Image Denoising using Brute Force Thresholding Algorithm

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Abstract- **The field of image processing grew from electronic engineering as an extension of the signal processing branch. The massive amount of data required for the development of many sub areas within the field of communication system. Visual information transmitted in the form of digital images is becoming a major method of communication in the modern age, but the image obtained after transmission is often corrupted with noise. The received image needs processing before it can be used for further applications. The main challenge in digital image processing is to remove noise from the original image. Hence, it is very essential to keep the data close to originality. Different noise models including additive and multiplicative types are discussed in the paper. Selection of the denoising algorithm is application dependent. Hence, it is necessary to have knowledge about the noise present in the image so as to select the appropriate denoising algorithm. In this paper, a new threshold estimation technique has been presented. And a comparative analysis of different denoising methods has been carried out very efficiently. The simulation results show that the proposed threshold estimation technique has superior features compared to conventional methods. This makes it an efficient method in image denoising applications; it can also remove the noise and retain the image details better. Image filtering algorithms are applied on images to remove the different types of noise that are either present in the image during capturing or injected in to the image during transmission. The performances of the filters are compared using the Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE).**

Keywords- Gray scale Image, Noise, Salt-and-pepper noise, Gaussian Noise, Random Noise Denoising Technique , Median Filter, Adaptive Median Filter (AMF), Threshold function , Brute force thresholding Peak Signal-to-Noise Ratio (PSNR), Mean Square Error (MSE), , Root Mean Square Error,

I. INTRODUCTION

In information age also known as computer age or digital age, visual knowledge and material is often transmitted in the form of digital images. Digital images plays very significant role in our daily routine like they are used in satellite television, Intelligent traffic monitoring, handwriting recognition on checks, signature validation, computer resonance imaging and in area of research and technology such as geographical information systems and astronomy. A digital image can be describe as two dimensional image as a finite set of discrete values, known as picture elements or pixels. Pixel ideals typically represent grey levels, colors, heights, opacities etc. Image processing is any form of signal processing for which the input is an image, such as photographs or frames of video and the output of image processing can be either an image or a set of characteristics or parameters related to the image. In image processing system depends on its ability to detect the presence of noisy pixels in the image. Image Processing is the analysis of a picture using different techniques that can identify relationships, shades and colors that cannot be perceived by the human eye. Image processing is a way to change an image into digital form and implement some operations on it, in order to get an image with increased quality or to obtain some useful information from it. Significant works have been done in both hardware and software to improve the signal-to-noise ratio for images. In software, a denoising filter is used to remove noise from an image. Each pixel is represented by three scalar values representing the red, green, and blue chromatic intensities. At each pixel studied, a filter takes into account the surrounding pixels to derive a more accurate version of this pixel. By taking neighboring pixels into consideration extreme “noisy” pixels can be replaced. However, outlier pixels may represent in corrupted fine details, which may be lost due to the smoothing process.

The several reasons due to which an image can reduce its quality or get corrupted are-motion between camera and object, improper opening of the shutter, atmospheric disturbances, misfocusing etc. Noise is addition of undesired components in the image that degrades the visual quality of an image. This undesired constituent needs to be removed before the process of retrieving the original image is to be start. The digital image acquisition process converts an optical image taken with an optical device into a continuous stream of electronic signals that is later sampled in the primary process by which noise appears in digital images. In some case when the images are sent by the sender, images get corrupted with undesirable noise & unwanted elements after transmission. In some cases noise gets intruded in the image at the time of acquisition. It is generally caused by malfunctioning of camera sensors, faulty memory locations in hardware or transmission in a noisy channel. Thereby receiver in many cases receives images with diminished quality. Therefore received images require processing before they can be used in various applications.

