Adaptive Filtering Of Impulsive Noise from the Image Using Local Statistics and Adaptive Window Size

D S BORMANE DR.T R SONTAKKE
S R T Marathawada Univesity ,Nanded

Abstract: - An effective adaptive algorithm is proposed for removal of impulsive noise components from the images. The algorithm uses the impulse detection criterion for effective removal of impulses and keeping intact the unaffected pixels and edges. The experimental results are included in the text along with the signal to noise ratio at the input and at the output. In this paper it is proposed an effective adaptive filtering scheme for the removal of impulsive noise in the images, which is based on the Lee's algorithm[1].

*I*ndex Terms– Adaptive filter, non-linear filter, impulse detection, modified mean.

1.**Introduction**

In many signal-processing applications, the suppression of unwanted (noise) components in an input signal sequence can be achieved by linear filtering. In some situations, however, linear filtering is inadequate for this purpose. If a desired signal with sharp edges is corrupted by noise, as in some noisy image data, the linear filters designed to remove the noise will also smooth out signal edges. In addition impulsive noise components can not be suppressed sufficiently by linear filtering.

To this end non-linear and adaptive filters have been found to provide satisfactory results in comparison with linear methods.

For instance median, generalised mean [2] and orderstatistic filters [3] have demonstrated somewhat good proficiency in the removal of impulsive noise, whereas modified trimmed mean (MTM) filter[4], adaptive filters works for removal of short tailed and middle tailed noise components from the images. However, because these approaches are typically implemented uniform across an image they also tend to modify pixels that are undistributed by noise. In addition they are prone to edge jitters, when percentage of impulse noise is large. Consequently the effect of removal of impulses is often at the expense of blurred and distorted features**.** Lee[1] has developed noise-filtering algorithm for both the additive and multiplicative noise cases. The technique based on the use of local mean and local variance. The only assumption is that the sample mean and variance of a pixel is equal to its local mean and variance based on pixels within a fixed neighbourhood surrounding it. In the additive noise filtering case, the a priori mean (variance) of an image is calculated as the difference between the local mean (variance) of the noise corrupted image and the mean (variance) of the noise. It is found in reference[1] that the filtering algorithm is a linear weighted sum of the local mean and the image itself. The distinct characteristic is that in very low contrast areas i.e. for low signal to noise ratio (homogeneous) areas, the estimated pixel approaches the local mean whereas in the high contrast i.e. high signal to noise ratio areas (edge areas),the estimated pixel favours the corrupted image pixel. It is possible to retain the edges while filtering the impulses by modifying the linear operation, which is the objective of this paper.

2.Lee's Algorithm:

Noise filtering on two dimensional image arrays is developed based on their local mean and variance. These algorithms are nonrecursive and do not require the use of any kind of transform. They share the time characteristics in that each pixel is processed independently [1].

For both the additive and multiplicative cases, the a priori mean and variance of each pixel is derived from its local mean and variance. Then, minimum mean-square error estimator in its simplest form is applied to obtain the noise filtering algorithms. For multiplicative noise a statistical optimal linear approximation is made. According to Lee's algorithm the local mean and local variance are calculated over a $(2n+1)(2m+1)$ window.

The local mean is defined as

$$m_{ij} = \frac{1}{(2n+1)(2m+1)} \sum_{k=i-n}^{n+i} \sum_{l=m-j}^{m+j} x_{k,l} \qquad \text{-------(1)}$$

Similarly, the local variance is

$$v_{ij} = \frac{1}{(2n+1)(2m+1)} \sum_{k=i-n}^{i+n} \sum_{l=j-m}^{j+m} (x_{k,l} - m_{i,j})^2 \text{ ----(2)}$$

Noise filtering by use of local statistics proposed by Lee [1] works better for removal of additive uniform noise, additive gaussian noise but its performance is fair for removal of impulsive noise, since linear operation is involved and it uses the local mean to replace the central pixel . The major problem associated with linear filter is its inability to remove impulsive noise and edge preservation .

Thus Lee's algorithm can be modified for the removal of impulsive noise from images . Lee's algorithm could be modified such that it is able to suppress impulsive noise components and also preserve edges.

According to Lee's algorithm, the input signal $x(i,j)$ obeys the following model.

