orcid: 0000-0002-5034-0113

*Author for Correspondence: Rana Riad K. Al-Taie
Ranaal_taie@uomustansiriyah.edu.iq Orcid:0000-0003-2570-3901

Abstract Nowadays, visual information is increasingly sent in the form of digital images, making the identification of noisy data a common challenge in many research and application domains. Many noise reduction techniques have been developed in the contemporary era to remove noise while preserving image information. The task of eliminating noise from an original image remains a difficult one for researchers. The primary focus of this study is on picture denoising and filtering. For performing a comparative examination of existing denoising techniques, such as linear and nonlinear filters. salt, pepper noise, Gaussian noise, and speckle noise are examples of different noise models. PSNR of color images provides a quantity measure of comparison.

Keywords: Image denoising, linear and nonlinear filters Gaussian noise, salt and pepper noise, speckle noise.

1. INTRODUCTION

Undoubtedly, images are tarnished by noise during acquisition, compression, and transmission due to the effect of the environment, transmission channel, and other variables, resulting in distortion and loss of picture information. Possible following image processing activities, such as processing of videos, analyzing of images, and tracking, are harmed by the presence of noise.

As a result, denoising is critical in today's image processing systems. The main objective of image denoising is to retrieve the true image through making free noise image. However, duo to noise, edge, and texture considered as high-frequency components, it is difficult to tell them apart during the denoising process, and the filtered images will definitely lose some details. Overall, retrieving relevant information from noisy photos throughout the noise removal process to generate high-quality images is a major challenge currently (1). A steadily increasing for both of the instrumentation and measurement sectors on picture data as multimedia and communication technologies have grown in popularity. Images contain measurement data that is useful in a wide range of study and application fields, including remote sensing, astronomy, biology, medical sciences, materials science, and so on. In any case, developing tools and approaches to improve the quality of picture data is critical. However, enhancing noisy photos is not a simple process. The filtering function should be able to tell the difference between undesired noise that needs to be removed and visual details that need to be enhanced (2). Binary, gray-scale, and color images are among the most often-used image kinds. Binary pictures are the most basic image types, with only two discrete values: black and white. The value ‘0' represents black, while ‘1' represents white. A gray-scale image is usually used to build a binary image. A binary image is useful in computer vision applications where the picture's general shape or outline is required. They are also known as one-bit/pixel pictures. Monochrome or one-color images are gray-scale images. The images utilized in this thesis for experimentation are all gray-scale photos. They are devoid of any color information. They represent the image's brightness. Because this image has 8 bits per pixel, it can reach to 256 (0-255) different brightness levels. A ‘0' symbolizes black, while a ‘255' denotes white. The multiple gray levels are represented by values ranging from 1 to 254. Intensity images are sometimes known as intensity images since they carry intensity information (3). Color pictures are three-band monochrome images with each band representing a distinct color. Each band provides the brightness information for each spectral band. Red, green, and blue images, commonly known as RGB images, are common color images. This image has a bit depth of 24 bits per pixel (4). Negative exponential noise, Rayleigh noise, Gaussian noise, salt and pepper noise, Poisson noise, and speckle noise are all common noise models.

The rest of the text is structured in the same way. The picture noises are described in Section II. In Section III, we will go through picture filtering techniques. A simulation experiment is described in Section IV. Performance estimation is discussed in Section V. Our findings are finally summarized in Section VI.

2. Image Noises

The most common cause of noise in digital photographs occurs during the acquisition or transmission of the image. The performance of an image sensor is influenced by a number of factors, including the environment during image acquisition and the quality of the sensing element itself. Ambient circumstances can have an impact on imaging sensors (5). During transmission, interference can be added to an image. During transmission, images can be damaged due to interference in the channel caused by phenomena such as lightning or meteorological disturbances. Image denoising will be described mathematically (6) as follows:

$$Y1 = x1 + n1 \tag{1}$$

where Y1 denotes the observed noisy image, x1 denotes the unknown clean image, and n1 denotes additive white Gaussian noise (AWGN) with standard deviation n, that could be estimated in practical applications by using a variety of methods including: block-based estimation, median absolute deviation and principle component analysis-based methods. The main objective of noise reduction is to reduce noise in natural photographs while preserving original features and increasing signal-to-noise ratio (1). The primary issues in image are:

- The Flat surfaces should be smooth.
- Protecting the edges without being blurred.
- While keeping the textures.

