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Analyze performance of Median Filter and Center Weighted Median Filter for Efficient Removal of Impulse Noise Using ARM

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Abstract— ***A methodology based on median filters for the removal of Salt and Pepper noise by its detection followed by filtering in both binary and gray level images has been proposed in this paper. Linear and nonlinear filters have been proposed earlier for the removal of impulse noise; however the removal of impulse noise often brings about blurring which results in edges being distorted and poor quality. Therefore the necessity to preserve the edges and fine details during filtering is the challenge faced by researchers today. The proposed method consists of noise detection followed by the removal of detected noise by median filter using selective pixels that are not noise themselves. The noise detection is based on simple thresholding of pixels. Computer simulations were carried out to analyze the performance of the proposed method and the results obtained were compared to that of conventional median filter and center weighted median (CWM) filter.***

Keywords— ***Improved median filter; conventional median filter; center weighted median(CWM) filter; Impulse noise; Salt and pepper; Image denoising; Non linear filters.***

I. INTRODUCTION

The field of digital image processing is continually evolving. During the past years there has been a significant increase in the level of interest in image morphology, image compression, image recognition, image restoration, image segmentation and other fields of image processing [1].

Interest in the field of digital image processing methods roots to two principal application areas: Improvement of pictorial information for human perception and Processing of scene data for autonomous machine perception.

From the days of the Bartlane systems till date digital images have played an important role in various fields of science. These include remote sensing, satellite television, biomedical imaging, computer tomography, astronomy, geology and the list keeps on increasing.

One important field of image processing is image restoration, the ultimate goal of which is to improve an image in some sense. Image restoration may be defined as a process that attempts to reconstruct or recover an image that has been degraded or corrupted by using some a'priori knowledge of the degradation phenomenon.

Image denoising finds applications in fields such as astronomy where the resolution limitations are severe, in medical imaging where the physical requirements for high quality imaging are needed for analyzing images of unique events, and in forensic science where potentially useful photographic evidence is sometimes of extremely bad quality [2].

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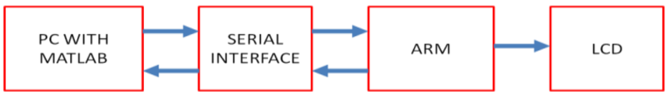
Noise may be considered to be any unwanted entity that corrupts information. Among the various types of noise known in digital images, Salt and Pepper noise typically cause error in pixel elements in camera sensors, faulty memory locations, or timing errors in the sampling process. Salt and Pepper noise can take only the maximum and minimum values in the dynamic range (0,255) and occurs impulsively at pixel positions.

Filters that are used for the purpose of denoising are broadly divided into two types, linear and nonlinear filter. Linear filters tend to blur the edges and other image details. Also these filters perform poorly on images corrupted by non-Gaussian type of noises. Hence for the removal of impulsive noise like salt and pepper noise nonlinear filters are used. Nonlinear filters can preserve edges and other fine details. Of the various nonlinear filters known median filters have provided the best results for salt and pepper noise removal. This is based on the fact that in these types of noisy images certain individual pixels have extreme values which can be removed with ease as the filter is primarily concerned about the median value only. Median filter replace every pixel of the image by the median value of its neighborhood. The filter performs well for noise densities less than 50% above which the noise present in the neighborhood is more than the information and hence the filter's performance deteriorates. The center weighted median (CWM) filter, which is a weighted median filter giving more weight only to the central value of each window also proves efficient only at low noise densities.

Various improvements have been made to the basic median filter to improve its performance on noisy images [3]- [8]. One such improvement is filtering after noise detection [9]-[11]. Noise detection is performed by various methods like second order differentiation, rank ordered logarithmic difference and several other efficient algorithms. One such improvement to the median filter has been proposed in this paper. Filtering is done after noise detection on the detected noisy pixels by median filtering with pixels in the neighborhood that are not noise themselves.

II. HARDWARE INFORMATION AND BLOCK DIAGRAM



BLOCK DIAGRAM

ARM7 LPC2148 Primer Board

The ARM7 LPC2148 Primer board is designed in such way that all the possible features of the microcontroller will be easily used by the students. The kit supports in system programming (ISP) which is done through serial port.

NXP's ARM7 (LPC2148), ARM Primer Kit is proposed to smooth the progress of developing and debugging of various designs encompassing of High speed 32-bit Microcontrollers.