$x(i,j) = s(i,j) + n(i,j)$,where $s(i,j)$- original signal, $n(i,j)$- is white noise with zero mean and variance σ_n^2 which is statistically independent of $s(i,j)$. Given $x(i,j)$,the $y(i,j)$ can be computed as,

$$y(i,j) = (1 - \sigma_n^2 / \sigma_x^2) * x(i,j) + (\sigma_n^2 / \sigma_x^2) * E[x(i,j)] \text{ ---------(3)}$$

$E[x(i,j)] \Rightarrow \bar{x}(i,j) \rightarrow$ local mean

$$x(i,j) = m_{ij} = \frac{1}{N} \sum_{m=-N}^{N} \sum_{n=-N}^{N} x(i+m, j+n) \text{ --------(4)}$$

Where $x(i+m, j+n) \in w(2n+1, 2m+1)$

3.Adaptive Algorithm

In the proposed algorithm the degraded pixel can be represented by $x(i,j) = s(i,j) + n(i,j)$ where $x(i,j)$ is degraded pixel, $s(i,j)$ is original pixel value & $n(i,j)$ is impulsive noise component .

In the proposed method each pixel in the window is checked for positive or negative impulse. If impulse is detected in the window ,its contribution from the local mean is removed and modified mean is used to replace the corrupted pixel . On the other hand ,if impulse is not detected ,then local mean is used to replace the central pixel. If impulse detected , modified mean is obtained as , Modified Mean x_m

$$x_m = \frac{\sum\sum x(i+m, j+n) - x_c(i,j)}{w - p} \text{ -----(5)}$$

where $x_c(i,j) \rightarrow$ denotes pixel corrupted by an impulse and parameter p is number of impulses detected in the window.

Lee's algorithm modified as follows :-

1.The local mean replaced by a modified mean, the local mean is calculated using (1), and then each pixel in the window is checked for the impulse, using impulse detection criterion[2]. If any pixel in the window is found to be an impulse ,its contribution from the local mean is removed . The local mean $x(i,j)$ is replaced by modified mean $x_m(i,j)$,and hence the modified mean is calculated as in equ.(5) and also the modified variance is calculated using (2) and (5).

2.If central pixel in the window x(i,j) is found to be corrupted by an impulse the weighting factor $b(i,j) = 1 - \sigma_n^2 / \sigma_x^2$ is made to be zero. The weighting factor for the proposed algorithm can be used as, $b(i,j) = 0;$ if $x(i,j)$ is an impulse or $\sigma_n^2 \geq \sigma_x^2$

$= 1 - \sigma_n^2 / \sigma_x^2$, otherwise

3.If the weighting factor $b(i,j)$ is below certain threshold t_1, the window size is increased & if the $b(i,j)$ is above threshold t_1 and window size is above 9, the window size is decreased . The window size is modified as follows ,

If $b(i,j) \prec t_1$, window $x_{size} = wxs$ & window $y_{size} = wys$,increased and if $b(i,j) \succ t_1$ and $ws \succ 9$, wxs & wys decreased.

The following equation is used to filter the impulse corrupted image.

$$y(i,j) = x_m(i,j) + (x(i,j) - x_m(i,j)) * b(i,j) \text{ ----------(6)}$$

The step-1 in addition to removing noise also helps in preserving edges, since if an edge enters into a window ,the data from the other side of the edge will be treated as impulsive noise component and will not be allowed to heavily influence the smoothened output value.

In step-2,the high frequency component are not allowed to pass in the output, since $b(i,j) = 0$,if central pixel is detected as impulse. The threshold t_1 is chosen in such a way that, in homogeneous regions where

$b(i,j)$ is nearly equal to zero ,the increase in window size leads to better suppression of non-impulsive noise. Since each pixel in the window has to be checked for an impulse , the following impulse detection criterion is used [2].