We can't derive the unique solution from the picture model with noise since solving the clean image x from Eq. (1) is an ill-posed problem. Over the last few years, in terms of image processing filed, image denoising has been extensively researched in order to produce a good estimation image x (7). In general, image denoising techniques can be divided into three categories:

2.1 Gaussian noise,

Which is defined as noise with a PDF equal to the normal distribution, that is why called the Gaussian distribution. Additive white Gaussian noise is the most frequent name for Gaussian noise. The noise having a Gaussian amplitude distribution is appropriately defined as Gaussian noise (8). A Gaussian random variable z is probability density function p is given by:

$$g(z1) = \frac{1}{\sigma 1\sqrt{2\pi}} e^{\frac{-(z1-\mu 1)^2}{2\sigma 1^2}} \tag{2}$$

Where, z1 represents the grey level, $\mu 1$ the mean value and $\sigma 1$ the standard deviation. Each pixel of an image changes by a little amount from its original value in Gaussian noise. This form of noise is well-represented by the Gaussian (normal) distribution. The central limit theorem states that the sum of many sounds tends to approximate a Gaussian distribution (9).

2.2 Salt and pepper noise,

The fixed-value and random-value types of impulse noise distributions are the most common. In impulse noise with a fixed value, a noise pixel takes either a max value of 255 or a min value of 0. Another name for impulse noise is salt and pepper noise.
In salt and peppers noise, the noise magnitude is equally distributed in the range [0,255]. The salt and pepper noise filters were proposed in the publications as a solution to the impulse noise of fixed pixels. Regardless of whether they are for a salt and pepper noise value or numerous noises, the above filters outweigh any other impulse noise filters. As a result, the focus of this work is solely on the random value salt and pepper noise (10).
In salt and pepper noise, the intensity of pixels in the image differs greatly from that of surrounding pixels. The color of a noisy pixel has no bearing on the color of nearby pixels. There are dark and white dots in it. This noise is caused by the existence of dust inside the camera and overheated or malfunctioning CCD elements (9).

2.3 Speckle noise,

Is a multiplicative noise type. Any distribution is multiplied by each pixel in the image as a result of this. Ultrasounds, lasers, and sonar pictures are all affected. Synthetic Aperture Radar (SAR) images are frequently severely degraded by this noise. Random fluctuations in the signal from an element smaller than a single image processing component cause the majority of the noise. Consistent processing of back scattered signals from a variety of distributed targets is also to blame. The image's mean gray level will also be raised as a result of the noise. This noise makes it difficult to comprehend the image (11). Texture is another name for it. The generalized speckle model is expressed as,

$$G1(n,m) = f1(n,m) * u1(n,m) + \xi 1(n,m) \tag{3}$$

where G1(n,m) is the observed image, u1(n,m) is the multiplicative component of the speckle noise, and 1(n,m) is the additive component (12).

3. IMAGE FILTERING TECHNIQUES

Based on spatial filtering methods, there are two primary ways to image denoising:

3.1 Linear filtering

There are two forms of linear filters, commonly known as average filters mean filters and wiener filters. Sharp edges are blurred, lines and other fine picture information are lost, and linear filters perform poorly in the presence of signal-dependent noise (13).

- **Mean Filter**

The neighborhood average method is the main method of the mean filter, often known as the linear filter. The primary premise of linear filtering is to use mean values for replacing the pixel values of the original image. That is, we should choose a template for the current pixel (x,y) that is made up of a number of pixels from its neighbor. The values of mean for all pixels will be determined, while the gray g1(x,y) at the points on the process image will be used to represent the mean values for the current pixel (x,y). This translates to (16):

$$g1(x,y)=\frac{1}{M1}\sum_{f\in s1} f(x,y) \qquad (4)$$

Where s1 denotes the template, and M1 is represnting the total number of pixels in the template, including the current pixel. To reduce granular noise from a scanning image, apply a mean filter using the neighborhood average approach. The noise is efficiently suppressed using the neighborhood average method. However, scenery edge points would be processed as part of the average value calculation. The image would then be in a low-resolution form. Based on this circumstance, a better algorithm for realizing various mean filters is proposed, and new mean filters, such as K nearest neighbor mean filter, gray minimum variance mean filter, weighted mean filter, symmetric neighbor mean filter, and so on, will be produced.

3.2 Non-linear filter

Low pass filtering is used on groups of pixels in spatial filters, with the premise that noise occupies the higher frequency area of the spectrum. In general, spatial filters reduce noise to a significant level, but on the other hand will increaese the blurring of images, which renders image edges invisible. A number of nonlinear filters have been created in the last year. The median filter is the most basic nonlinear filter (17). Noise is reduced using non-linear filters without the need to explicitly identify it. The median of the neighboring pixels, rather than the mean, determines the value of an output pixel in this situation (18).