Image restoration or denoising is required, to make a visually high quality image, which includes the process of changing, correcting or moving of the image data to produce noise free image. Denoising is the pre-processing step in the Image Enhancement process. Denoising is necessary and first step to be taken before the image data is analyzed for further use. Because after introducing the noise in image, the important details and features of image are destroyed. It is necessary to apply efficient denoising technique to compensate for such data corruption. Image denoising is used to remove the noise while retaining as much as possible the important signal features. The purpose of image denoising is to estimate the original image from the noisy data.

Denoising is more significant than any other tasks in image processing, analysis and applications. Preserving the details of an image and removing the random noise as far as possible is the goal of image denoising approaches. Besides the noisy image produces undesirable visual quality, it also lowers the visibility of low contrast objects. Hence noise removal is essential in digital imaging applications in order to enhance and recover fine details that are hidden in the data. In many occasions, noise in digital images is found to be additive in nature with uniform power in the whole bandwidth and with Gaussian probability distribution. Digital images are corrupted by noise during image acquisition or transmission process. There are different types of noises in digital images.

II. NOISES IN DIGITAL IMAGES

In common use the word noise means unwanted sound or noise pollution. Image noise is the random variation of brightness or colour information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise is considered as an undesirable by-product of image capture. The types of noises are as follows:-

1. *Salt-and-pepper noise*- As the name suggests, this noise looks like salt and pepper. It gives the effect of "On and off" pixels. An image with salt-and-pepper noise contains dark pixels at bright regions and bright pixels at dark regions.[6]
2. Gaussian *noise (Amplifier noise)*- The standard model of gaussian noise is accessory. Gaussian noise is independent at each pixel and independent of the signal intensity.
3. Random noise- random noise is characterized by intensity and color fluctuations above and below the actual image intensity. There will always be some random noise at any exposure length and it is most influenced by ISO speed. The pattern of random noise changes even if the exposure settings are identical.

III. DENOISING TECHNIQUE

Image analysis is easy task after noise is filtered. An engineer working in signal processing has different meaning of the term filter which requires certain operations which tell us the area of interest in the image. Image filters may be used to highlight edges that is, parts of objects in images or boundaries between objects**.** Filters provide better visual interpretation of images, and can also be used as a predecessor to further digital processing, such as segmentation. Image Denoising is the process of obtaining the original image from the degraded image if value of the degrading factors is known. It is used to eliminate the noise from the corrupted image while retaining the edges and other major detail without hampering the visual information of image.

Two types of filtering technique- linear and Non-linear filtering techniques are discussed below:
1. Linear filters: The approach output values are linear function of the pixels in the original image. Linear methods are easy to analyze mathematically than the nonlinear Filters
2. Non-linear filters: These filters have accurate results because they are able to reduce noise levels without blurring the edges.

Regular median filtering

Median Filter Median filter is a best order static, non-linear filter, whose response is based on the positioning of pixel values on basis of rank contained under the filter region. The Median Filter performs filtration by taking the magnitude of all of the vectors within a mask and sorted according to the magnitudes. The pixel with the median magnitude is then used to replace the pixel studied. The median of a set is more robust with respect to the presence of noise. The median filter is given by

$$\text{Median filter}(x_1 \ldots x_N) = \text{Median}(\|x_1\|^2 \ldots\ldots \|x_N\|^2)$$

Median filter yields good result for salt and pepper noise. These filters are basically smoothers for image processing as well as in signal processing. The benefit of the median filter over linear filters is that the median filter can remove the effect of input noise values with huge magnitudes which means median filter can eliminate the effect of input noise values with extremely large magnitudes.