UART

UART (Universal Asynchronous Receiver Transmitter) are one of the basic interfaces which provide a cost effective simple and reliable communication between one controller to another controller or between a controller and PC.

RS-232 Level Converter

Usually all the digital ICs work on TTL or CMOS voltage levels which cannot be used to communicate over RS-232 protocol. So a voltage or level converter is needed which can convert TTL to RS232 and RS232 to TTL voltage levels. The most commonly used RS-232 level converter is MAX232.

This IC includes charge pump which can generate RS232 voltage levels (-10V and +10V) from 5V power supply. It also includes two receiver and two transmitters and is capable of full-duplex UART/USART communication.

- RS-232 communication enables point-to-point data transfer. It is commonly used in data acquisition applications, for the transfer of data between the microcontroller and a PC.
- The voltage levels of a microcontroller and PC are not directly compatible with those of RS-232, a level transition buffer such as MAX232 be used.

Interfacing UART

Fig. 1 shows how to interface the UART to microcontroller. To communicate over UART or USART, we just need three basic signals which are namely, RXD (receive), TXD (transmit), GND (common ground). So to interface UART with LPC2148, we just need the basic signals.

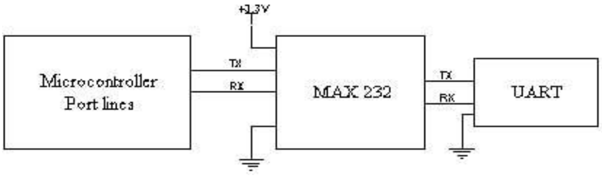


Figure 1 Interfacing UART to Microcontroller

III. IMPLEMENTATION

Higher correlation gives rise to better edge preservation. In addition, this algorithm named fast and efficient impulse noise removal (FEINR) uses simple fixed length window of size 3 x 3, and hence, it requires significantly lower processing time compared with other algorithms. whether the value of a current pixel lies between the maximum and minimum values that occur inside the selected window. The impulse noise pixels can take the maximum value 255 and minimum values 0. If the value of the pixel processed is within the range, then it is an uncorrupted pixel and left unchanged. If the value does not lie within this range, then it is a noisy pixel and is replaced by the median value of the window.

MAIN RESULTS

In order to maintain the tradeoff between noise removal and edge preservation the filter length was set to 3 x 3. The following cases were considered: (a) the impulsive noise is 20%, (b) the impulsive noise is50% and (c) the impulsive noise is 90%. The median and FEINR filters were applied successive in several passes in order to enhance the quality of reconstructed image.

IV. EXPERIMENTAL RESULTS

The performance of the proposed improved median filter, conventional median filter and center weighted median (CWM) filter were analyzed for different noise density (ND) of salt and pepper noise added to gray level Lena image shown in Fig.1 and binary Circles image shown in Fig.2. The threshold was varied to obtain maximum PSNR and Correlation**.**

Figure 2 Original Lena Image

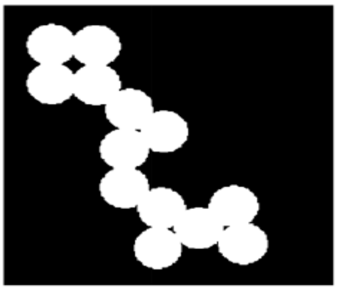


Figure 3 Original Circles Image

TABLE I

MEDIAN FILTER, CWM FILTER RESULTS FOR LENA IMAGE AT DIFFERENT NOISE DENSITIES

ND (%)	Median Filter		CWM Filter	
	PSNR (dB)	*COR*	*PSNR (dB)*	*COR*
10	39.6988	0.9933	42.4061	0.9828
20	38.5953	0.9776	38.7417	0.8941
30	37.4590	0.9118	35.8089	0.7340
40	35.8279	0.7756	33.5187	0.5564
50	34.1251	0.5866	31.7560	0.4082
60	32.4119	0.4205	30.3837	0.2877
70	30.8335	0.2758	29.2978	0.1985
80	29.3291	0.1729	28.4178	0.1179
90	28.1719	0.0877	27.8251	0.0547
91	28.0393	0.0666	27.8053	0.0529
92	27.9288	0.0638	27.7411	0.0408
93	27.8099	0.0545	27.6953	0.0420
94	27.6928	0.0437	27.6891	0.0267
95	27.5934	0.0353	27.6621	0.0212
96	27.4705	0.0301	27.6354	0.0249
97	27.4064	0.0235	27.5977	0.201
98	27.3399	0.0189	27.5844	0.0108
99	27.2396	0.0176	27.5795	0.0077

The results obtained for gray level Lena image in TABLE I were at a threshold of zero where the proposed method produced maximal result.

