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Noise-Free Pixel Based Video De-noising Algorithm

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Abstract--This paper proposes a novel method for denoising a video corrupted with impulse noise. Adaptive median filtering is modified to include only noise-free pixels to estimate the original pixel values from the noised ones as accurately as possible. In the absence of noise-free neighborhood pixels, the kernel dimensions are increased and the process is repeated. The proposed method proves effective at noise densities as high as 80%. Comparisons with existing algorithms are done using various video quality parameters like- MSE, PSNR, UQI, MSSIM, VIF.

***Index Terms*-video denoising, MSE, PSNR, MSSIM, VIF, UQI, adaptive filtering**

I. INTRODUCTION

Videos are often corrupted by various types of noise through transmission channels (e.g. broadcasting, satellite links), image acquisition (e.g. cameras) and media storage. In order to remove this noise, various filtering techniques are incorporated. One such technique is Intra-frame filtering [1].

Intraframe Filtering Technique is the one wherein the noise is removed from each of the frame of the video, separating each video frame and the denoised video is obtained thereafter.

Various filtering techniques have been used for removing the impulse noise. One such technique is Mean Filter[ ], which smoothes the video by replacing the center pixel in the window with the average of all the neighbouring pixel values including itself. Its biggest disadvantage is that it does not preserve the edges within the image. Thus, it is found that linear filters produce blurring effect. As a consequence, non-linear filters have been proposed to preserve the fine details of the video. One such technique is Median Filter[2], which replaces the center pixel with the median of all the neighboring pixel values in the given window. It's biggest disadvantage is that it cannot distinguish from noisy and noise-free pixels.

The weighted median (WM) filter [6], that uses weights to control the filtering behavior preserves features of given shapes and size [7]. The Center- weighted median (CWM) filter [8,10] only weights the center pixel of the filtering window. The tri-state median filter [9] and the soft switching median filter [10] incorporate standard median and CWM filter into a noise detection frame work to enhance the noise attenuation while preserving the detail.

The existing Adaptive Median Filter[2] 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 labeled as impulse noise. This misled the classification of pixels at higher noise density. So, a new proposed algorithm was developed based on the concept of noise-free pixels. This algorithm provides a better estimation of corrupted pixel values.

The outline of this paper is as follows:
Section II describes proposed Adaptive Median Filter which includes pixel classification and restoration of noisy pixel and Section III deals with comparison parameters for a video. Section IV gives the comparison of results of Mean , Median and proposed Adaptive Median Filter and conclusion is presented in Section V.

II. ADAPTIVE MEDIAN FILTER

Unlike the conventional Median Filter [2], Adaptive Median Filter [2] has an advantage of being capable of changing the kernel size depending upon the number of noise free pixels in the video frame.

A. Pixel Classification

Based on the intensity values, the pixels are classified into two categories, namely, "noise-free pixel" and "noisy pixel". The classification expresses the noisy pixels as 0 or 255. The intermediate pixel values from 1 to 254 are classified as noise-free pixels. If the center pixel contains pixel values between 1 to 254, then it is a noise-free pixel. So, the window is moved further. However, if the center pixel contains either 0 or 255, then it is retained in the window size and is replaced by the median of all the neighboring noise free pixels in the window.

B. Restoration of Noisy pixel

The basic concept behind the proposed filter is the use of only noise-free pixels for denoising the frames. This provides a better estimation of the corrupted pixel value as the noised pixels are disabled from skewing the results towards either extremes (0 or 255) thus retaining the noise. Furthermore, if no noise-free pixels are detected within the current kernel, its size is increased by 2. The use of this approach, as evident in the results, proves efficient even at high noise densities.

Consider a 3x3 sample matrix as shown in fig. 1, which is typically encountered in frames with high noise density. The pixels encircled are the pixels corrupted with SPN. Taking simply the median of all 9 pixels results in a median value of 255(salt) which fails to serve the purpose of denoising. If only the noise-free pixels are used instead, as proposed by the filter in this paper, the median value turns out to be 52, which is a better estimation of the original, uncorrupted pixel value.