- **Median filter**

The main advantage of using a median filter to keep edges while reducing noise. In this filter, each pixel in the image will be replaced with the median of adjecent pixels for each pixel that is being evaluated. The input image is subjected to a median filter, which is a nonlinear digital filtering technique. It's a pre-processing technique that improves the image and prepares it for further processing. The window is the pattern of neighbors that moves pixel by pixel over the entire image. The median will be derived by sorting all the pixel values in the window into numerical order, then replacing the respective pixel with the middle (median) pixel value. Let's pretend that the image pixels in the window are M1,M2,M3,M4,M5 (14). To get the median, the first step is to rank the items in order to obtain the sorted list provided by:

$$\text{Ranking } \{M3, M1, M4, M2, M5\} \text{ given } M3<M1<M4<M2<M5 \quad (5)$$

Then Median =M4.

Because it occurs in the middle of the sorted pixels, we can determine that the median is M4. The use of a median filter de-noises the input image, making it suitable for segmentation and feature extraction modules (15). A nonlinear filtering approach is median filtering. The median filter has the advantage of being simple to use and fast, as well as having good performance in filtering out both of long tail noise and white noise and. However, median filtering should not be used for certain more details, particularly for a point, line, or multi-spire image. The median filter has various enhanced algorithms, such as switching median filter algorithm based on threshold, weighted median filter, and adaptive median filter, to broaden the scope of its application. The weighted median filter adjusts the conflict between noise reduction and detail preservation by assigning varying weights to pixels inside the window. However, when compared to a typical filter, the approach achieves better detail preservation at the expense of noise suppression. The algorithm of switching median filter will be deployed based on threshold and will achieve a better effect for the noise point and flat region by using the median filter. For providing a good protection effect, this algorithm does not handle details. It can be used to deal impulsive noise of high probability by using an adaptive median filter. When it is processing, the neighborhood region it is in can be changed depending on the situation. Its benefit is that it saves details when processing smooth non-impulse noise (16).

4. Simulation Experiment

The simulation experiments are performed on a classical computer with an AMD A8-4500M APU with Randeon™ HD graphics 1.9 GHz 6.00GB RAM, 64-bit operating system, and MATLAB 2019b to compare the results from the original median filtering technique and optimum median filter (19). The well- known ‘‘Parrot ’’ picture has been taken as the benchmark image with (10%, 20%, 30%, 40%, and 50%) value of noise. ‘‘ Parrot ’’ is colored images, with 1200 × 650 size, results of the comparative experiment are shown as (Fig. 1).

