International Journal of Advanced Scientific Technologies, Engineering and Management Sciences (IJASTEMS-ISSN: 2454-356X) Volume.3,Special Issue.1,March.2017

Performance of Arithmetic Mean Filter with different kernel sizes in removing Poisson Noise

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Abstract---Image Processing has become one of the most promising areas of research. Images are easily susceptible to different types of noise such as Gaussian noise, Salt and pepper noise, Speckle noise, Poisson noise etc. The present work analyzes the performance of the Arithmetic mean filter with different kernel sizes in the context of removing Poisson noise. Mean Squared Error and Peak Signal to Noise Ratio have been considered as parameters for performance evaluation. The results obtained show that for a kernel of size n×n, where n≥3, when applied with Arithmetic mean filter to Poisson noise corrupted images, the Mean squared error obtained between the original image and the filtered image increases with the increasing value of n. It is also evident that the filtered images obtained from Poisson noise corrupted images by applying Arithmetic mean filter of increasing kernel size go on blurring.

Index terms--- Arithmetic Mean Filter, kernel, Poisson Noise

I. INTRODUCTION

An image may be defined as a two dimensional function, $f(x, y)$, where x and y are spatial coordinates and the amplitude of f at any pair of coordinates (x, y) is called the intensity of the image at that point. Noise in an image refers to any degradation caused in an image signal. The sources of noise in digital images arise during image acquisition and transmission. A noisy image can be modeled as $g(x,y) = f(x,y) + n(x,y)$ where $f(x,y)$ is the original image pixel, $n(x,y)$ is the noise term and $g(x,y)$ is the noisy image pixel. The different models for noise term $n(x,y)$ are Gaussian, Rayleigh, Erlang, Exponential, Uniform, Poisson etc. Poisson noise is a type of electronic noise which can be modeled by a Poisson distribution. The probability distribution of a Poisson random variable is called Poisson distribution. The probability density function of Poisson distribution is given by $P(x,u) = \frac{e^{-\mu}\mu^{x}}{x!}$ Where P(x,μ) represents the Poisson probability that exactly x successes occur in a Poisson experiment, when the mean number of successes is μ. e is a constant approximately equal to 2.71828. x is the actual number of successes that occur in a specified region. μ is the mean number of successes that occur in a specified region.

Filtering is a technique for modifying or enhancing an image. Filtering is a neighborhood operation, in which the value of any given pixel in the output image is determined by applying some algorithm to the values of pixels in the neighborhood of the corresponding input pixel. A pixel's neighborhood is some set of pixels, defined by their locations relative to that pixel, which is called the center pixel. A kernel is a small matrix useful for blurring, sharpening, embossing, edge-detection etc. The center pixel is the actual pixel in the input image being processed by the operation. If the neighborhood has an odd number of rows and columns, the center pixel is actually in the center of the neighborhood. If one of the dimensions has even length, the center pixel is just to the left of center or just above center. For any m-by-n neighborhood, the center pixel is Floor (([m n] +1)/2). Image filtering is useful for many applications, including smoothing, sharpening, removing noise, and edge detection.

Arithmetic mean filter is one of the simplest filters. Let S_{xy} represent the set of coordinates in a rectangular sub image window of size $m \times n$, centered at point (x,y).The arithmetic mean filtering process computes the average value of the corrupted image $g(x,y)$ in the area defined by S_{xy}. The value of the restored image f at any point (x,y) is simply the arithmetic mean computed using the pixels in the region defined by S_{xy}. In other words $\hat{f}(x,y) = \frac{1}{mn}\sum_{(s,t)\in S_{xy}} g(s,t)$.This process will be repeated for each pixel in the corrupted image. This can be understood with the help of the following example. Let us assume the following 10×10 matrix represents the intensities in a noisy image and how it will be changed when arithmetic mean filter is applied to the noisy image.

Arithmetic Mean of the pixel intensities in 3×3 kernel

3×3 Kernel

5×5 Kernel

150	150	10	150	150	150	150	150	150	150
150	150	10	150	150	150	150	150	150	150
10	10	10	10	10	10	10	10	10	10
150	150	10	150	150	150	150	150	150	150
150	150	10	150	150	150	150	150	150	150
150	150	10	150	150	150	150	150	150	150
150	150	10	150	150	150	150	150	150	150
150	150	10	150	150	150	150	150	150	150
150	150	10	150	150	150	150	150	150	150
150	150	10	150	150	150	150	150	150	150

$$= \frac{150+150+10+150+150+10+10+10+10}{3x3} = \frac{650}{9} = 72$$

The intensity of the center pixel in noisy image with respect to 3×3 kernel is 150 and it will be replaced by 72 after applying the Arithmetic Mean Filter with 3×3 kernel to the noisy image.