$x(i,j) =$ Negative impulse; if

$x(i,j) - \bar{x}(i,j) \succ \theta_{\max} / 3$

= Positive impulse ; if

$x(i,j) - \bar{x}(i,j) \prec (\theta_{\min} - G_{\max}) / 2$

$= x(i,j)$; otherwise ----------- (7)

Where $\theta_{\min} and \theta_{\max}$ are the minimum and maximum gray values in the window and $G_{\max}$ is the maximum gray value in the image . The algorithm is tested for the noise corrupted girl image using (6) and Calculation of signal to noise ratio and enhance factor is as follows

S/Ni =signal to noise ratio at input,

$= 10 * \log(s(i,j)^2 / (s(i,j)^2 - x(i,j)^2))$

S/No =signal to noise ratio at output,

$= 10 * \log(s(i,j)^2 / (s(i,j)^2 - y(i,j)^2))$

Enhance factor :-

$= (s(i,j)^2 - x(i,j)^2) / (s(i,j)^2 - y(i,j)^2)$

4.Results

Fig.1 Original image

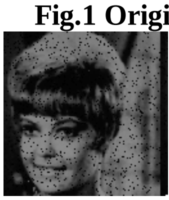


Fig.1.1 Fig.1.2

S/Ni RATIO IS →1.13 dB

S/No RATIOIS →1.24 dB

ENHANCE FACTOR →1.03 dB

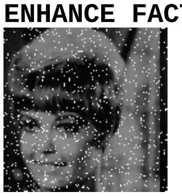


Fig.1.3 **Fig.1.4**

S/Ni RATIO IS →0.10 dB

S/No RATIO IS →1.24 dB

ENHANCE FACTOR →1.30 dB


Fig.1.5 **Fig.1.6**

S/Ni RATIO IS → 0.02 dB

S/No RATIO IS → 1.22 dB

ENHANCE FACTOR→ 1.32 dB


Fig.1.7 **Fig.1.8**

S/Ni RATIO IS → -0.13 dB

S/No RATIO IS → 1.12 dB

ENHANCE FACTOR → 1.33 dB

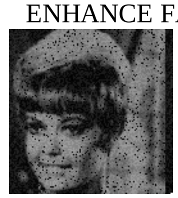


Fig.1.9 **Fig.1.10**

S/Ni RATIO IS → 0.97 dB

S/No RATIO IS → 1.15 dB

ENHANCE FACTOR → 1.04 dB

Image of girl corrupted by noise is filtered by adaptive filter based on Lee's algorithm. Fig.1 is 8-bit original image of girl . Fig.1.1 is corrupted by 10% negative impulses and fig.1.2 is filtered image. Fig.1.3- corrupted by positive impulses (10%),fig. 1.4 noise filtered image. Fig.1.5- corrupted by positive and negative impulses (both 10%),fig. 1.6 noise filtered image. Fig.1.7 corrupted by positive impulses (5%)and gaussian noise with variance 25 and fig. 1.8 noise filtered image. Fig.1.9 corrupted by negative impulses (5%) plus gaussian noise with variance 25, fig. 1.10 noise filtered image.

5.Conclusion :-

Adaptive impulsive noise filtering algorithm based on local statistic and impulse detection criterion presented in this paper.Local mean ,local variance are computed from the neghbourhood pixels , the mean is modified to the new modified mean when impulse is detected in the image i.e.contribution of the impulse is removed from the local mean. Based on this ,modified variance is also computed to improve the performance of the filter. The weighting factor and the window size is also made adaptive to obtain better results. Results shows the improved performance of the filter over the linear filters and also retains the edges and fine details in the images.

- D S Bormane :- working as head of Electronics and Telecommunication at S T B College of Engineering, Tuljapur-413601 (India)

- Dr.T R Sontakke working as principal SGGS College oF Engineering,Nanded.

6. References:-

[1].J.S.Lee, " Digital image enhancement and noise filtering by use of local statistics", IEEE Trans. on pattern analysis and machine intelligence PAMI-2, No.2, 1980,165-168.

[2].A.Kundu,S.K. Mitra And P.P.Vaidyanathan , "Application Of Two Dimensional Generalized Mean Filtering For Removal Of Impulse Noises From Images," IEEE Trans. On Acoustic, Speech And Signal Processing, Vol.ASSP-32, No.3, June 1984.

[3].I.Pitas And A.N. Venetsanpoulos, " Nonlinear Order Statistic Filters For Image Filtering And Edge Detection," Signal Processing, Vol.10, No.4, June-1986.

[4]. J.B. Bednar And T.L. Watt, "Alpha-Trimmed Means And Their Relationship To Median Filters ,"IEEE Trans. On Acoustic, Speech and Signal Processing, Vol. ASSP-32, No.1

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