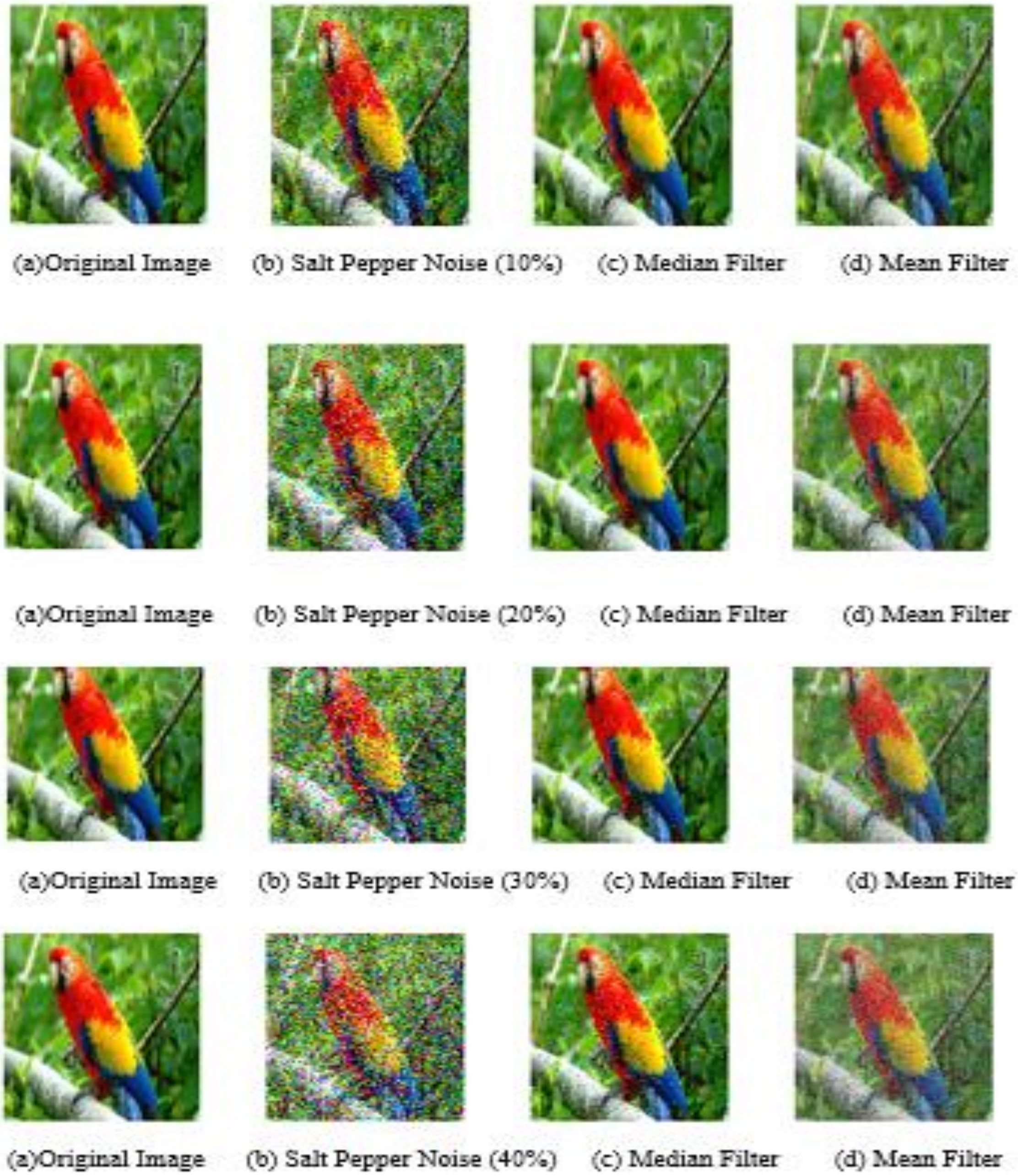


Fig. 1. (a) The benchmark ''Parrot'' image; (b) The noised ''Parrot'' with salt and peppers noise; (c) The median filter; (d) The mean filter.

Technium Vol. 3, Issue 9 pp.1-11 (2021)
ISSN: 2668-778X
www.techniumscience.com

Fig. 2. (a) The benchmark ''Parrot'' image; (b) The noised ''Parrot'' with Gaussian noise; (c) The median filter; (d) The mean filter.