Arithmetic Mean of the pixel intensities in 5×5 kernel = $\frac{3050}{25} = 122$

The intensity of the center pixel in noisy image with respect to 5×5 kernel is 150 and it will be replaced by 122 after applying the Arithmetic Mean Filter with 5×5 kernel to the noisy image.

Mean Squared Error and Peak Signal-to-Noise Ratio have been considered as parameters for performance evaluation of Arithmetic mean filter with different kernel sizes.

Mean Squared Error (MSE) is defined as the cumulative squared error between the original image and the noise corrupted image. It is given by the following formula.

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

Where $I(i,j)$ is the original image and $K(i,j)$ is the Noise corrupted image.

Peak Signal-to-Noise Ratio (PSNR) is defined as the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. It is measured in decibels. It is given by the following formula.

$$PSNR = 10\log 10\left[\frac{MAX_I^2}{MSE}\right]$$ Where

MAX_I is the maximum possible pixel value of the image and MSE is the Mean Squared Error.

II. EXPERIMENTAL WORK AND RESULTS

Images of different sizes (1024 × 768 pixels, 1440 × 852 pixels and 1000 × 666 pixels) have been considered and then they are corrupted with Poisson noise. Then an Arithmetic Mean Filter with kernel of different sizes (2×2, 3×3, 4×4, 5×5, 6×6, 7×7, 8×8, 9×9, 10×10, 11×11, 14×14, 15×15, 24×24, 25×25, 45×45, 48×48, 64×64 and 75×75) has been applied on the images corrupted with Poisson noise and the resulting images are recorded and analyzed. Mean Squared Error and Peak Signal-to-Noise ratio has been calculated and tabulated.

TABLE 1:ANALYSIS OF THE QUALITY OF IMAGES OBTAINED AFTER APPLYING ARITHMETIC MEAN FILTER WITH DIFFERENT KERNEL SIZES ON THE POISSON NOISE CORRUPTED IMAGE OF SIZE 1024×768 PIXELS

Original Image	Image Corrupted with Poisson Noise	Image obtained after applying Arithmetic Mean Filter with kernel of size 2×2 pixels
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 3×3 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 4×4 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 5×5 pixels
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 6×6 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 7×7 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 8×8 pixels
		

TABLE 1: CONTINUED

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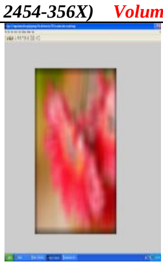
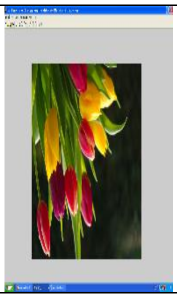
Image obtained after applying Arithmetic Mean Filter with kernel of size 9×9 pixels	**Image obtained after applying Arithmetic Mean Filter with kernel of size 10×10 pixels**	**Image obtained after applying Arithmetic Mean Filter with kernel of size 11×11 pixels**
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 14×14 pixels	**Image obtained after applying Arithmetic Mean Filter with kernel of size 15×15 pixels**	**Image obtained after applying Arithmetic Mean Filter with kernel of size 24×24 pixels**
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 25×25 pixels	**Image obtained after applying Arithmetic Mean Filter with kernel of size 45×45 pixels**	**Image obtained after applying Arithmetic Mean Filter with kernel of size 48×48 pixels**
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 64×64 pixels	**Image obtained after applying Arithmetic Mean Filter with kernel of size 75×75 pixels**	
		

TABLE 2:ANALYSIS OF THE QUALITY OF IMAGES OBTAINED AFTER APPLYING ARITHMETIC MEAN FILTER WITH DIFFERENT KERNEL SIZES ON THE POISSON NOISE CORRUPTED IMAGE OF SIZE 1440×852 PIXELS

Original Image	**Image Corrupted with Poisson Noise**	**Image obtained after applying Arithmetic Mean Filter with kernel of size 2×2 pixels**
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 3×3 pixels	**Image obtained after applying Arithmetic Mean Filter with kernel of size 4×4 pixels**	**Image obtained after applying Arithmetic Mean Filter with kernel of size 5×5 pixels**
		
Image obtained after applying Arithmetic Mean Filter	**Image obtained after applying Arithmetic Mean Filter with kernel of**	**Image obtained after applying Arithmetic Mean Filter**

