Improved 2-D Median Filter for On-Line Impulse Noise Suppression

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Abstract—An improved 2-D median filter employing multishell concept to suppress impulse noise, is presented. The performance of proposed filter is evaluated over image 'LENA'. The impulsive noise is added using MATLAB utility. The modified strategy reduces the number of replacement and results in better performance and simple hardware realization that is suitable for on-line implementation.

Index Terms—Median Filter, Multi-shell Median Filter, Impulse Noise

I. INTRODUCTION

In TV and other imaging systems, impulse noise is a common impairment. The standard T. V. broadcast signal is often contaminated with impulsive noise arising from various sources such as household electrical appliances and atmospheric disturbances. Broad banding of the signal further increases the level of impulsive noise. Various filters are proposed to suppress such impairments [1]. The median filter (MF) [1-2] is widely used for impulse noise suppression and the multishell median filter (MMF) [3] introduces the concept of missing line recovery. Although these filters have satisfactory performance, MMF fails to filter two impulse noises in the same processing window. Moreover, these filters tend to blur the images due to too many replacements. C. J. Juan proposed a modified multishell median filter (MMMF) [4], which removes most of the shortcomings associated with the MF and the MMF. However, it is observed that under certain conditions, to be discussed in the following sections, MMMF fails to perform the desired filtering operation. Moreover, the number of calculations/replacements involved on the basis of MIN/MAX conditions is still too large and makes the filter difficult to realize, particularly for real time applications.

In this paper, the threshold strategy of MMMF is modified so that:

(a) effective noise filtering operations are performed under all conditions, and

(b) number of calculations / replacements is reduced and simplified.

This results in a simple hardware realization of the filter.

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II. PROPOSED MODIFICATION

Consider a 3x3-processing window, with P_5 as the central pixel, as shown in Figure 1.

P_1	P_2	P_3
P_4	P_5	P_6
P_7	P_8	P_9

Fig. 1. A 3 x 3 processing window

The output of MMMF as proposed in [4] is

$$\text{Output}\,(x, y) = \begin{cases} \text{Max}\,(P_2, P_8) \text{ if } P_5 > \text{Max}\,[S] \\ P_5 \text{ if } \text{Min}\,[S] < P_5 < \text{Max}\,[S] \\ \text{Min}\,(P_2, P_8) \text{ if } P_5 < \text{Min}\,[S] \end{cases} \tag{1}$$

Where S is the set of samples surrounding central pixels except (P_4, P_6) i.e.

$$S = \{P_1, P_2, P_3, P_7, P_8, P_9\} \tag{2}$$

The principle involved in the replacement strategy of Equation (1) is that if P_5 is corrupted by noise, it is better to replace its gray level by P_2 or P_8 than by using Min[S] or Max[S]. Also, due to missing lines error, since P_4 and P_6 may be lost, they are not considered in Equation (2).

The limitation of Equation (1) is that when Min[S] or Max[S] are also corrupted by impulse noise, i.e. either Min[S] or Max[S] is equal to P_5, Equation (1) fails to perform the desired filtering operation. To overcome this limitation following modifications in the replacement strategy of Equation (1), are proposed.

$$\text{Output}\quad (x,y)=\begin{cases}\text{Max}\,(P_2,P_8)\text{ if }P_5\geq \text{Max}\,[S]\\ P_5\text{ if Min}\,[S]<P_5<\text{Max}\,[S]\\ \text{Min}\,(P_2,P_8)\text{ if }P_5\leq \text{Min}\,[S]\end{cases}\qquad (3)$$

It has been observed that for more than 70-80% points in an image, the gray level distances of P_5 from (P_2 or P_8) and from Max[S] are below 16. This is shown in Fig. 2 for the image 'LENA'. This fact is used to further reduce unnecessary replacements, thereby reducing the blurring of the images. Thus taking into consideration the gray level distribution of Figure 2, the proposed replacement strategy of Equation (3) can be further modified as

$$\text{Output}\,(x,y)=\begin{cases}\text{Max}\,(P_2,P_8)\text{ if }P_5-\text{Max}\,[S]\geq 16\\ \text{Min}\,(P_2,P_8)\text{ if Min}\,[S]-P_5\geq 16\\ P_5\ \text{ otherwise}\end{cases}\qquad (4)$$

Equation 4 indicates that replacing action takes place only when the distance between P_5 and Max[S] or Min[S] is no smaller than 16. This strategy thus avoids the unnecessary replacements and reduces blurring of the images. Moreover it can be implemented using simple comparators and subtractors.

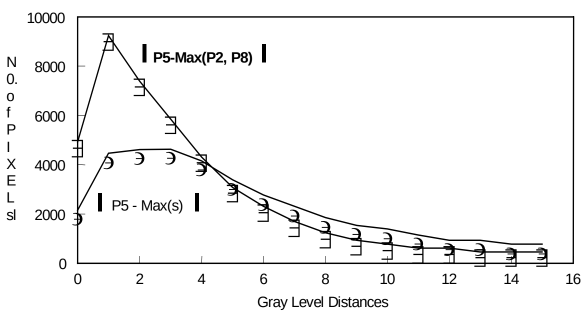

Fig. 2. Gray level distances between central point and its neighboring points for the image 'LENNA'

III. RESULTS

Figure 3 shows the original image 'LENNNA' and
Figure 4 shows the same image when corrupted with impulse noise. Results of median filter and the proposed filter are given in Figures 5 and 6, respectively. Comparing Figures 5 and 6, it is observed that the result of the proposed filter is much better than those obtained using the median filter. Although, the median filter removes the impulsive noise effectively, however, the image gets blurred. The proposed filter removes the impulsive noise and also preserves the details of the image.