255	10	255
52	255	255
0	85	255

A1={0, 10, 52, 85, **255**, 255, 255, 255, 255}
Median=255
A2={10, **52**, 85}
Median=52

Fig. 1 A 3x3 sample matrix illustrating the novelty of the filter

C. Algorithm for the proposed filter

The algorithm for the proposed filter is given in the following steps.

1. Read the image.
2. Initially, set the size of the kernel as 3X3.
3. Compute the number of noise-free pixels, say N. If the center pixel does not contain noisy pixel, window size is moved further. If the center pixel is noisy, then it replaces it with the median of the neighboring noise-free pixels in the window.
4. If N>0, replace the centre pixel with the median of noise-free pixels.
5. Else, increase the window size by 2 such that it does not exceed 9X9. Goto Step-3.
6. Move the kernel to scan the image. Goto step 2.

The flowchart for the above algorithm is show in fig. 2.

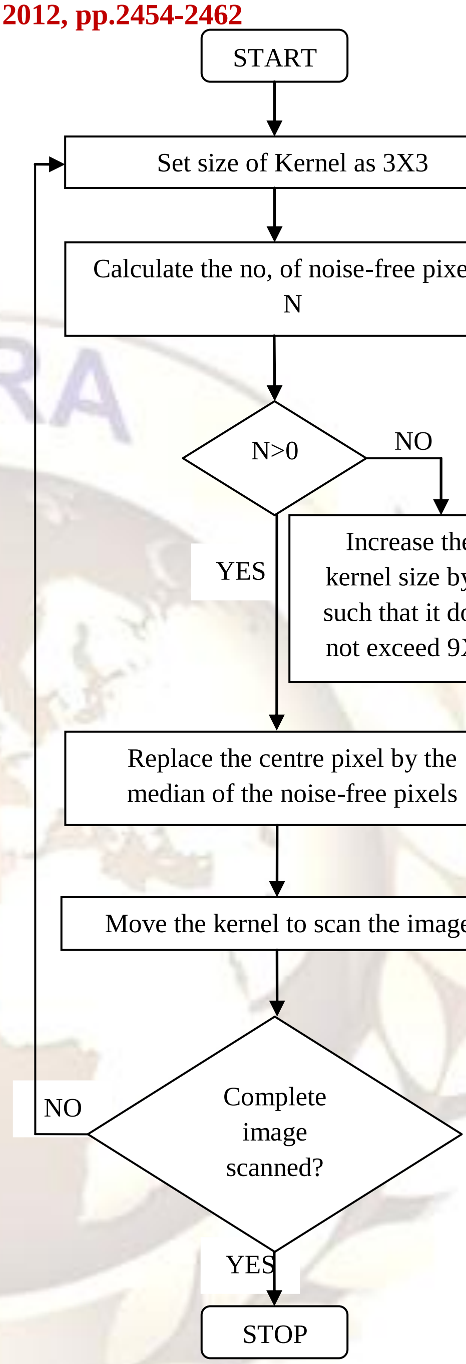

Fig. 2 Flowchart for Adaptive Median Filter

III. COMPARISON PARAMETERS

A. Mean Squared Error (MSE)

It is the square of difference between the original pixel value and the denoised pixel value of a frame.

MSE=∑[I1(m.n)-I2(m,n)]^2/M*N

Here, M and N are the number of rows and columns in the input images, respectively.

B. Peak Signal-To-Noise Ratio (PSNR)

It is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation, expressed in decibels (dB).

C. Mean Structural Similarity Index (MSSIM)

It is a method for quality assessment of still images, extended to video. The MSSIM index was applied frame-by-frame on the video [3]. Matlab implementations of MSSIM are available from [4].

D. Visual Information Fidelity (VIF)

The visual information fidelity in pixel domain (VIFP) is derived from a quantification of two mutual information quantities: the mutual information between the input and the output of the HVS channel when no distortion channel is present and the mutual information between the input of the distortion channel and the output of the HVS channel for the test image. Code implementations for VIF is given in [5].

E. Universal Quality Index (UQI)

Instead of using traditional error summation methods, Wang and Bovik proposed a method to model any image distortion via a combination of three factors: loss of correlation, luminance distortion, and contrast distortion and named it as Universal Quality Index (UQI).