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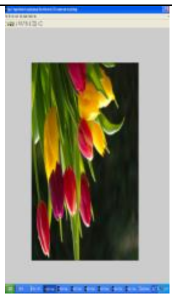
with kernel of size 6×6 pixels	size 7×7 pixels	with kernel of size 8×8 pixels
		

TABLE 2: CONTINUED

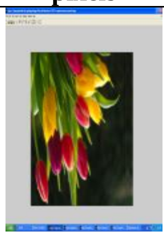
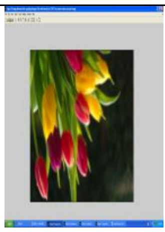
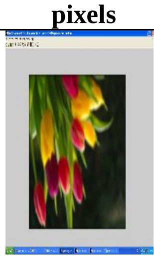
Image obtained after applying Arithmetic Mean Filter with kernel of size 9×9 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 10×10 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size11×11 pixels
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 14×14 pixels	**Image obtained after applying Arithmetic Mean Filter with kernel of size 15×15 pixels**	**Image obtained after applying Arithmetic Mean Filter with kernel of size 24×24 pixels**
		

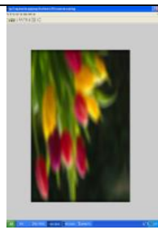
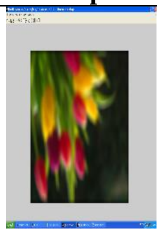
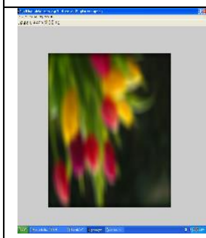
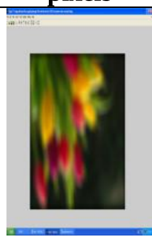
Image obtained after applying Arithmetic Mean Filter with kernel of size 25×25 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 45×45 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 48×48 pixels
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 64×64 pixels	**Image obtained after applying Arithmetic Mean Filter with kernel of size 75×75 pixels**	
		

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TABLE 3:ANALYSIS OF THE QUALITY OF IMAGES OBTAINED AFTER APPLYING ARITHMETIC MEAN FILTER WITH DIFFERENT KERNEL SIZES ON THE POISSON NOISE CORRUPTED IMAGE OF SIZE 1000×666 PIXELS

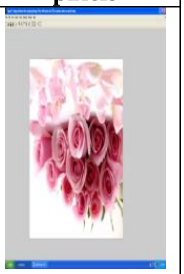
Original Image	Image Corrupted with Poisson Noise	Image obtained after applying Arithmetic Mean Filter with kernel of size 2×2 pixels
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 3×3 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 4×4 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 5×5 pixels
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 6×6 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 7×7 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 8×8 pixels
		

TABLE 3:CONTINUED

Image obtained after applying Arithmetic Mean Filter with kernel of size 9×9 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 10×10 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 11×11 pixels

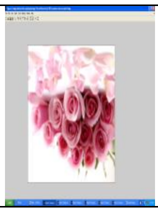



Image obtained after applying Arithmetic Mean Filter with kernel of size 14×14 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 15×15 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 24×24 pixels
		
Image obtained after applying Arithmetic Mean Filter with kernel of size 25×25 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 45×45 pixels	Image obtained after applying Arithmetic Mean Filter with kernel of size 48×48 pixels

		
Image obtained after applying Arithmetic Mean Filter with kernel of size 64×64 pixels	**Image obtained after applying Arithmetic Mean Filter with kernel of size 75×75 pixels**	
		

TABLE 4: ANALYSIS OF MEAN SQUARED ERROR AND PEAK SIGNAL TO NOISE RATIO OBTAINED FROM ORIGINAL IMAGE AND FILTERED IMAGES WHICH WERE OBTAINED FROM POISSON NOISE CORRUPTED IMAGE OF SIZE 1024×768 PIXELS BY APPLYING ARITHMETIC MEAN FILTER WITH DIFFERENT KERNEL SIZES

Kernel Size in Pixels	2×2	3×3	4×4
MSE	0.0015	9.1452e-004	0.0023
PSNR	76.3195	78.5189	74.6051

TABLE 4: CONTINUED

Kernel Size in Pixels	5×5	6×6	7×7
MSE	0.0025	0.0035	0.0039
PSNR	74.1916	72.6429	72.1665

TABLE 4: CONTINUED

Kernel Size in Pixels	8×8	9×9	10×10
MSE	0.0048	0.0053	0.0060
PSNR	71.2920	70.9032	70.3160

TABLE 4: CONTINUED

Kernel Size in Pixels	11×11	14×14	15×15
MSE	0.0065	0.0082	0.0087
PSNR	69.9995	68.9668	68.7425