Results in TABLE II were obtained for the binary image Circles at different noise densities for different thresholds and the value tabulated are those corresponding to maximum PSNR. These need not correspond to the maximum Correlation values. These results are compared to that of a Conventional median filter obtained using a 3×3 window applied once on the noisy image. The weights for the CWM filter were set at three for maximum performance.

TABLE II
MEDIAN FILTER, CWM FILTER RESULTS FOR CIRCLES IMAGE AT DIFFERENT NOISE DENSITIES

ND (%)	Median Filter		CWM Filter	
	PSNR (dB)	COR	PSNR (dB)	COR
10	54.8266	0.9937	53.2539	0.9942
20	51.366	0.9875	46.5482	0.9689
30	48.4827	0.9692	42.7461	0.9184
40	45.0869	0.9255	40.0871	0.8289
50	42.2607	0.8406	38.9410	0.7197
60	40.0004	0.7211	36.9410	0.5829
70	38.0224	0.5648	35.5641	0.4271
80	36.0854	0.3779	34.7928	0.2908
90	34.6449	0.1794	33.9740	0.1459

The threshold by itself takes only discrete values 0, 31.875, 63.75, 95.625, 127.5, 159.325, 191.25, 223.125 in binary images. Any value between these values produces the same result as that corresponding to the nearest upper threshold. For e.g., a threshold of 140.45 produces the same result as that corresponding to 159.325.

These values are nothing but arithmetic means when the mask contains only one noisy pixel, two noisy pixels and so on respectively till there is only one information pixel in the neighborhood. Therefore these thresholds put a restrain on the minimum number of noisy pixels that can be present in the neighborhood so that the pixel might not be considered as noise.

The parameters used to define the performance of the proposed filter are defined as follows:

PSNR (Peak Signal to Noise Ratio)

$$PSNR = 20\,\log_{10}\left(\frac{255}{RMSE}\right) \quad (1)$$

Where,

$$RMSE = \sqrt{\frac{1}{MN}\sum_{i,j}\left(y_{ij} - x_{ij}\right)^2} \quad (2)$$

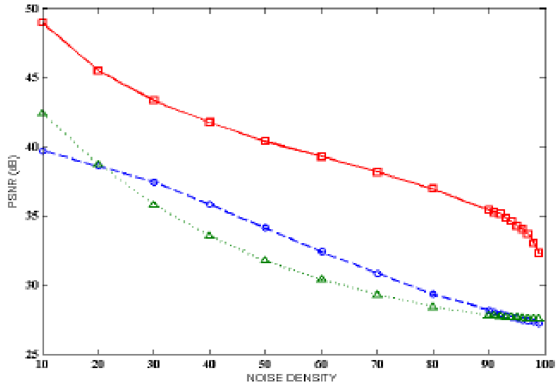
COR (Correlation)

$$COR = \frac{\sum_{i,j}(y_{ij} - \mu_y)(x_{ij} - \mu_x)}{\sqrt{\sum_{i,j}(y_{ij} - \mu_y)^2 \sum_{i,j}(x_{ij} - \mu_x)^2}} \quad (3)$$

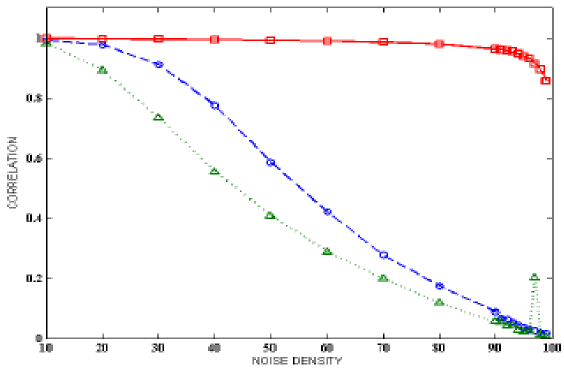
Where, y_{ij} and x_{ij} denote the pixel values of the restored and original image respectively, M×N is the size of the image, μ_x and μ_y represent the mean of the original and restored images.

The results in TABLE I and TABLE II are plotted as in the graphs shown below in Fig.3. The dashed lines represent the performance of conventional median filter while the dotted lines that of CWM filter and the solid lines represent the performance of proposed improved median filter.

