A review of Image Enhancement Systems and a case study of Salt &pepper noise removing

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Abstract—The main purpose of this paper is to review the essential techniques in the field of image processing and enhancement. The image enhancement is an important and challenging research area. The primary objective of image enhancement is to improve the visual appearance of the original image to produce an enhanced image which is more suitable for specific applications. Digital image enhancement techniques offer a multitude of adoptions for improving the visual quality of images. There are many types of pictures, such as medical images, satellite images and aerial photographs and even images and real-life suffering from the weakness of contrast and noise. Therefore, it is necessary to improve applications for increasing the image quality that could help to enhance contrast and remove the noise from the original image. Therefore, this paper aims to provide an overview of fundamental concepts, algorithms, processing methods used for image enhancement. A case study is deploying a salt and pepper noise on cameraman and spin images is presented and addressed using MATLAB software.

***Index Terms*—Computer Vision, Image processing, Image Enhancement, Image Noise remover, Image Filters.**

I. INTRODUCTION

With the increasing usage of digital images in science and engineering, the need for digital image processing has emerged as a rapidly evolving field. Digital pictures typically come with noise resulting from the way that the digital image is created, scanned, or compressed. For example, when images are photographed using a camera, they cannot handle low light levels, and then it will result in a noise image. Removing noise from digital images is an essential problem in image processing and requires extensive study to reach competent results. Image processing is a broad field in examining computer image that deals with processing and serving video or picture as an input, and the output from it is either with specific parameters or specific character or an image [1]. Converting an image from singles to digital to be operated is a primary concern of most researchers, where the use of image processing is increased. There are two principal methods of processing the image, which are analogue that change the image using electric ways and digital that uses a scanner to convert the figure of an image into numeric. In current days most of researchers are interested in the field of image enhancement and processing in different real life application such as engineering, education, science, medicine, social, space and satellite, etc. Therefore, the understanding of image processing and enhancement are essential field in modern research. Digital image enhancement techniques offer a multitude of adoptions for improving the visual quality of images [2] as presented in Figure 1.

Noise defines as a field of image processing as unwanted information distributed in arbitrary way on the level of the image distort and weakness the image appearance. images often accompanied by the appearance of different types of interference and noise as a result of environmental changes or changes in the sensitivity of the detector in addition to the changes occurring during the transfer.

Image enhancement plays an important role in image processing. There are many techniques available to remove different types of noises from the image. However, the best technique that able to remove the noise and keep image details. The enhancement of an image is divided in two categories which are linear and nonlinear model. Generally linear model is fast in removing noise but unable to preserve image details. Whereas, the nonlinear model can remove the noise and preserve the details of image but with more time [3]. The noise domination or noise removal is considering as an essential task in images processing that the researcher are focused on. Generally, the most used methods for implementing the noise in images include a Gaussian, uniform, or salt-and-pepper distribution. The Gaussian Noise is used to model natural noise processes that happen from electronic noise in the image acquisition system. Figure 2 presents an example of spin image and the effects of Gaussian noise (AF: Average Filter; AAF: Adaptive Average Filter ; MF: Median Filter ; WMF; Weighted Median Filter ; WCMF: Weighted Coefficients Median Filter).

Uniform Noise is beneficial that because it uses to generate any other type of noise distributed. Also, it applies to corrupt images in the restoration algorithms. And Salt and Pepper's noise is usually produced by errors in the data transmission. Also, Salt and pepper noise it can cause as result of an error in data transmission or a defect pixel elements in camera sensors, etc. Usually, the noise appears in the image that creates using a scanner because of darker dots and disturbances.

Sometimes, the image interpreted wrongly because the noise cannot overcome in some cases.

Removal of noise is considered one of the significant tasks in computer vision and image enhancement processing since unwanted noise leads to the erroneousness in the image. Filtering techniques are used to reduce the noise for enhancing images and sharpening them as illustrated in Figure3.