Adaptive median filtering

Traditional median filter doesn't take into consideration for how image characteristics vary from one location to another. It replaces every point in the image by the median of the corresponding neighborhood. Adaptive filters are capable of denoising non-stationary images that is, images that have abrupt changes in intensity. Such filters are known for their ability in automatically tracking an unknown circumstance or when a signal is variable with little a priori knowledge about the signal to be processed [20].The Adaptive Median Filter performs processing to determine which pixels in an image have been affected by noise. It classifies pixels as noise by comparing each pixel in the image to its surrounding neighbor pixels. A pixel that is different from a majority of its neighbors, as well as being not structurally aligned with those pixels to which it is similar, is designated as impulse noise. These noisy pixels are then replaced by the median value of the pixels in the neighborhood that have passed the noise detection test. The output of the filter is a single value used to replace the value of the pixel at *(x, y).* Consider the following notation:

Z_{min} = minimum intensity value in S_{xy}
Z_{max} = maximum intensity value in S_{xy}
Z_{med} = median of the intensity values in S_{xy}
Z_{xy} = intensity value at coordinates (x, y)
S_{max} = maximum allowed size of S_{xy}

Guassian filtering

Gaussian filter is windowed filter of linear class by its nature is weighted mean. Named after a famous scientist Carl Gauss, because weights in the filter are calculated according to Gaussian distribution. The Gaussian filter is known as a 'smoothing' operator, as its convolution with an image averages the pixels in the image, affectively decreasing the difference in value between neighboring pixels. In addition to applications such as feature extraction, filters can be used for denoising signals and images. Many different filters can achieve this purpose and the optimal filter often depends on the particular requirements of the application. One such filter is called a Gaussian, so named because the filter's kernel is a discrete approximation of the Gaussian (normal) distribution. The Gaussian filter is known as a 'smoothing' operator, as its convolution with an image averages the pixels in the image, affectively decreasing the difference in value between neighboring pixels.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

Gaussian distribution has surprising property. Look, its expression could be rewritten as:

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{y^2}{2\sigma^2}} = G(x)G(y)$$

The σ parameter in equation is equal to the standard deviation of the Gaussian, and can be adjusted according to the desired distribution.

Bilateral filter

Bilateral filtering is a technique to smooth images while preserving edges. It can be traced back to 1995 with the work of Aurich and Weule [4] on nonlinear Gaussian filters. It was later rediscovered by Smith and Brady as part of their SUSAN framework, and Tomasi and Manduchi who gave it its current name. Since then, the use of bilateral filtering has grown rapidly and is now ubiquitous in image processing applications. It has been used in various contexts such as denoising, texture editing. The bilateral filter has several qualities that explain its success:

• Its formulation is simple: each pixel is replaced by a weighted average of its neighbors. This aspect is important because it makes it easy to acquire intuition about its behavior, to adapt it to application-specific requirements, and to implement it.

• It depends only on two parameters that indicate the size and contrast of the features to preserve.

• It can be used in a non-iterative manner. This makes the parameters easy to set since their effect is not cumulative over several iterations.

IV. THRESHOLDING FUNCTION

PROPOSED THRESHOLD METHOD

Finding an optimized value (λ) for threshold is a major problem. A small change in optimum threshold value destroys some important image details that may cause blur and artifacts. So, optimum threshold value should be found out, which is adaptive to different sub band characteristics. Here we proposed a new threshold estimation technique which gives an efficient threshold value for noise to get high value of PSNR as compared to previously explained methods.

Brute Force Thresholding

Threshold follows the same concept as in basic electronics, Brute force Threshold is given 5 times the maximum pixel intensity, which will be 127 in most of the images. Brute force thresholding always outclass other existing thresholding techniques in terms of better results. Algorithm for brute force thresholding is given

- Input wavelet sub band.
- Find maximum (max) and minimum (min) value of sub band coefficients.
- loop through (threshold=min to max) and execute desired algorithm
- save the results in array for each loop such that F= [threshold, result]
- When loop completed, select the (threshold) that gives best result.

