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Positive–negative impulse noise removal based on row and column filtering

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ABSTRACT

In the field of photo-electronic imaging, impulse noise seriously affects the image quality. In order to remove it, a new positive–negative impulse denoise filter based on the row and column filtering (PN-RCF) is proposed and its performance of noise removal and detail protection is analyzed. Compared with other nonlinear filters through the simulations, the given filter not only can suppress the positive–negative impulse noise, but also can protect the edges and detail well with simple row and column processing.

1. Introduction

Image processing, such as edge detection, image segmentation and so on [1], is to make the images damaged by external causes restored more better [2]. However, the impulse noise may influence the effect of image processing. During the image acquisition and transmission, the impulse noise is caused by various factors, such as the imaging conditions, the quality of their components.

In order to deal with the impulse noise, many filter based approaches have been proposed, and the key problem to the filter's based approaches is to improve the filter ability. In general, the filter ability is inherently decided by: (1) the ability of removing the noise; (2) the filter's edge and detail protection. The conventional linear filters [3], such as median filter, recursive median filter, adaptive filters, robust statistical adaptive filter and so on, have a better ability in removing noise. However, they all have some drawbacks. For example, the median filter and its transform methods [4–8], may cause the edge of image evacuation and smears, which make the image distortion [9]. In addition to the traditional filters, there are many new filters appeared. For example, a two-output nonlinear filter [10] can remove impulse noise and has a good deal with the image detail, but it only deals with black and white images. Quaternion switching filter for impulse noise reduction for color image [11] is another filter that has a better performance of noise suppression and detail preservation, but the method is more complicated. An effective 2-stage techniques for removing impulse noise is presented [12], it is of great noise removal effect, but the edge and detail protection is limited.

To deal with the positive and negative impulse noise, we carried out a nonlinear filter (PN-RCF) based our previous work [13]. Compared with several kinds of nonlinear filters, the experimental results demonstrated that PN-RCF can remove positive–negative impulse noise, and it has a better ability to protect the edge and detail than others, which is very important in some cases.

2. Filter based on row and column processing and its properties

2.1. Definition of PN-RCF

PN-RCF based on RCF distinguishes the impulse noise by following two steps: (1) comparing the difference of adjacent data with thresholds, (2) replace impulse noise with the following operation on adjacent data.

Suppose $X = \{x(i,j) \in Z;\ i,j \in Z\}$ be the original image that contains positive–negative impulse, $x(i,j)$ be the gray value of pixel (i,j), Z be the set of integers. An image is firstly filtered by line-by-line, and then by column by column. The definition of the filter is defined as follows:

$$y_r(i,j) = \begin{cases} x(i,j+1), & |x(i,j) - x(i,j-1)| \geq k\sigma[\nabla x(i,\bullet)] \\ x(i,j), & otherwise \end{cases} \quad (1)$$

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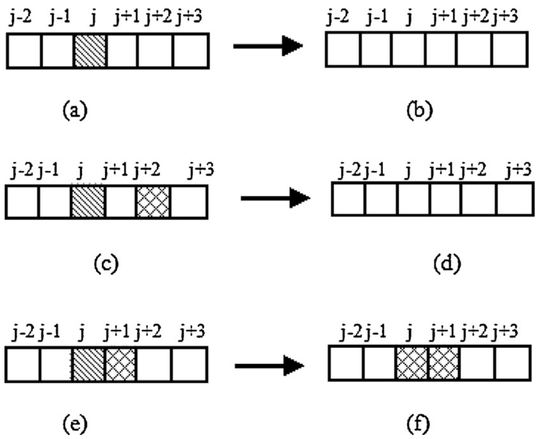

Fig. 1. Row or column filtering performance. (a), (c) and (e) are three typical distribution of impulses, (b), (d) and (f) are filtering results respectively by PN-RCF.

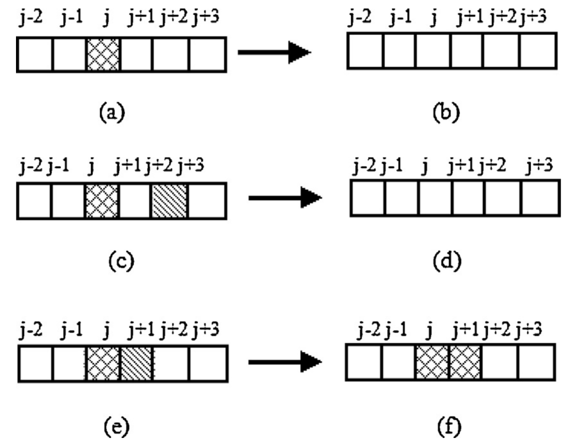

Fig. 2. situations opposite to Fig. 1. (a), (c) and (e) are three typical distribution of impulses, (b), (d) and (f) are filtering results respectively by PN-RCF.

$$y_{RC}(i,j)=\begin{cases} y_R(i+1,j)\ ,\ |y_R(i,j)-y_R(i-1,j)|\geq k\sigma[\nabla y_R(\bullet,j)] \\ y_R(i,j), \qquad\qquad \textit{otherwise} \end{cases} \tag{2}$$

where $\nabla x(i,\bullet)$ and $\nabla y_R(\bullet,j)$ stand for the first order difference of the ith row of image X and jth column of image y_R, respectively. σ is the sign of standard deviation. k is a tuning coefficient, and is generally setted as $k=1.0$. If k is larger (than one), only higher gray-level impulses are removed and vice versa.