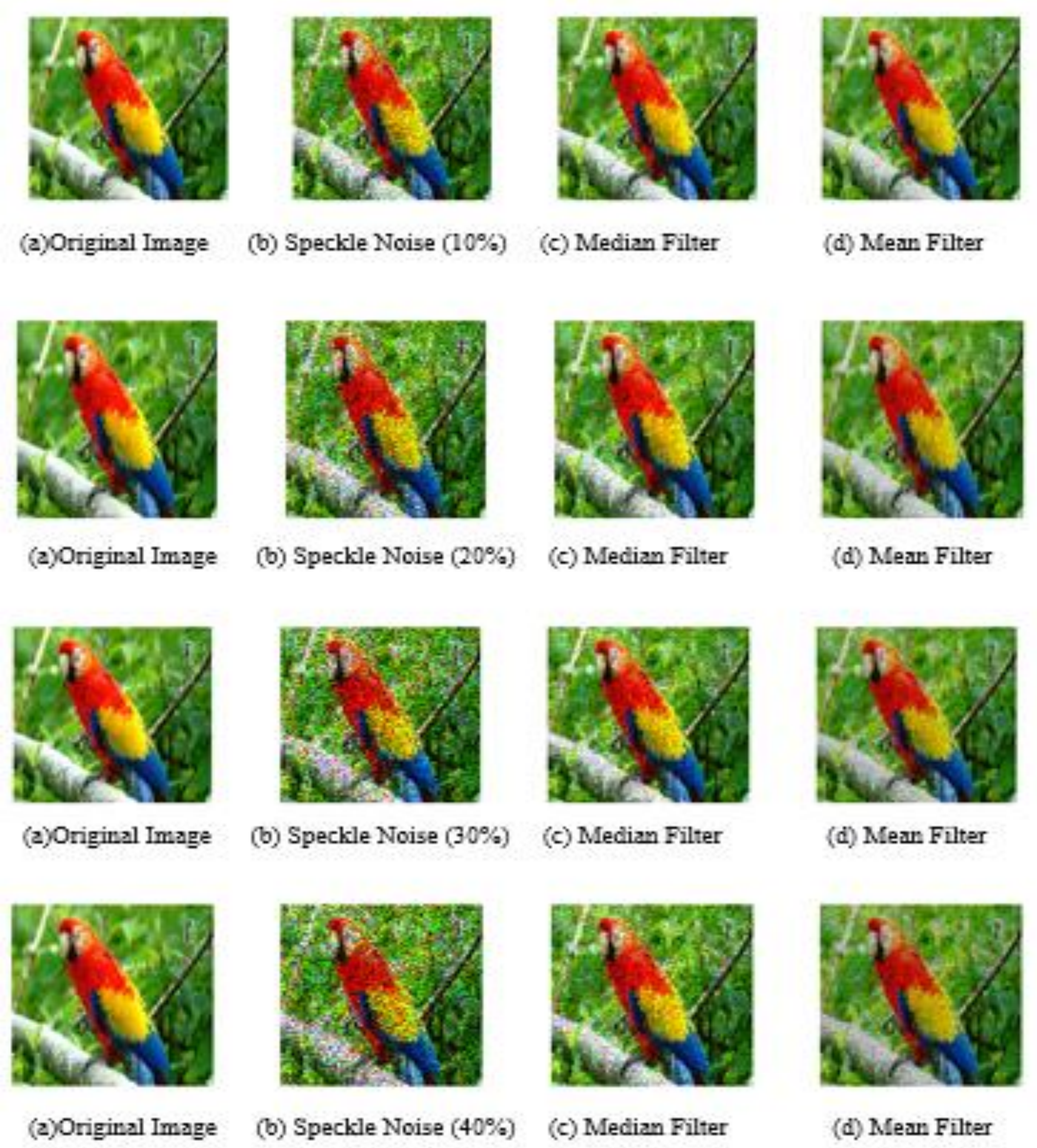


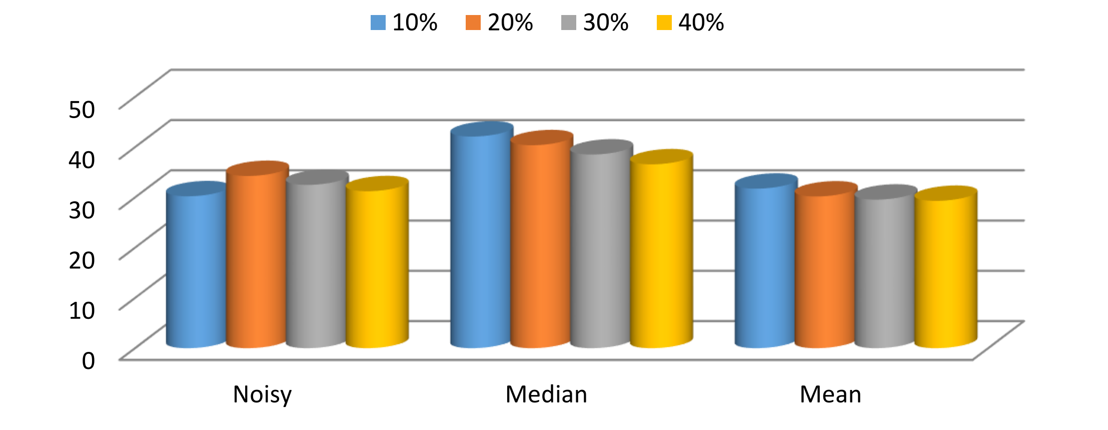
FIg 3. (a) The benchmark ''Parrot'' image; (b) The noised ''Parrot'' with speckle noise; (c) The median filter; (d) The mean filter.