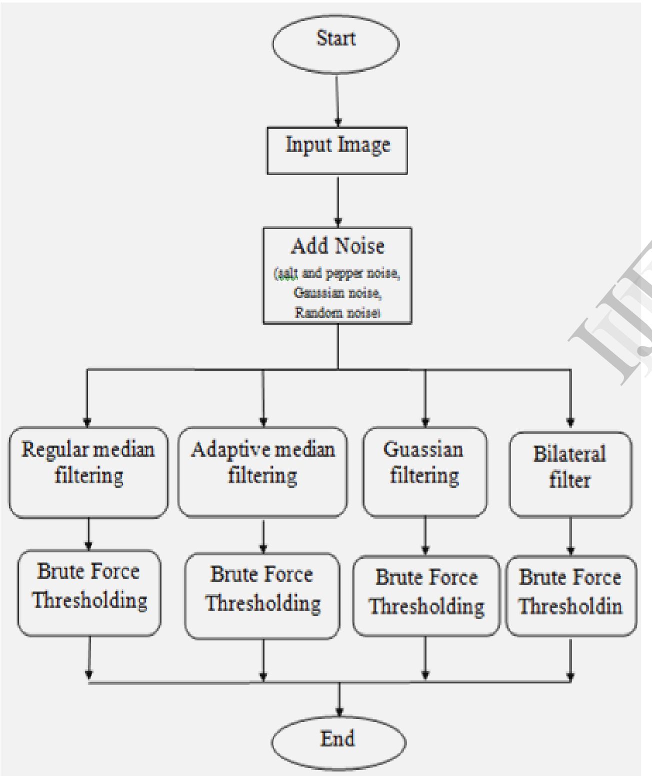


Fig. Flow Chart of proposed Algorithm

V. SIMULATION AND PERFORMANCE ANALYSIS RESULTS

This method has been implemented using Matlab as the simulation tool. The proposed filter is tested with Image' Lena.bmp' of size 512 x 512. The image is corrupted by salt and pepper noise, Gaussian noise, Random noise at various noise densities and performance is measured using the parameters such as Signal-to-Noise Ratio (SNR), Peak-Signal-to-Noise Ratio (PSNR), Mean Absolute Error (MAE), Mean Square Error (MSE), and Universal Quality Index (UQI).The parameters used to define the performance are:

Mean Square Error (MSE)

In statistics and signal processing, a Mean square error (MSE) estimator describes the approach which minimizes the mean square error (MSE), which is a common measure of estimator quality.

The MSE estimator is then defined as the estimator achieving minimal MSE. In many cases, it is not possible to determine a closed form for the MMSE estimator. In these cases, one possibility is to seek the technique minimizing the MSE within a particular class, such as the class of linear estimators. The linear MSE estimator is the estimator achieving minimum MSE.

$$MSE = \frac{\sum \left(Is(r,c) - Id(r,c) \right)^2}{R \times C}$$

Where R*C is the size of image.
Is = original Image
Id = Despeckled Image

Root Mean Square Error (RMSE)

In mathematics, the root mean square (abbreviated RMS or rms), also known as the quadratic mean, is a statistical measure of the magnitude of a varying quantity. It is especially useful when variations are positive and negative, e.g., sinusoidal. RMS is used in various fields, including electrical engineering; one of the more prominent uses of RMS is in the field of signal amplifiers. It can be calculated for a series of discrete values or for a continuously varying function. The name comes from the fact that it is the square root of the mean of the squares of the values. It is a special case of the generalized mean with the exponent p = 2. The RMS value of a set of values (or a continuous-time waveform) is the square root of the arithmetic mean (average) of the squares of the original values (or the square of the function that defines the continuous waveform). The RMS over all time of a periodic function is equal to the RMS of one period of the function. The RMS value of a continuous function or signal can be approximated by taking the RMS of a series of equally spaced samples.

$$\text{RMSE} = \frac{2550}{e^{PSNR/20}}$$

Peak to Signal Noise Ratio (PSNR)