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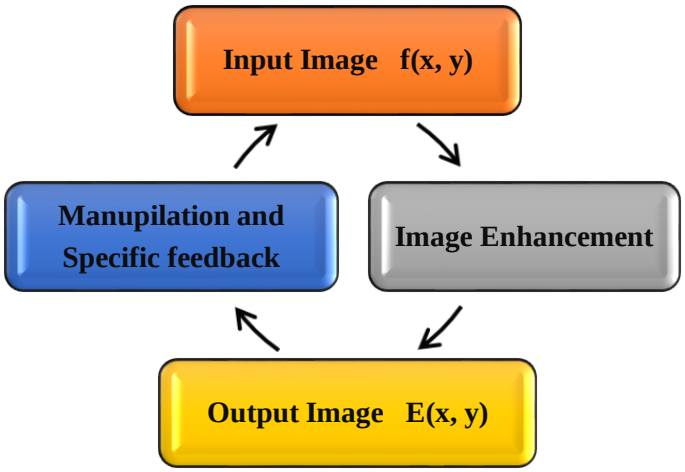

Figure 1: Image enhancement module

Therefore, filters aim to cut out the noise and to emphasize the low and high spatial frequency components. The appearance of noise is unwanted data that disturbs the information present in the image. It is turned into values, which is added or subtracted to the true grey values on a grey level pixel [4].

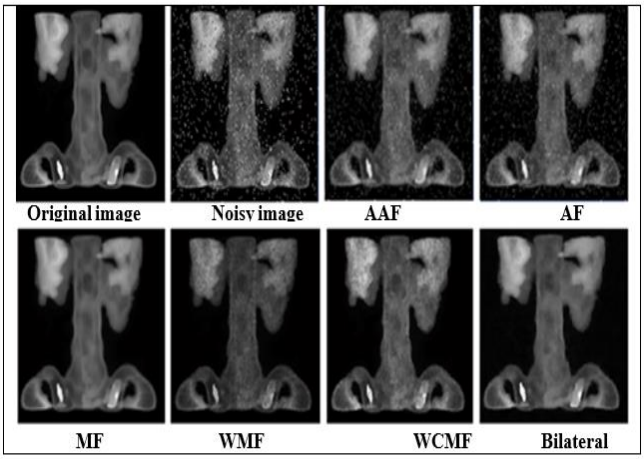

Figure 2: Spine image using Gaussian noise

Figure 3: Original image (left) and The Enhance image(right)

The nonlinear filters are successfully implemented in many applications for smoothing images because of their better edge preservation and impulse rejection capabilities as depicted in Figure 4. Weighted median filter is an extension of the median filter. It introduces the concept of weight coefficient into the median filter. Weighted median filters are used to reduce impulsive noise and to preserve sharp edges in image signal efficiently [5].

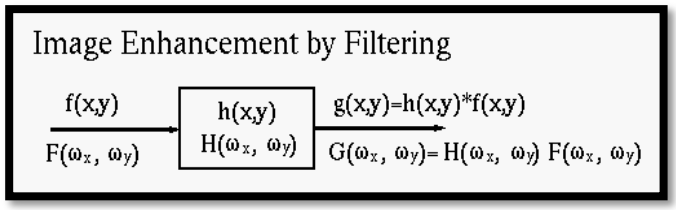

Figure 4: Image enhancement function

The Median filter is used to remove an impulsive noise from images. The nonlinearity function that implements in the median filter helps to smooth the image without any blurring that could appear in the linear filter. The median filter is not adjustable and imperfect because it could remove essential details as result of an edge streaking.

The important deployment in information technology today have led to the emergence of applications for a wide range of cloud computing that customizes a process of any software, hardware and networks [6].

Cloud computing services fall into the category of service-oriented architecture applications that enable access to any device from anywhere [7]. It can provide a set of resources on demand to a group of subscribers at the same time and meet any request immediately and implemented with the least effort and the fastest time. For example, a group of algorithms and software to handle images in cloud computing can share several subscribers with the most rapid, least cost and least knowledge of network management and software. Aforementioned will help to improve and enhance an image in less time and high quality [8].

II. TYPES OF DIGITAL IMAGE

In the field of image processing, it is useful to include both types of image analogue and digital. The mathematical model of computing the value of image depends on the calculation of two variables (X direction and Y direction). The digital image is represented in a two-dimensional array of discrete values of the image.

Several techniques are used to enhance and process an image. Therefore, it is recommended to define the type of image first and then choose the suitable method to enhance it.

An image is defined as 2D function f(x, y). Where x and y is spatial coordinate and f is amplitude of any pair (x, y) is called intensity level of the image at any point. Image has a finite number of elements, which has a specific value and location. Each element called a pixel. The digital image is a numeric representation of predefined pixels. The digital image can be classified into three categories as shown in Figure 5.