Fig. 3. Image LENNA scanned at 100 dpi and 8 bits/pixel

Fig. 4. Image LENNA corrupted with impulse noise

Fig. 5. Output of the Median Filter

Fig. 6. Output of the proposed filter

IV. CONCLUSIONS

A multishell filter employing the modified replacement strategy is presented in this paper. The modified filter effectively suppresses the impulse noise. It uses threshold conditions that require fewer comparisons and replacements and is faster as compared to the other multishell median filters. Moreover, it can be realized using simple comparators and subtractors and hence can be effectively used in real time applications.

V. REFERENCES

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JACOBI MOMENTS AS IMAGE FEATURES

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ABSTRACT

In this paper, we introduce a set of moments which is based on Jacobi polynomials. The set of Jacobi polynomials are orthogonal and this ensures minimal information redundancy between the moments. By changing the parameters α and β, it is shown that the moments are able to extract both global and local features. This is unseen in moments such as geometric, Legendre and Zernike moments as they are all global moments. This means that, by using Jacobi moments, local information at a particular position of the image can be extracted. Experimental results are given to support these claims.

1. INTRODUCTION

Back in 1962, Hu [1] started using geometric moments for image pattern recognition. Hu's moments are invariant to rotation, scale change and translation and this is especially important for the recognition task for patterns under different orientations. One important development in moments in the field of image processing is done by Teague [2]. Teague introduced the notion of orthogonal moments. In particular, Legendre and Zernike moments are proposed by Teague as image features. Recent development in image moments includes [3]–[8]. Mukundan et al. [3] set of discrete Tchebichef moments which are well-suited for digitial images since no approximation is needed in the process of computing the moments. The set of Krawtchouk moments was proposed by Yap et al. [6]. An interesting of property of Krawtchouk moments is that the moments are *local* moments, that is, information extracted by Krawtchouk moments is from only a portion of the image.

In this paper, we introduce a set of moments which is based on the set of Jacobi polynomials, $\{P_n(x;\alpha,\beta)\}$. Depending on the values of α and β, Jacobi polynomials have many well-known special cases. When $\alpha = \beta = \lambda - \frac{1}{2}$, $\lambda \neq 0$, we have the Gegenbauer or Ultraspherical polynomials. When $\alpha = \beta = -\frac{1}{2}$ and $\alpha = \beta = -\frac{1}{2}$, we have the Chebyshev polynomials of the first and second kind, respectively. When $\alpha = \beta = 0$, we have the Legendre or Spherical polynomials. Our intention here is not to limit ourselves to these special cases; arbitrary values for α and β are considered instead.

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The set of Jacobi polynomials are orthogonal and this ensures minimal information redundancy between the moments. By changing the parameters α and β, it is shown that the moments are able to extract both global and local features. Hence, Jacobi moments encompass the properties of both the global moments (e.g. geometric, Legendre, Zernike and Tchebichef moments) and local moments (e.g. Krawtchouk moments). Experimental results are given to support these claims.

2. JACOBI POLYNOMIALS

The kernel of the Jacobi moments consists of the set of Jacobi polynomials. The Jacobi polynomial of the n-th order, with parameters α and β, is defined as [9]:

$$P_n(x;\alpha,\beta) = \frac{(\alpha+1)_n}{n!} \times {}_2F_1\left(\begin{array}{c} -n, n+\alpha+\beta+1 \\ \alpha+1 \end{array} \middle| \frac{1-x}{2} \right) \quad (1)$$

where $x \in [-1,1]$. The generalized hypergeometric function, ${}_rF_s$, is defined as:

$${}_rF_s\left(\begin{array}{c} a_1,\ldots,a_r \\ b_1,\ldots,b_r \end{array} \middle| z \right) = \sum_{k=0}^{\infty} \frac{(a_1,\ldots,a_r)_k}{(b_1,\ldots,b_r)_k} \frac{z^k}{k!} \quad (2)$$

where $(a_1,\ldots,a_r)_k = (a_1)_k,\ldots,(a_r)_k$ and the Pochhammer-symbol:

$$(a)_k = a(a+1)(a+2)\ldots(a+k-1) \quad (3)$$

with $k = 1,2,3,\ldots$ and $(a)_0 = 1$. The Jacobi polynomials can be written in teh Rodrigues-type formula as:

$$(1-x)^\alpha(1+x)^\beta P_n(x;\alpha,\beta) = \frac{(-1)^n}{2^n n!}\left(\frac{d}{dx}\right)^n \left[(1-x)^{n+\alpha}(1+x)^{n+\beta}\right]. \quad (4)$$

For $\alpha > -1$, $\beta > -1$, the set of Jacobi polynomials satisfy the orthogonality condition:

$$\int_{-1}^{-1} w(x;\alpha,\beta)P_m(x;\alpha,\beta)P_n(x;\alpha,\beta)dx = \rho(n;\alpha,\beta)\delta_{mn}, \quad (5)$$