Let X= {x_i | i= 1, 2, . . N} and Y= {y_i | i= 1, 2, . . N} be the original and test image signal respectively. If $\bar{x}$ is the mean of x, σ_x^2 the variance of x, σ_{xy} is covariance of x, y, then, UQI is given by:

$$UQI = \frac{4\sigma_{xy}\,\overline{xy}}{(\bar{x}^2+\bar{y}^2)(\sigma_x^2+\sigma_y^2)}$$

Where, $\bar{x} = \frac{1}{N}\sum_1^N x_i$ and $\bar{y} = \frac{1}{N}\sum_1^N y_i$

IV. RESULT

The standard gray-scale test videos-miss_america.avi, vipmen.avi and Hall monitor.avi were used for experimentation. The actual effectiveness of the proposed filter was compared with that of Median Filter and Mean Filter on the basis of the parameters mentioned in IV and the results of comparison are shown in table 1, table 2 and table 3 respectively. Figures 6, 7, 8, 9, 10 show the plots of MSE, PSNR, MSSIM, VIF, UQI vs. the noise density (%).

From the comparison tables and plots, it is found that the proposed algorithm produces better results than the existing methods. The proposed algorithm removes salt and pepper noise along with the preservation of fine details and edges at noise densities up to 80%.

V. CONCLUSION

It is evident from the plots, values of visual quality parameters and visual results alike that the proposed filter provides improved results over the existing algorithms that it is compared with. It uses the maximum window size of 9*9 which helps in reducing the excessive thinning and thickening of boundaries. Above this window size, the corrupted pixels are replaced by median of the processed neighboring pixels that leads to better result than other existing methods. The proposed method has been proved effective at noise densities ranging from 20% to 80% .

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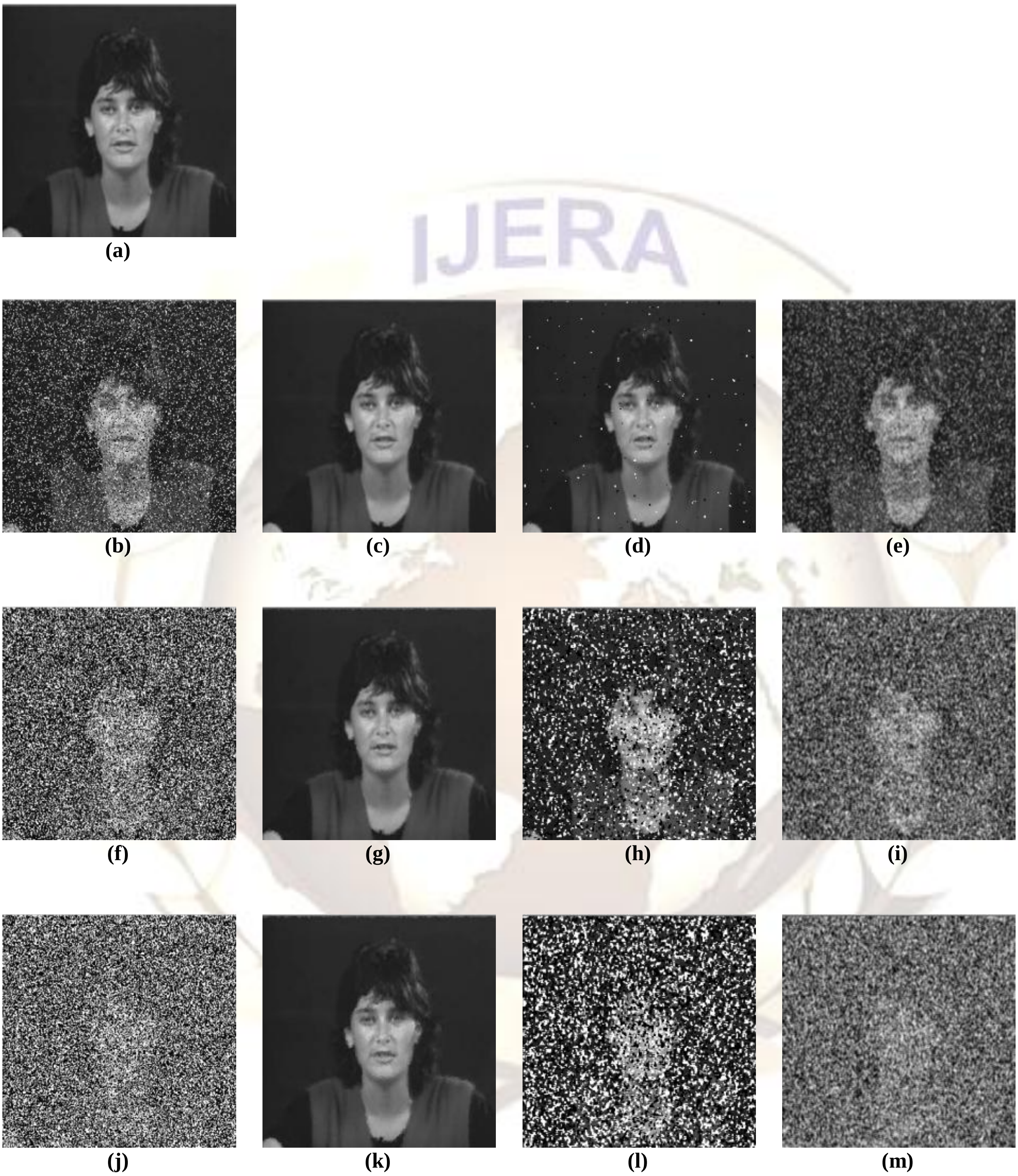