1- **Binary image:** means the pixel value is either white or black. There are only two possible values for each pixel either 0(black) or 1(White), one bit per pixel is needed.
2- **Grayscale image:** In this type of images, each pixel is grey shade, which has value normally 0 to 255, which means each pixel in the image can be shown by eight bits (one byte). However, ranges of grayscale can be used.
3- **True Color or RGB:** RGB image has three values; red, green and blue. Each pixel in the RGB image carries one of these colours. The range of RGB image is from 0 – 255, and that means 2563 different possibilities of colours values. Each pixel in the image represents three values which are red, green and blue [3]. However, there is a particular type of colour image called Indexed or palette. The difference is that the indexed image has a fewer number of diverse colours

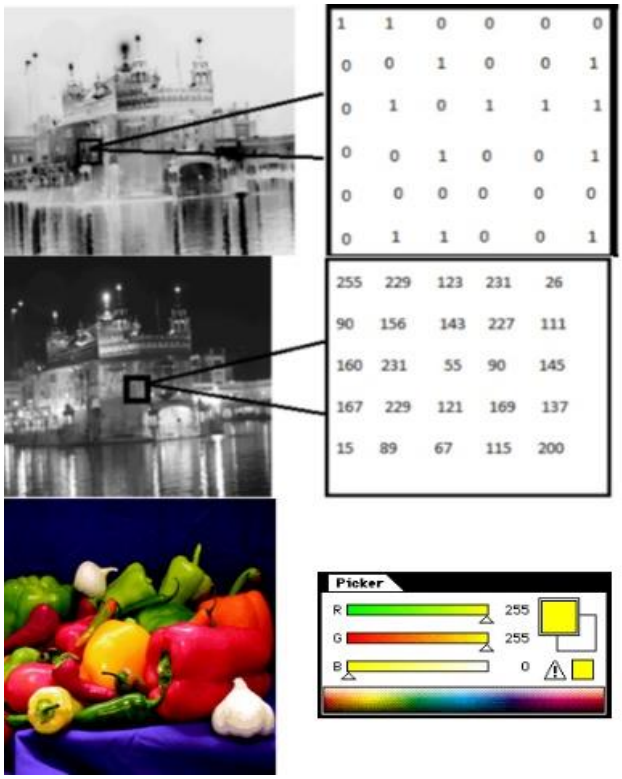

Figure 5: example of image color type

III. IMAGE RESTORATION

Image processing has different fields like enhancement, restoration, segmentation, classification, etc. as illustrated in Figure 6. Image enhancement is used as preprocessing step to enhance image quality without any effect on original image. Noise is removed and contrast is adjusted to produce better appearance quality for the desired image. Image enhancement is an important task in image processing has two categories which are spatial domain and frequency domain. Spatial domain enhancement deals with pixel values but in frequency domain deals with Fourier transform for the image. Image Restoration is the process of obtaining the original image from the degraded image given the knowledge of the degrading factors.

The restoration of the digital image is a field that investigates techniques, which are used to improve original scene from the corrupted images and observations.

Several methods are used for image restoration towards modeling and enhancing the damaged images. Various filters are applying an approximation method to remove a blur and noise from the original scene. Also, image restoration is an essential task in many applications in the field of digital image processing. The image degradations involve blurring, motion and noise. Blurring appears when the object is out of range of the camera's depth during the exposure.

The motion blur happens when the object moves during an exposure [9].

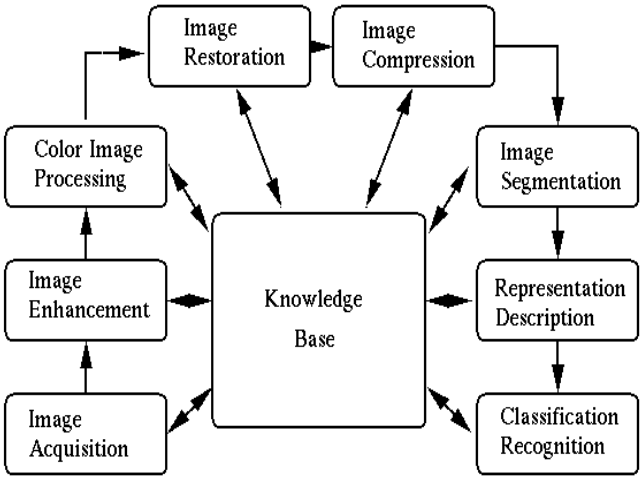

Figure 6: Image processing steps.