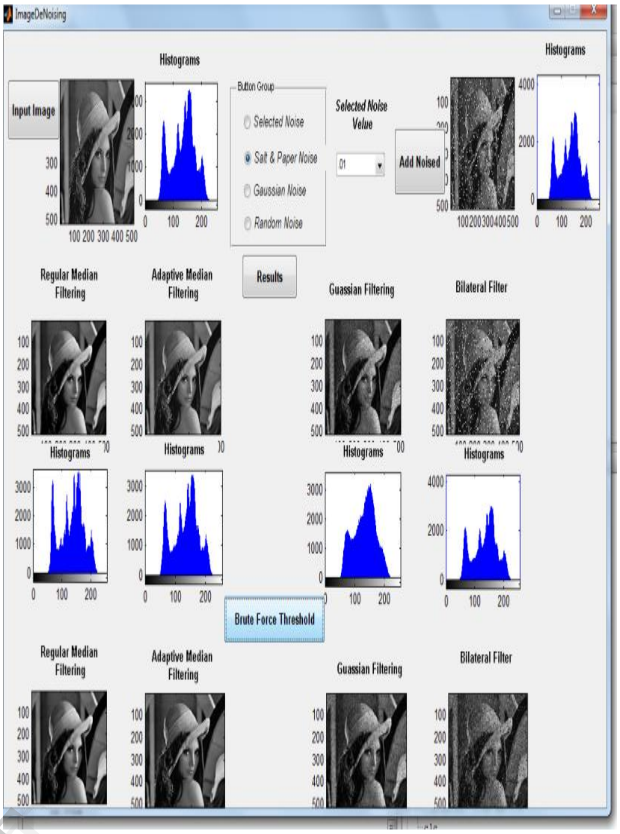
The phrase peak signal-to-noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the (or codec type) and same content. It is most easily defined via the mean square error (MSE) which for two m×n monochrome images I and K where one of the images is considered a noisy approximation of the other is defined as:

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

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

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

Results on LENA image:



SALT AND PEPPER NOISE												
NOISE VALUE	REGULAR MEDIAN FILTER			ADAPTIVE MEDIAN FILTER			GAUSSIAN FILTER			BILAERAL FILTER		
	PSNR	RMSE	MSE	PSNR	RMSE	MSE	PSNR	RMSE	MSE	PSNR	RMSE	MSE
0.01	41.1983	325.03525	10564.791	35.1217	440.435	19398.3285	36.8014	404.9561	16398.9434	16.7524	1103.485	121767.9159
0.02	40.7791	331.919	11017.081	34.4899	454.571	20663.4596	34.3334	458.1478	20989.3865	13.9173	1271.5395	161681.2662
0.03	40.096	343.45	11795.9577	34.2441	460.1919	21177.6611	32.8651	493.0416	24309.0061	12.178	1387.0697	192396.2225
0.04	39.5327	353.26	12479.45	33.6563	473.9176	22459.7969	31.52	527.3417	27808.922	10.9586	1474.2706	217347.3803
0.05	39.0637	361.645	13078.725	32.9858	490.075	24017.3601	31.0604	539.6003	29116.8459	10.0506	1542.7451	238006.243
0.06	35.2534	437.544	19144.5275	32.3925	504.831	25485.4296	30.2989	560.5417	31420.6998	9.3158	1600.4796	256153.5077
0.07	26.3897	681.545	46450.4845	31.3602	531.5719	28256.8782	29.3689	587.2224	34483.0157	8.6812	1652.0771	272935.8823
0.08	19.4085	966.25	93364.1001	31.0209	540.667	29232.0849	28.9744	598.9204	35870.56	8.1585	1695.823	287581.6743
0.09	15.275	1188.0857	141154.7658	26. 2137	687.5699	47275.2501	28.7105	606.8755	36829.7854	7.6769	1737.1544	301770.5331