Fig. 3 Video Frames of miss_america.avi: (a) Original Frame; (b) at 20% noise density; (c) after Adaptive Median Filtering; (d) after Median Filtering; (e) After Mean Filtering; (f) at 60% noise density; (g) after Adaptive Median Filtering; (h) after Median Filtering; (i) After Mean Filtering; (j) at 75% noise density; (k) after Adaptive Median Filtering; (l) after Median Filtering; (m) After Mean Filtering.

Fig. 4 Video Frames of vipmen.avi: (a) Original Frame; (b) at 20% noise density; (c) after Adaptive Median Filtering; (d) after Median Filtering; (e) After Mean Filtering; (f) at 60% noise density; (g) after Adaptive Median Filtering; (h) after Median Filtering; (i) After Mean Filtering; (j) at 75% noise density; (k) after Adaptive Median Filtering; (l) after Median Filtering; (m) After Mean Filtering.

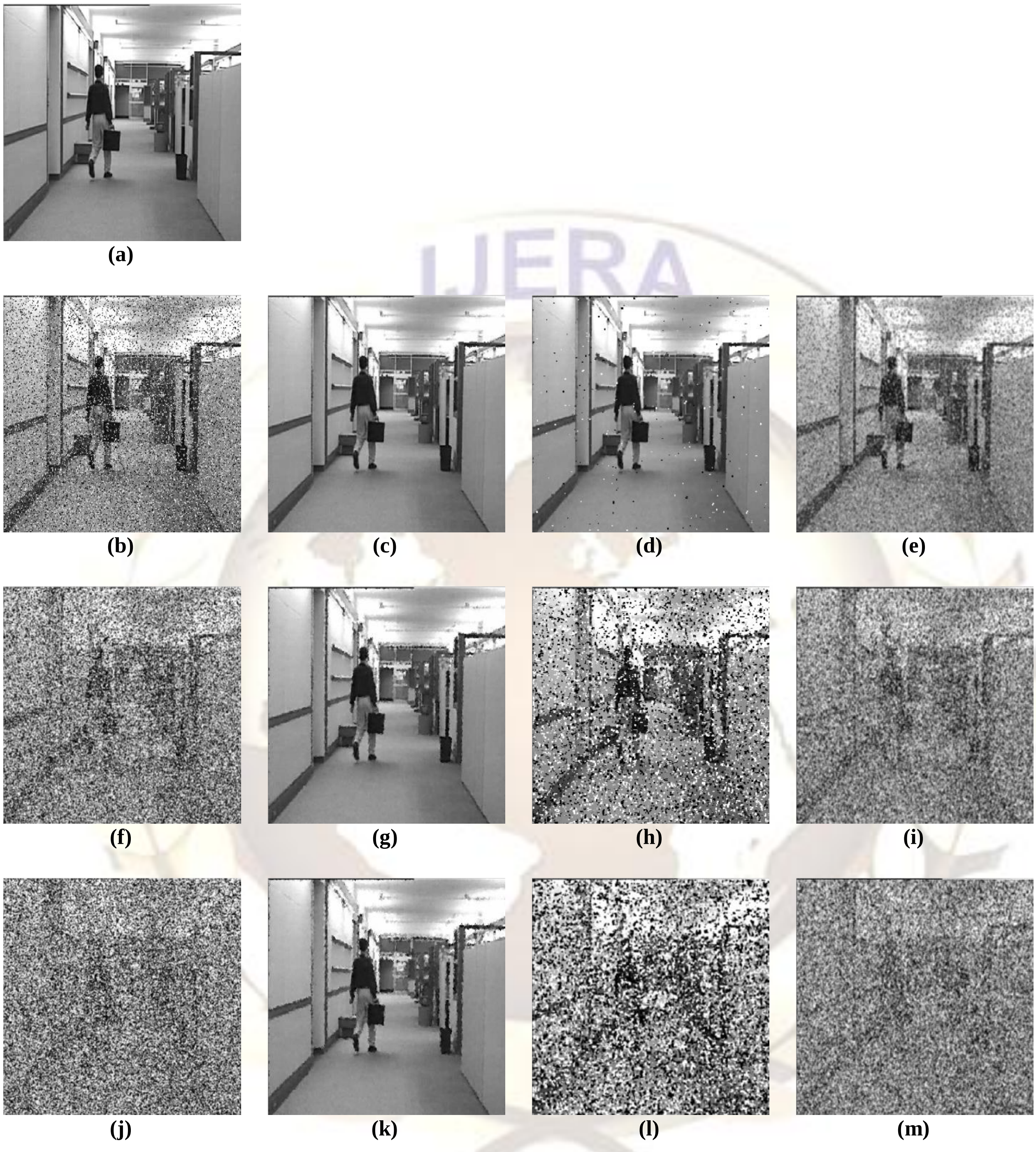