IV. RELATED WORK

Many works were done in the field of image processing and enhancement in the last decade. Today, the researchers focus on using a combination of methods to introduced efficient techniques.

BegillE, MadaanE [10], presented a comprehensive review of various image enhancement techniques such as spatial domain, Histogram equalization and Fuzzy technique. Also, major medical image application using un-sharp mask filter and log Gabor filter is applied. Spatial domain deals directly with pixels and it has various types. One of them is image negative that deal with gray level pixel values of original image and converted to negative image. Where s = 1.0 – r. Sanyam Anand, Navjeet Kaur, 2012[11] presents a fuzzy classical filter as enhancement technique used to remove more than one types of noise at the same time. Previously, removing different noise is done by implement a combination of different type of filters that each of them could eliminate certain noises. the fuzzy fillet is taken gray image as input and implement a mean filter to perform the convolution neural network. Feras N. Hasson et al. [12] proposed an effective method for image enhancement, which is median filter based

on the random trail method, which is capable to remove the noise from a noisy image and preserve edge details. Also, they implement a random trail method in median filter because it produces a weighted coefficient of median filter. A mask (3*3) is deployed for duplication operation of noise image (256 * 256). The proposed filter achieved a less mean square error (MSE) in comparison with other filters like average and median. Ibrahim, H., et al. [13], introduced a simple adaptive median filter to remove an impulse noise from high corrupted images. It deals with density values where the pixels are split into two phases: corrupt pixel and non-corrupt pixel, then remove the noise from the image. The proposed filter is consisting of two stages. In the first stage, it discovers the impulse noise in the image based on the intensity values. And then it removes the impulse noise from the image. The experimental results for testing 100 images exhibited that the proposed filter can eliminate the noise from highly corrupted images up to 95% noise with less than 2.7 seconds.

In particular, many researchers focused on improving filters and approved their success in removing noise from images. Fabijańska, A. [14], proposed a median two-pass filter that is used to remove impulse noise from corrupted images in variety of applications. However, median two-pass filter can deal with all image pixels equally which will cause removing of fine details such as corner, thin lines and blurring. The testing results prove that the proposed filter is much better than traditional approaches. It reconstructs a noisy image presenting different details accurately matches the original source. Besides, it can use for image enhancement as portable stage in any digital image processing and analysis applications. BeniwalPreeti, Tarunjeet Singh, 2013 [15], proposed hybrid filter using median and wiener filters. Hybrid filters are useful to remove either impulsive or Gaussian from the image. These encompass the median filter and wiener filters. Combination of these filters has been proposed to remove mixed types of noise during image processing from corrupted images. Median filter is used to reduce noise (salt & pepper). Median filter characterizes with removing noise and preserve image details unlike some other filters like mean filter that remove noise vastly and losing some details. TomasiC., and Manduchi R. [16], proposed Bilateral filter to preserve image detail and smoothing. It is a nonlinear filter based on collection of nearby values of image. This filter combines colors or gray levels according to their photometric similarity and also on geometric closeness. It deals with nearest values whether in range or in domain. However, the filters of color images work on three bands independently, a bilateral filter can impose the cognitive measure based on preserve edges, smooth colors and CIE-Lab color space in similar way of human perception. Moreover, unlike standard filter, the bilateral filter reduces untrue colors and produces untrue in color images in the original image. V.R. Vijaykumar, et al. [17] proposed a nonlinear filter called detail preserving median, which can remove two noises type salt and pepper noise and random valued impulse noise.

The proposed filter corrupted the impulse pixel using a threshold values and then replaced uncorrupted pixels in the filtering window by the median value. The proposed filter could accurately with noise up to 70% with less time and computation in comparison with other techniques. Deng, X., Xiong, Y. and Peng, H. [18] introduced weighted median filter using noise detection to detect noise points in image, then resize filtering window adaptively based on points number of noise in the window. Noise points are grouped together adaptively using some rules with specific weight to each group of points depending on similarity. At the end, detected noise is processed using weighted median filtering algorithm. R.Pushpavalli, G.Sivarajde, 2013 [19], proposed a hybrid filter from neural network and fuzzy system called Adaptive Neuro-fuzzy Inference System (ANFIS). The proposed combines a Nonlinear Filter (NF) and Canny Edge Detector (CED). Besides, the proposed filter is performed effectively for removing the impulse noise from the image by implementing an excellent line, edge, and fine detail preservation. The experimental tests proved that the hybrid filter is efficient restoration of digital images with impulse noise and keeping the useful features in the image. Bansal, Upma, et al. 2015 [20] presented a hybrid filter to deal with noise in digital gray image that often notably in scanned documents. Generally, i.e. scan text, image, data can be degraded by an additive noise during scanning process. The expected result from the designed filter is to remove such noise like salt & pepper (SP Noise). The proposed filters designed to remove white and black spots after taking some knowledge about Median Filter and adaptive filter to remove image noise and other distortion. The methodology is based on applying Adaptive Histogram Equalization on original image, then apply Adaptive Contrast Enhancement Technique on the output image. After that, apply filters Such as Homomorphic filtering to get finally free noisy image.