TABLE 4: CONTINUED

Kernel Size in Pixels	24×24	25×25	45×45
MSE	0.0129	0.0133	0.0200
PSNR	67.0324	66.9058	65.1260

TABLE 4: CONTINUED

Kernel Size in Pixels	48×48	64×64	75×75
MSE	0.0208	0.0248	0.0272
PSNR	64.9489	64.1887	63.7882

TABLE 5: ANALYSIS OF MEAN SQUARED ERROR AND PEAK SIGNAL TO NOISE RATIO OBTAINED FROM ORIGINAL IMAGE AND FILTERED IMAGES WHICH WERE OBTAINED FROM POISSON NOISE CORRUPTED IMAGE OF SIZE 1440×852 PIXELS BY APPLYING ARITHMETIC MEAN FILTER WITH DIFFERENT KERNEL SIZES

Kernel Size in Pixels	2×2	3×3	4×4
MSE	4.7826e-004	2.1744e-004	5.9905e-004
PSNR	81.3341	84.7575	80.3562

TABLE 5: CONTINUED

Kernel Size in Pixels	5×5	6×6	7×7
MSE	6.2815e-004	9.4476e-004	9,9856e-004
PSNR	80.1502	78.3776	78.1371

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TABLE 5: CONTINUED

Kernel Size in Pixels	8×8	9×9	10×10
MSE	0.0013	0.0014	0.0017
PSNR	76.9449	76.6249	75.7985

TABLE 5: CONTINUED

Kernel Size in Pixels	11×11	14×14	15×15
MSE	0.0018	0.0025	0.0027
PSNR	75.4827	74.0801	73.8157

TABLE 5: CONTINUED

Kernel Size in Pixels	24×24	25×25	45×45
MSE	0.0046	0.0048	0.0083
PSNR	71.5174	71.3577	68.9640

TABLE 5: CONTINUED

Kernel Size in Pixels	48×48	64×64	75×75
MSE	0.0087	0.0109	0.0123
PSNR	68.7282	67.7503	67.2439

TABLE 6: ANALYSIS OF MEAN SQUARED ERROR AND PEAK SIGNAL TO NOISE RATIO OBTAINED FROM ORIGINAL IMAGE AND FILTERED IMAGES WHICH WERE OBTAINED FROM POISSON NOISE CORRUPTED IMAGE OF SIZE 1000×666 PIXELS BY APPLYING ARITHMETIC MEAN FILTER WITH DIFFERENT KERNEL SIZES

Kernel Size in Pixels	2×2	3×3	4×4
MSE	9.9909e-004	7.1346e-004	0.0015
PSNR	78.1348	79.5971	76.3805

TABLE 6: CONTINUED

Kernel Size in Pixels	5×5	6×6	7×7
MSE	0.0016	0.0023	0.0026
PSNR	76.0573	74.4879	73.9890

TABLE 6: CONTINUED

Kernel Size in Pixels	8×8	9×9	10×10
MSE	0.0032	0.0036	0.0042
PSNR	73.0209	72.5602	71.8821

TABLE 6: CONTINUED

Kernel Size in Pixels	11×11	14×14	15×15
MSE	0.0046	0.0062	0.0066
PSNR	71.4814	70.2194	69.9182

TABLE 6: CONTINUED

Kernel Size in Pixels	24×24	25×25	45×45
MSE	0.0108	0.0113	0.0192
PSNR	67.7874	67.6160	65.2879

TABLE 6: CONTINUED

Kernel Size in Pixels	48×48	64×64	75×75
MSE	0.0203	0.0259	0.0297
PSNR	65.0523	63.9901	63.4051

From the results obtained it is clearly evident that for a kernel of size n×n, where n≥3, when applied with Arithmetic mean filter to Poisson noise corrupted images, the Mean squared error obtained between the original image and the filtered image increases with the increasing value of n. It is also observed that the filtered images obtained from Poisson noise corrupted images by applying Arithmetic mean filter of increasing kernel size go on blurring.

III.CONCLUSION

Images are often corrupted with different types of noise either during acquisition or transmission. Poisson noise is one of the different types of noises that corrupt images. Arithmetic mean filter is used to denoise the corrupted images. The performance of Arithmetic mean filter with different kernel sizes has been analyzed in the context of removing Poisson noise. The results obtained show that the Mean squared error increases and the Peak signal to noise ratio decreases with the increasing kernel size ($n \times n$ pixels, where $n \geq 3$) of Arithmetic mean filter when applied to Poisson noise corrupted images. It is also evident that the quality of the image goes on blurring with the increasing kernel size of Arithmetic mean filter when applied to Poisson noise corrupted images.

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