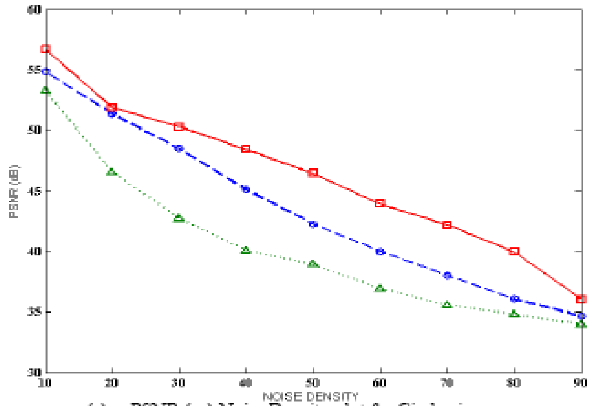
The qualitative performance of the filter is observed from the outputs shown in Fig.4 and Fig.5. It is seen that the filter has preserved the edges and other fine details to an extent so that its outputs are better perceived by the human eye.



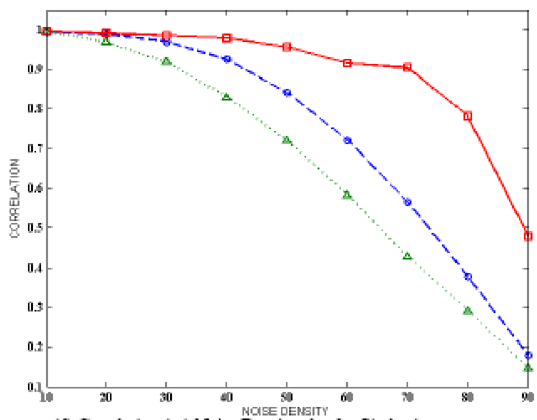
(a) PSNR (vs) Noise Density plot for Lena image.



(b) Correlation (vs) Noise Density plot for Lena image.



(c) PSNR (vs) Noise Density plot for Circles image.



(d) Correlation (vs) Noise Density plot for Circles image.

Fig.3. Comparison graphs for the performance analysis of the proposed method, median filter and CWM filter.