V. PERFORMANCE EVALUATION

Different metrics are suggested to measure the performance filters on different types of images with different parameters. Matlab 2010 framework is selected as a best simulator to evaluate the performance of smoothing filters in image processing, by using one or more of the following performance metrics:

- Mean Square Error (MSE)

Mean Square Error measures the error difference between resulted image and original image and error rate is calculated as in equations 1 and 2

$$MSE = (\frac{1}{M} * N) \sum_{i=1}^{M} \sum_{i=1}^{M} (a_{ij} - b_{ij})^2 \; .... \; 1$$

Also, color image can be defined as in equation 3-2:

$$MSE = \frac{1}{M*N*3} \sum_{c=1}^{3} \sum_{y=1}^{N} \sum_{x=1}^{M} [F^c(x,y) - F^{c\sim}(x,y)]\text{^}2 \; .... \; 2$$

Where:

M x N: represent width and height (image size) of image.

C=1 to 3: refers to Green, Red and Blue color.

$F^c(x,y)$: Position (x, y) of pixel value in original image, c is the color plane.

$F^{c\sim}(x,y)$: Position (x, y) of pixel value in deteriorate image, c is the color plane.

- Mean Absolute Error (MAE)

Represent MAE value of original image and effected image. It refers to the average value of given deviation for each pixel that belongs to the original image, as given by equation 3:

$$MAE = \frac{1}{M*N*3}\sum_{c=1}^{3}\sum_{y=1}^{N}\sum_{x=1}^{M} Abs[F^{c}(x,y) - F^{c\sim}(x,y)]\text{^}2 \quad \ldots\ldots 3$$

Where:
M x N: represent width and height (image size) of image.
C=1 to 3: refers to Green, Red and Blue color.
$F^{c}(x,y)$: Position (x, y) of pixel value in original image, c is a color plane.
$F^{c\sim}(x,y)$: Position (x, y) of pixel value in deteriorate image, c is a color plane.

- Peak Signal to Noise Ratio (PSNR):

This parameter represents how much the similarity between resulting image and the original image. Also, the value is increases whenever the rate of similarity increases. PSNR equation is defined by equation 4:

$$\text{PSNR} = 10\log_{10}\left(\frac{MAX^2}{MSE}\right) \quad \ldots\ldots 4$$

Where
MAX: represent maximum possibility of pixel value in the image. MAX can be represented by 8 bit which equal to 255 for image.

- Perceptual Quality

It is working with low MAE, MSE and high PSNR instead of working with deteriorate image that expected to be clean and smooth. Also, it should be fine and looks natural for human observer. It should not have odd looking structure or color blurriness.

- Time Complexity

To estimate the consuming time in the processing task, the "tic" and "toc" function is used. The "tic" is used in the beginning of program process and "toc" at the end of processing:
Tic % start time of processing
% processing code.
Toc % the end time of processing (final value)
Toc function give the total consuming time at the end of processing. "tic" and "toc" function measure the speed of filter processing.

VI. Discussion and Case Study

The subject of image processing and enhancement is an important subject that needs a continuous study for discovering new algorithms that meet the requirements of modern technology. For example, there is a great interest in compressing the image to reduce the amount of data necessary to describe the image to reduce the size of storage and increase the speed of transmission and sharing images over the Internet. Hence, it generates less visible images, and deformation may occur with some image characteristics. And also use the electronic reader and scanner in the conversion of a hard copy of pictures on paper to digital images may result in the appearance of some noise in the picture. It is, therefore, useful to continue working towards the discovery of new algorithms suited to the requirements of processing and improving digital images.