GAUSSIAN NOISE												
NOISE VALUE	REGULAR MEDIAN FILTER			ADAPTIVE MEDIAN FILTER			GAUSSIAN FILTER			BILAERAL FILTER		
	PSNR	RMSE	MSE	PSNR	RMSE	MSE	PSNR	RMSE	MSE	PSNR	RMSE	MSE
0.01	21.755	859.2833	73836.7743	24.5914	745.6666	55601.87392	40.1721	342.14808	11706.53115	34.7098	449.60015	20214.0297
0.02	19.3909	967.1017	93528.56562	19.4198	965.7052	93258.65827	35.7392	427.04468	18240.36334	24.0941	764.44008	58436.86288
0.03	18.0905	1032.0719	10657.2458	16.7589	1103.1264	121688.7925	33.4013	479.9988	23039.88638	18.058	1033.7504	106863.99
0.04	17.1594	1081.256	116911.461	15.4261	1944.079	139037.9482	32.1996	509.72361	25981.81589	14.9385	1208.2444	145985.442
0.05	16.1941	1134.7228	128759.5748	14.759	1219.1372	148629.5405	31.3058	533.01984	28411.0145	13.0594	1327.2689	176164.2686
0.06	15.629	1167.2416	136245.2955	14.4522	1237.9829	153260.1653	30.8008	546.64994	29882.61593	11.9793	1400.9189	196257.3689
0.07	15.1183	1197.431	143384.0801	14.3226	1246.0311	155259.3438	30.1304	565.28421	31954.62425	11.1389	1461.0398	213463.7234
0.08	14.7042	1222.4822	149446.2661	14.2715	1249.2188	156054.7495	29.8758	572.52628	32778.63412	10.6144	1499.8624	224958.7164
0.09	14.3745	1242.8018	154455.6352	14.2523	1250.4186	156354.6625	29.7046	577.44814	33344.63548	10.1468	1535.3423	235727.6008

RANDOM NOISE												
NOISE VALUE	REGULAR MEDIAN FILTER			ADAPTIVE MEDIAN FILTER			GAUSSIAN FILTER			BILAERAL FILTER		
	PSNR	RMSE	MSE	PSNR	RMSE	MSE	PSNR	RMSE	MSE	PSNR	RMSE	MSE
0.01	21.7204	860.7711	74092.692	24.5929	745.6101	55593.534	40.1883	341.8717	11687.58193	34.7374	448.98013	20158.31593
0.02	19.5644	958.7243	91915.2451	19.3752	967.8613	93675.5208	35.8239	425.2399	18082.90297	24.1795	761.1829	57939.93696
0.03	18.0618	1033.554	106823.3894	16.7638	1102.8561	121629.1796	33.4627	478.5275	22898.85489	18.1256	1030.2622	106144.0256
0.04	16.8454	1098.3657	120640.7239	15.3963	1180.9018	139480.7926	32.0197	514.3293	26453.45846	14.9829	1205.565	145338.7034
0.05	16.2162	1133.4696	128475.3304	14.7584	1219.1737	148638.4585	31.1498	537.19364	28857.70142	13.1996	1317.9973	160624.1083
0.06	15.6332	1166.9965	136188.0845	14.4684	1236.9805	153012.0849	30.4672	555.845	30896.31448	12.0091	1398.8331	195673.3925
0.07	15.0829	1199.5522	143892.5592	14.3076	1246.9659	155492.4076	30.1314	565.25595	31951.42895	11.1539	1459.9444	213143.7678
0.08	14.7514	1219.6005	148742.5418	14.2411	1251.119	156529.8778	29.8531	573.1765	32853.12613	10.5665	1503.4589	226038.8539
0.09	14.4486	1238.2056	153315.3489	15.2411	1190.1012	141634.0905	29.8211	574.0943	32958.42453	10.1916	1531.907	234673.9032

VI. CONCLUSION

In this paper, we have proposed a new threshold estimation technique in which a gray scale image in 'bmp' format is injected salt and pepper noise, Gaussian noise, Random noise. Further, the noised image is denoised by using different filtering and Thresholding techniques ("Brute Force Thresholding"). A particular algorithm is to be selected according to the noise present in the image. The proposed threshold mentioned in this paper shows better performance over other techniques. Thus we can say that the proposed threshold may find applications in image recognition system, image compression, medical ultrasounds and a host of other applications.

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