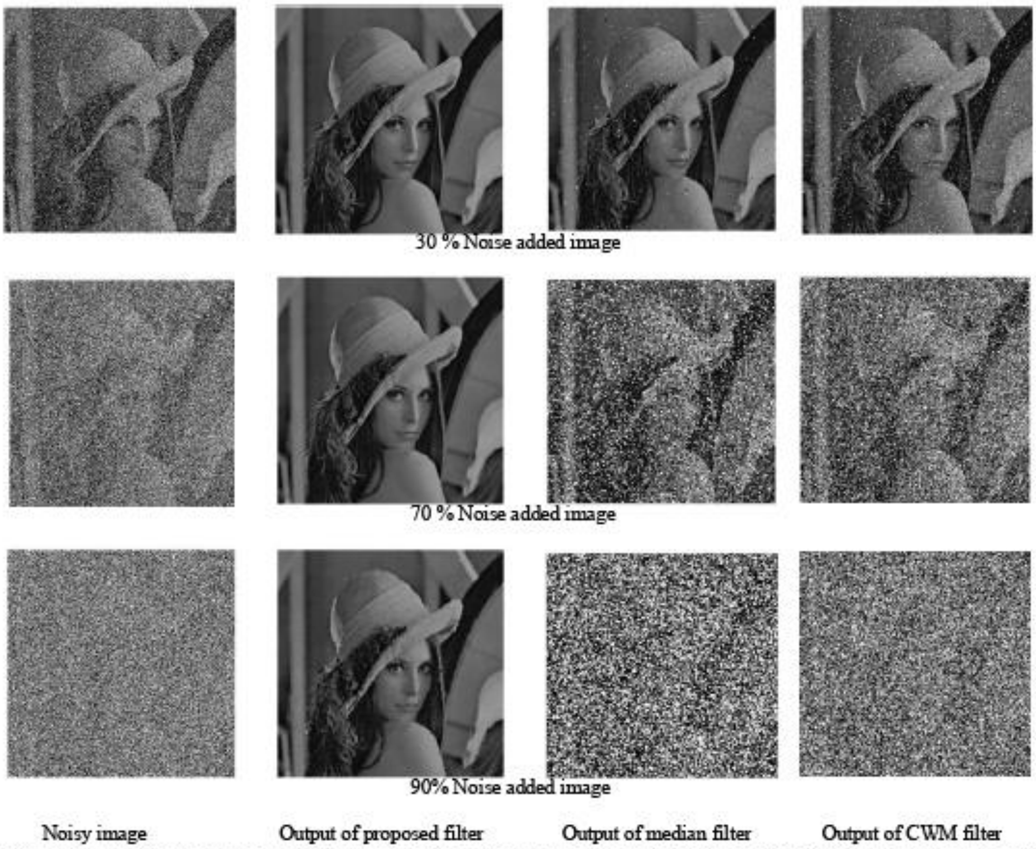


Fig.4. Pictorial results of salt and pepper noise removal for the proposed method, median filter and CWM filter on gray level Lena image.

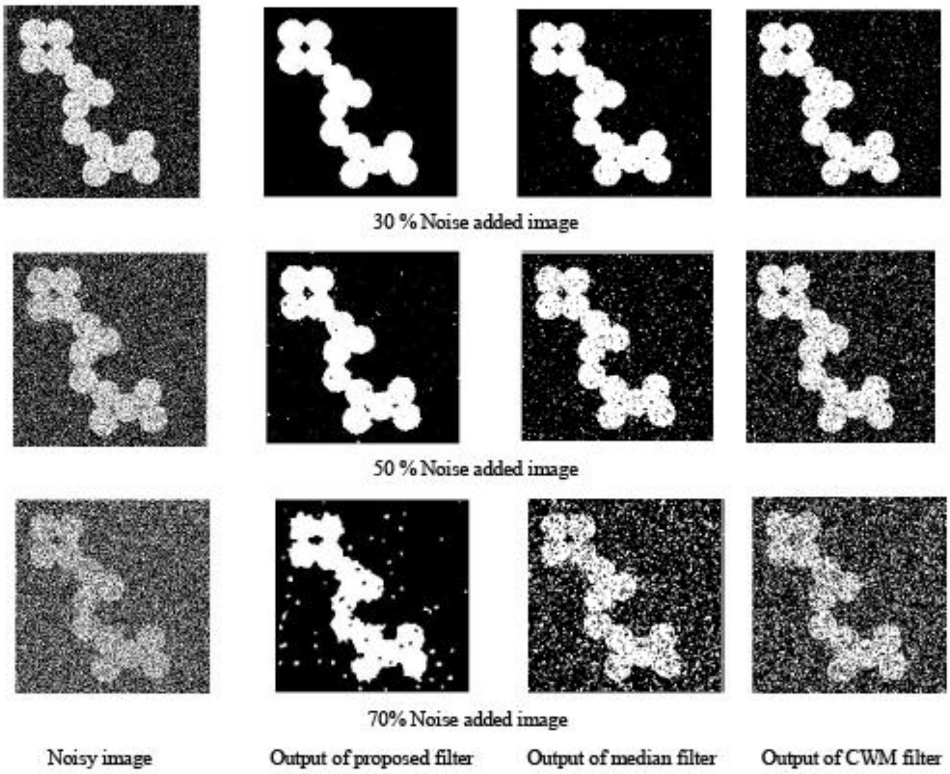


Fig.5 Pictorial results of salt and pepper noise removal for the proposed method, median filter and CWM filter on binary Circles image.

V. CONCLUSIONS

From the exhaustive experimental results obtained for the filter as a denoising technique at various noise densities for both gray level and binary images the following conclusions are drawn

- The proposed method provides better image restoration compared to the conventional median filter and center weighted median filter at both low and high noise densities in the case of binary and gray level images.
- The computation time required increases as noise density increases which are quite acceptable for the result it produces. The increase in computation time

might be explained by the fact that at higher noise densities the filter is applied again and again till the noise detector is unable to detect any noise in the image.

- The threshold chosen for gray level images is zero for which the filter performs its best. This means in gray level images all minimum and maximum gray level values that occur abnormally are considered as noise (0,255).
- For binary images the best results were obtained by trial and error method at different thresholds. It was further found that the threshold corresponding to the maximum result varies from image to image.

The only difficulty faced by the proposed filter is the threshold which is to be given manually for binary images that varies from image to image. The threshold has to be checked for performance by trial and error every time which is quite tedious and time consuming. This can be overcome by an algorithm that decides the threshold and is adaptive to the image. This provides future scope for the improvement of the proposed filter as a denoising technique. Also the noise detection technique used was of the simplest form and a better detector is expected to improve the performance of the filter.

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