Also, discover new algorithms to isolate the distinctive elements in the picture from the other components and identify the unique edges or similar parts regarding colour or engraving of the primary functions.

However, the filter can be used to adjust and improve the image for highlighting the desired features of the image such as detect edges or remove some defects such as blurry. Some researchers have addressed the use of filter models based on combining two or more filters in one to remove more than one noise at the same time like in [15,16,17].

The case study is implemented using Salt and Pepper noise filter with a mask window of 3X3 using different images like cameraman.tiff and spine.tiff, which is given good results in comparing with WMF and other filters. The MSE of current filter using cameraman is 0.456146, PSNR is 51.5398. Also, The MSE of (WMFS) filter using spine is 0.232224, and it achieved a PSNR is 54.4717. The result of implementation of Salt and Pepper noise filter is depicted in Figure 7.

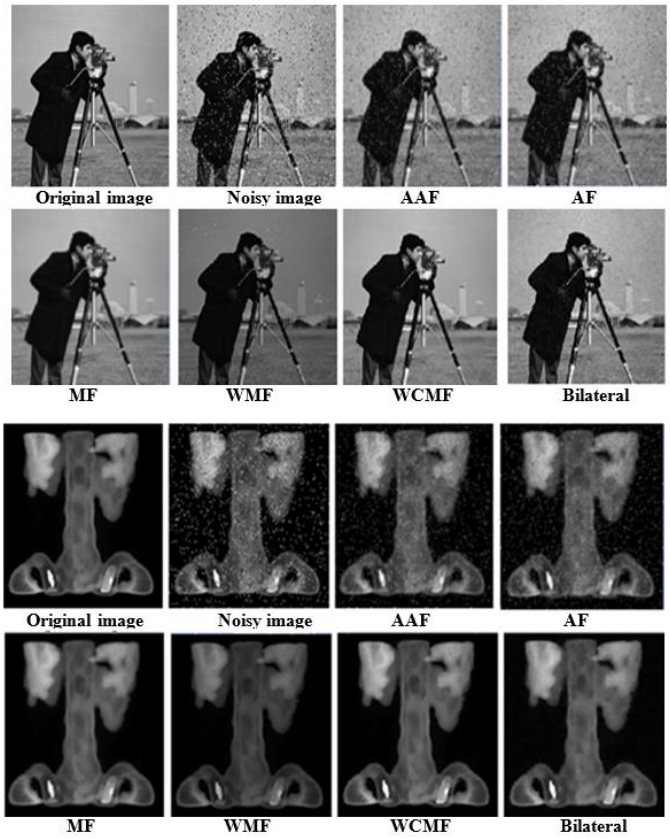

Figure 7: Results of Proposed filter and WMF using Salt &Pepper

Figures 8,9,10 show the results of current filter, which is capable in removing both types of noises either from cameraman or spine image and keeping image details. Moreover, the contrast of image is improved using current Weighted Median Filter (WMF) filter compared with the original Weighted Median Filter.