Fig. 5 Video Frames of Hall Monitor.avi: (a) Original Frame; (b) at 20% noise density; (c) after Adaptive Median Filtering; (d) after Median Filtering; (e) After Mean Filtering; (f) at 60% noise density; (g) after Adaptive Median Filtering; (h) after Median Filtering; (i) After Mean Filtering; (j) at 75% noise density; (k) after Adaptive Median Filtering; (l) after Median Filtering; (m) After Mean Filtering.

TABLE I

ADAPTIVE MEDIAN FILTER

Noise Density=20%							
Video Sequence	**No. of Frames**	**Resolution**	**MSE**	**PSNR**	**UQI**	**MSSIM**	**VIF**
Miss America	83	240*320	0.4681	51.4273	0.9994	0.9966	0.9900
Vipmen	283	120*160	1.5730	46.1636	0.9988	0.9888	0.9819
Hall Monitor	300	291*355	5.7996	40.4968	0.9947	0.9689	0.9112
Noise Density=60%							
Miss America	83	240*320	2.8497	43.5828	0.9940	0.9805	0.9426
Vipmen	283	120*160	8.7088	38.7312	0.9911	0.9339	0.8508
Hall Monitor	300	291*355	15.5164	36.2229	0.9755	0.8857	0.7692
Noise Density=75%							
Miss America	83	240*320	3.9285	42.1885	0.9916	0.9690	0.9075
Vipmen	283	120*160	11.5192	37.5166	0.9862	0.9004	0.7993
Hall Monitor	300	291*355	19.1677	35.3051	0.9685	0.8441	0.7066