2.2. Filtering properties of PN-RCF

Impulse noise in image can be divided into positive and negative impulse noise. Gray-levels of the positive impulse noise are larger than their neighborhood and negative impulse noises' gray-levels are less than their neighborhood. According to the limitation, the PN-RCF cannot remove more than 2×2 noise blocks. The possible situations both in one-dimension and two-dimension are listed below.

Fig. 1 shows the possible one-dimensional situations: single, interval and adjacent impulse (each case includes two situations: the positive and the negative). According to (1), the value of single impulse at jth position in Fig. 1(a) may be replaced by its neighborhood $j+1$th shown in Fig. 1(b). Similarly, the two impulses in Fig. 1(c) may be removed as shown in Fig. 1(d). Under the situation of adjacent impulse in Fig. 1(e), the value of unit jth may be substituted by the unit $j+1$th, and unit $j+1$th remains the same and stands for the positive and negative impulse noise respectively in Fig. 1.

Fig. 2 is a similar discussion which is opposite to the situation mentioned above.

Fig. 3 shows the possible two-dimensional situations: single consecutive impulses shown in Fig. 3(a), double consecutive impulses shown in Fig. 3(d). According to (1) and (2), Fig. 3(a) turns into Fig. 3(b) through the row filtering line-by-line, then all of the noise are removed through the filter column-by-column, which is shown in Fig. 3(c). As the double consecutive impulses, Fig. 3(d) is changed into Fig. 3(e) by (1), and the noise is not removed completely after column-by-column, which is shown in Fig. 3(f). Therefore, we can remove all of single consecutive impulses except for double consecutive impulse noise totally with PN-RCF.

2.3. Detail preservation properties of PN-RCF

For images, the valuable edge and detail information hides within one or several pixels. So, the detail and edge protection is very important during the filtering. As the PN-RCF filter that removes the noise is slightly worse than the 3×3 median filter, PN-RCF compares the absolute value of differences of adjacent pixels with the certain thresholds for distinguishing impulse noise: if it is the impulse noise, replace it by the pixel after it. This strategy can greatly ensure the integrity of the original image edges and details, which is superior to the other filters.

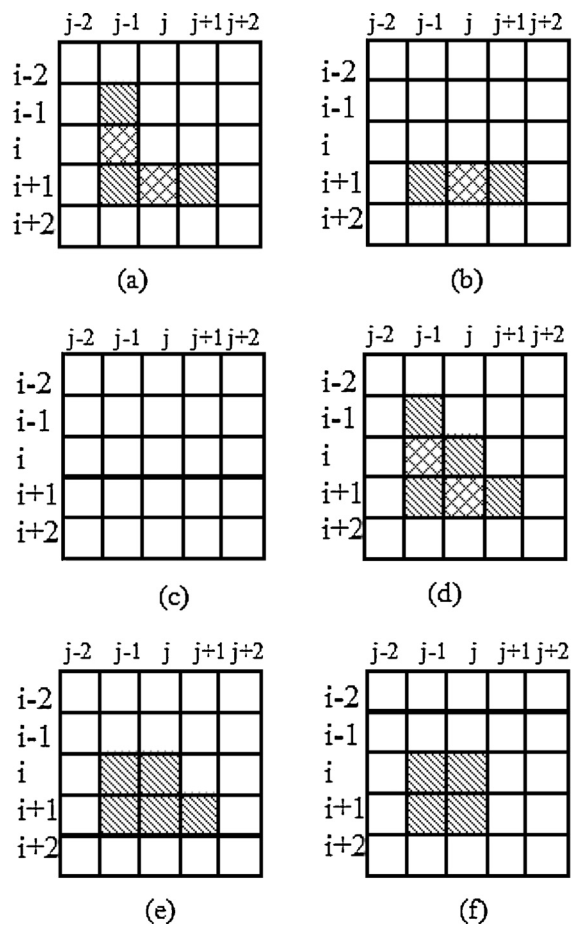

Fig. 3. Two-dimensional possible situations. 2-D filtering properties, (a) and (d) are two typical distribution of impulses, (b) and (e) are filtering results of rows, (c) and (f) are final results responding to (a) and (d).