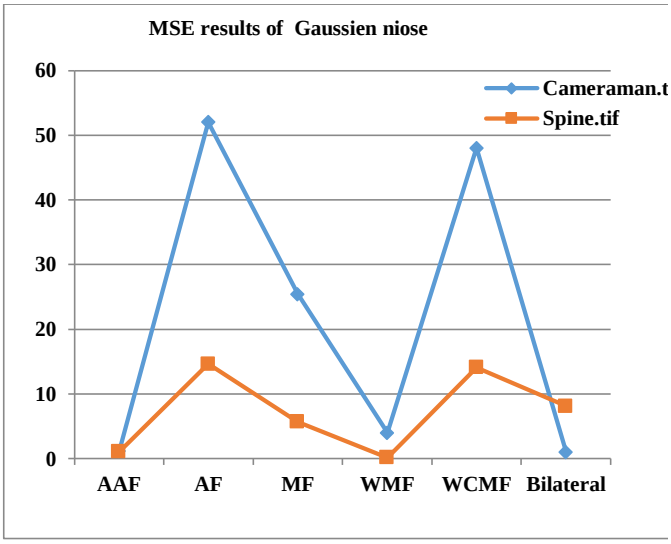

Figure8 : MSE result using Gaussian noise

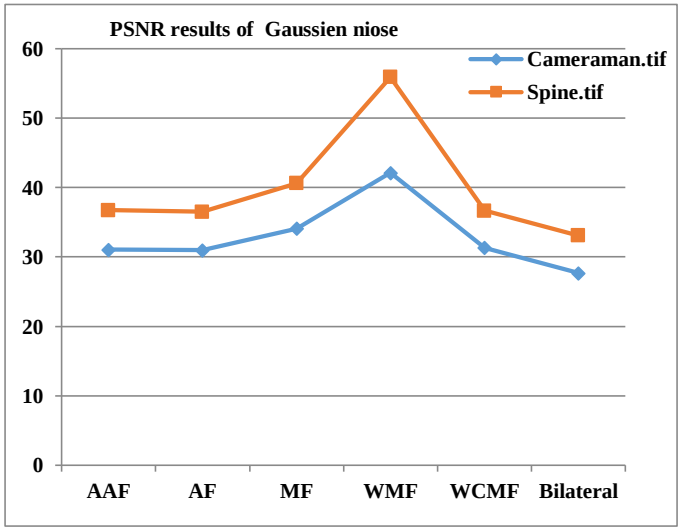

Figure 9 : PSNR result using Gaussian noise

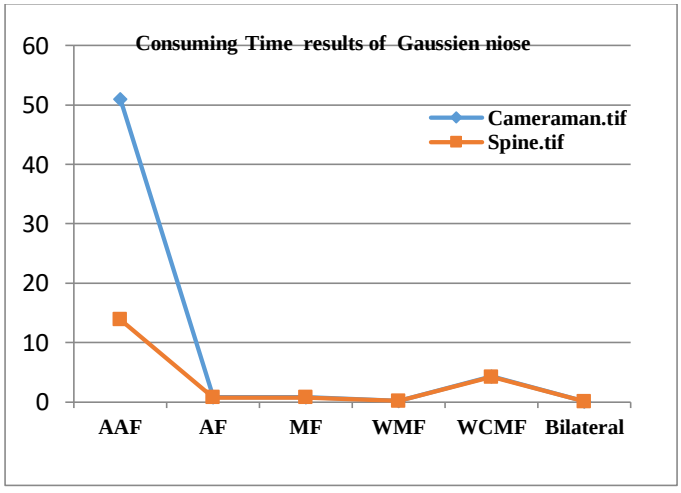

Figure 10: The results of Consuming Time using Gaussian noise

TABLE 1: the results of using salt & pepper noise and a mask window of 3x3

Filter type	Parameter	Cameraman Image	Consuming Time	Spine Image	Consuming Time
WMFS	MSE	0.456146	0.624004	0.23222	0.156001
		51.5398		54.4717	
AAF	PSNR	1.38841	44.0423	1.04521	43.0951
	PSNR	31.6921		31.7865	
AF	MSE	44.8455	0.82685	44.6459	0.748805
	PSNR	31.6136		31.633	
MF	MSE	25.4244	0.84240	5.6693	0.733205
	PSNR	34.0783		40.5955	
WMF	MSE	2.56035	0.15600	0.26992	0.156001
	PSNR	44.0478		53.818	
WCMF	MSE	13.9055	4.52403	1.62262	4.21203
	PSNR	36.6989		46.0286	
Bilateral	MSE	1.00237	0.06698	8.2672	0.058076

And the results of deploying the Salt & Pepper noise using window mask of 3X3 is shown in Table1.

VII. CONCLUSION

This paper discussed and reviewed number of enhancement techniques in the area of digital image processing. However, this paper did not focus on the computational cost of enhancement techniques which is an important criterion for real time applications. The paper addressed that implementing a hybrid algorithms based a combination of effective techniques help to produce the best results in image enhancement. Besides, it deployed a fuzzy and neural network as a filtering algorithm help to remove two or more noise type in the same time. Also, based on implementing different transmission techniques in sending and receiving digital images, a new noise type is introduced. Therefore, still need more research and efforts to discover new filters type that could applied for new types of noise.

Beside, a case study of deploying a salt and pepper noise on cameraman and spin images is presented and addressed using MATLAB software. A graphical user interface is implemented and design for testing the proposed filter. The GUI is consisting of many phases like read the image and then converts it to a binary form. And then, adding the suitable type of noise based on certain percentage of noise. Implementing different types of fillers and histogram like equalization and adaptive. The results show that the current proposed filter is efficient and accurate. For the sake of improving image quality, filters based on neural models [21,22] could adopt as noise removal. The application of cloud computing

technologies [23] to access data quickly and accurately, which could help to improve the image appearance.

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