5. PERFORMANCE ESTIMATION:

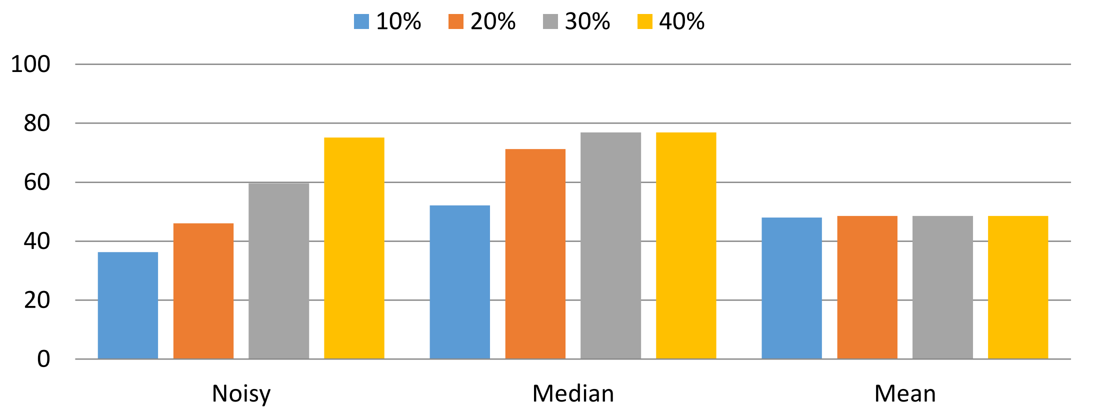
The visual influence of the subjective or the method of estimating the purpose may estimate the effect of the noise reduction from image. The work takes the mean absolute error (MAE) and the mean square error (MSE) between the denoised image Z(k,l) with the rows and columns is $Q \times R$ and the original image M(k,l) with the rows and columns is $Q \times R$, at which k=1,2,3,….. Q and l=1,2,3,…. R , The performance estimation index was chosen. The definition of PSNR at Eq.(6) from (20),

$$\text{PSNR} = 20\ \log_{10}\left(\frac{255}{\sqrt{\text{MSE}}}\right) \quad (6)$$

We present the data of three noises experimentations in Fig. 4. The results of the experiment demonstrate that PSNR variables and graph (from (Fig. 1, Fig. 2, and Fig. 3)) we analyze implementing the median filter based on salt and pepper and Gaussian noises in this work is better than the mean filter technique but mean filter is better with speckle noise. The better method has significant advantages, especially at high peak-signal-to-noise criteria.



(a) PSNR of Salt and Pepper Noise



(b) PSNR of Gaussian Noise

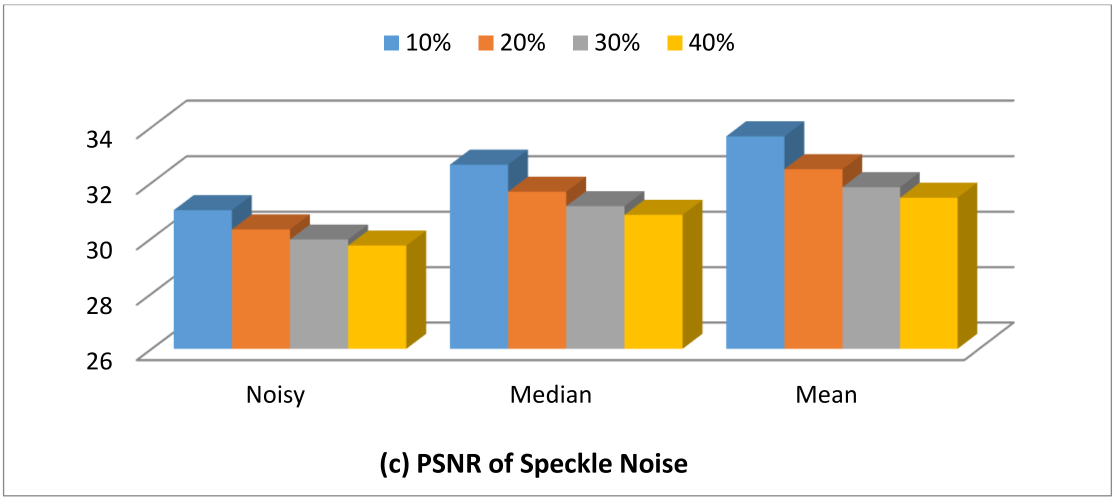


Figure -4- The PSNR of different noises.

Conclusion

In this paper, simple filtering techniques used to recover two types of images (gray and color) from noise contamination effectively. The whole procedure to denoised images has been implemented in MATLAB (R2019b). In addition to denoising of the images, a comparison between filtering techniques has been made. The effectiveness of these techniques has been compared by comparing the signal-to-noise ratios of the denoised images by these techniques. It is observed that median filter better results in terms of signal-to-noise ratio in impulsive and Gaussian noise but the mean filter better with speckle noise.

Acknowledgments

The authors would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq) Baghdad- Iraq for its support in the present work.

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