TABLE II

MEDIAN FILTER

Noise Density=20%							
Video Sequence	No. of Frames	Resolution	MSE	PSNR	UQI	MSSIM	VIF
Miss America	83	240*320	2.6233	43.9424	0.9913	0.8873	0.8188
Vipmen	283	120*160	7.1477	39.5891	0.9922	0.8843	0.8273
Hall Monitor	300	291*355	13.9295	36.6914	0.9776	0.8167	0.7282
Noise Density=60%							
Miss America	83	240*320	34.1943	32.7913	0.6071	0.0575	0.1119
Vipmen	283	120*160	39.8714	32.1242	0.8785	0.1159	0.1434
Hall Monitor	300	291*355	45.2977	31.5700	0.8653	0.0998	0.1242
Noise Density=75%							
Miss America	83	240*320	63.3627	30.1125	0.4600	0.0166	0.0745
Vipmen	283	120*160	64.2581	30.0515	0.7535	0.0454	0.0631
Hall Monitor	300	291*355	70.6395	29.6403	0.7706	0.0458	0.0582

TABLE III

MEAN FILTER

Noise Density=20%							
Video Sequence	**No. of Frames**	**Resolution**	**MSE**	**PSNR**	**UQI**	**MSSIM**	**VIF**
Miss America	83	240*320	25.0472	34.1432	0.7060	0.2203	0.2803
Vipmen	283	120*160	66.2624	29.9181	0.9013	0.3716	0.3632
Hall Monitor	300	291*355	90.9706	28.5418	0.8801	0.3270	0.3361
Noise Density=60%							
Miss America	83	240*320	22.9870	34.5160	0.4772	0.0723	0.0982
Vipmen	283	120*160	78.4111	29.1870	0.7362	0.1458	0.1085
Hall Monitor	300	291*355	123.0262	27.2308	0.7473	0.1288	0.1087
Noise Density=75%							
Miss America	83	240*320	21.2378	34.8597	0.3852	0.0517	0.0654
Vipmen	283	120*160	83.9755	28.8893	0.6392	0.0865	0.0562
Hall Monitor	300	291*355	128.3566	27.0466	0.6790	0.0919	0.0552

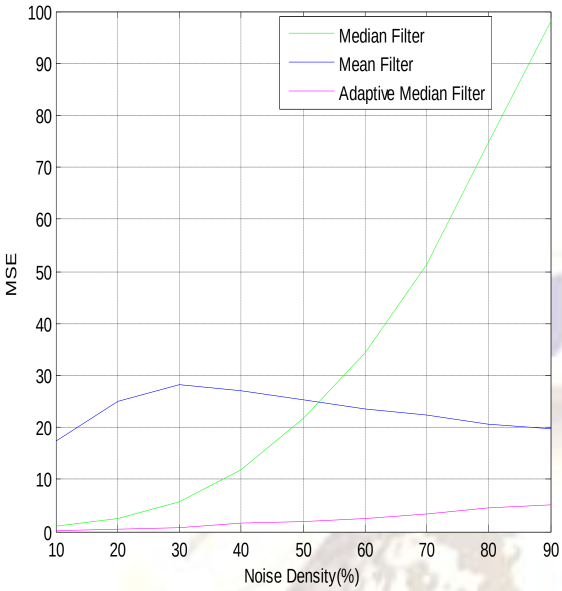

Fig.6 Plot of Mean Squared Error (MSE) vs. Noise Density (%)

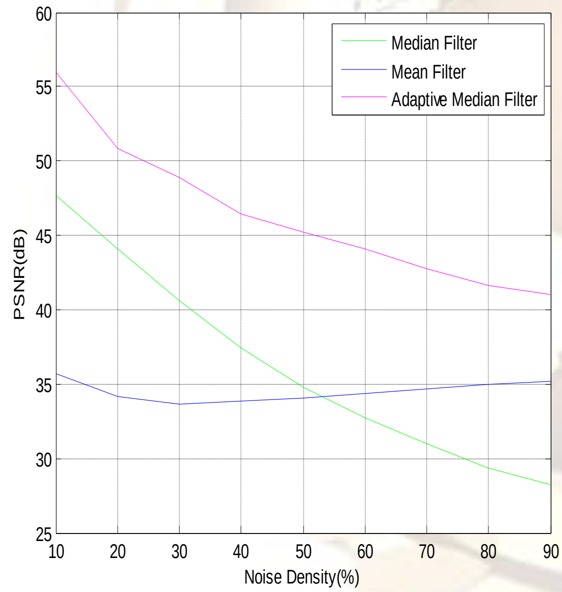

Fig. 7 Plot of Peak Signal to Noise Ratio (PSNR) in dB vs. Noise Density (%)

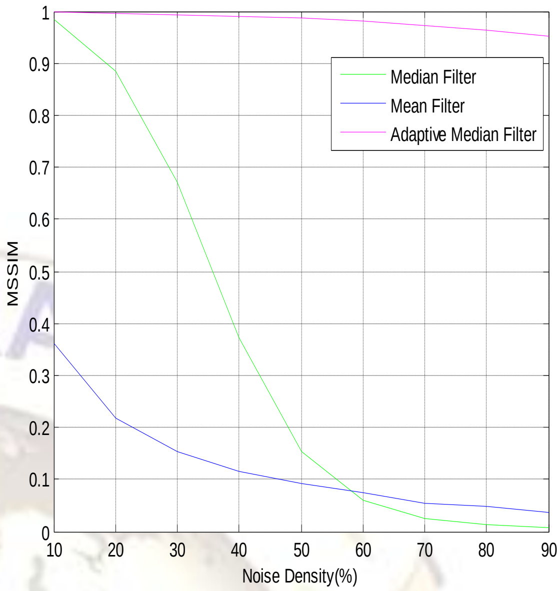

Fig. 8 Plot of Structural Similarity Index (MSSIM) vs. Noise Density (%)

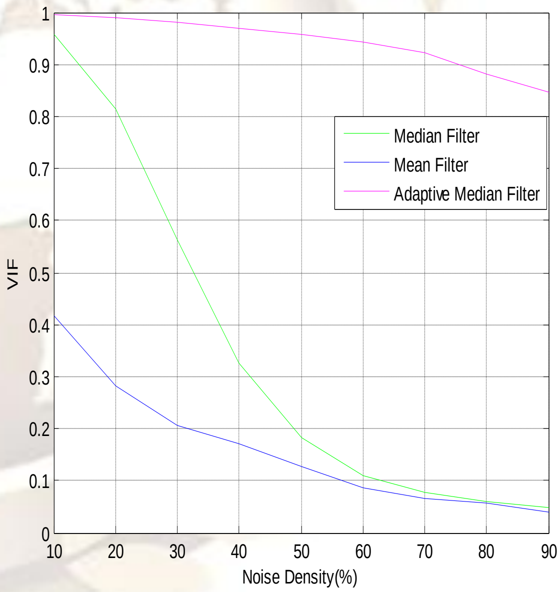

Fig. 9 Plot of Visual Information Fidelity (VIF) vs. Noise Density(%)

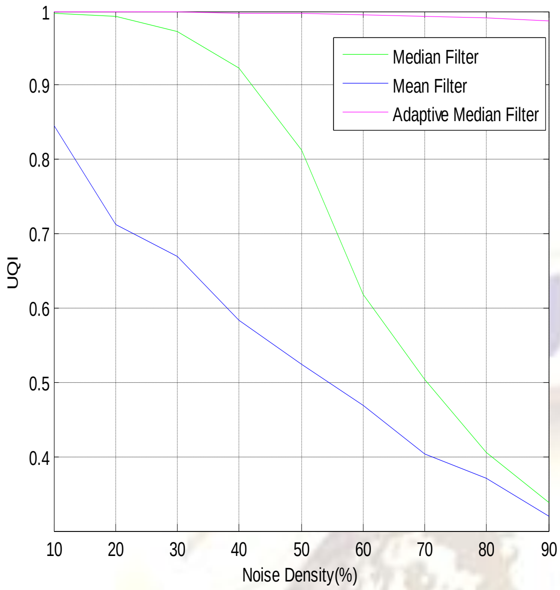

Fig. 10 Plot of Universal Quality Index (UQI) vs. Noise Density (%)