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Sorensen Filter For Impulse Noise Removal

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Abstract:
In digital Image Processing, removal of noise is a highly demanded area of research. Impulsive noise is regular in images which happen at the time of image acquisition and or transmission of images. In this paper, a new Sorensen filtering algorithm is presented for the removal of impulse noise from digital images. This proposed filter uses diagonal element alone with Sorensen similarity to obtain appreciable results in terms of computational complexity and visual appearance than existing algorithms.

Keywords: Digital image processing; Sorensen filter; impulsive noise.

1. Introduction

Digital images play an important role both in daily life applications such as Satellite television, Magnetic Resonance Imaging, Computer Tomography as well as in areas of research and technology such as geographical information systems and astronomy. Digital images are often corrupted by different types of noise during its acquisition and transmission phase. Such degradation negatively influences the performance of many image processing techniques and a preprocessing module to filter the images is often required [1,2]. To enhance the quality of images various images enhancement or restoration techniques are used. Efficiency of every method is depends on the quality of input images.

The overall noise characteristics in an image depend on many factors, including the type of sensor, pixel dimensions, temperature, exposure time, and speed. The goal of image denoising is to remove the noise while retaining the important signal features. The denoising of a natural image corrupted by noise is an important significant in image processing. Image denoising still remains a challenge for researchers because noise removal introduces artifacts and causes blurring of the images. This chapter discusses the methods of noise reduction of impulse noise image using Sorensen approach [3-6].

2. Literature

Images are often corrupted by impulse noise, also known as salt and pepper noise. Image might be corrupted by impulse noise in the process of signal acquisition and transmission, so variety of denoising techniques has been proposed. For this correspondence, in this section we discuss some of the techniques which are mainly related to similarity measure particularly in neighbor or diagonal pixels. For this regard K.S. Srinivasan and D.Ebenezer [7,8]proposed Decision Based algorithm in which corrupted pixels are replaced by either the median pixel or neighborhood pixel and other existing algorithms that use only median values for replacement of corrupted pixels. At higher noise densities, the median value may also be a noisy pixel in which case neighborhood pixels are used for replacement. In addition, the new Decision based algorithm (DBA) uses simple fixed length window of size 3X3, and hence, it requires significantly lower processing time compared to other algorithms. The DBA processes the corrupted image by first detecting the impulse noise. The detection of noisy and noise-free pixels is decided by checking whether the value of a processed pixel lies between the maximum and minimum values that occur inside the selected window. This is because the impulse noise pixels can take the maximum and minimum values in the dynamic range (0, 255). 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 or by its neighborhood values.

Pei Yin Chen et.al [9] proposed the alternative method, which is edge preserving filter consists of two components namely efficient impulse detector and edge preserving filter. The former determines which pixels are corrupted by fixed-valued impulse noise. The latter reconstructs the noisy pixels by observing the spatial correlation and preserving the edges efficiently. The proposed edge-preserving image filter adopts a directional. Correlation-dependent filtering technique based on observing the sample correlations of eight different directions namely E, W , S, N, ES, SW, NE, NW. For each noisy pixel, the image filter detects edges in six directions first and estimates the intensity value of the pixel accordingly.

Gang Qian et.al [10] compare two commonly used distance measures in vector models, namely, Euclidean distance (EUD) and cosine angle distance (CAD), for nearest neighbor (NN) queries in high dimensional data spaces. Using theoretical analysis and experimental results, it shows that the retrieval results based on EUD are similar to those based on CAD when dimension is high. We have applied CAD for content based image retrieval (CBIR). Retrieval results show that CAD works no worse than EUD, which is a commonly used distance measure for CBIR, while providing other advantages, such as naturally normalized distance. The results conclude that EUD and CAD are similar when applied to high dimensional NN queries. For normalized data and clustered data, EUD and CAD become even more similar.

Dapeng Zhang and Zhou Wang [11] proposed novel filtering algorithm for restore images corrupted by impulsive noise. As a preprocessing procedure of the noise cancellation filter, an improved impulse detector is used to generate a binary flag image, which gives each pixel a flag indicating whether it is an impulse. To remove noises from the corrupted image used a polynomial approximation (PA) filter, which is developed by modeling a local region with a polynomial that can best approximate the region under the condition of least squared error. The proposed impulse replacement method breaks through the traditional framework in that it is not designed by employing merely the ranking or statistical information and replacing the corrupted value with one from the local window or some linear combination of local samples, but is implemented by modeling the local region using a polynomial, which is more powerful in representing the real structure of the region. An adaptive method is also presented that can automatically give an appropriate polynomial order for a local region.

Arumugam rajamani et.al [12] proposed another novel approach called Lone Diagonal Sorting (LDS) for denoising color images and videos corrupted with salt and pepper noise. This method uses diagonal sorting alone for denoising of impulse noise and clearly reduces the computational time required for denoising the corrupted images because of the lower number of computations required as compared to other standard approaches. Also since the noisy pixels are replaced with the immediate neighborhood pixels, the simulation results shows that the proposed approach was comparatively appreciable

Rajoo Pandey [13] proposed a new algorithm to improve the performance of switching median filter in detection of uniformly distributed impulse noise. In the proposed scheme, the image is assumed to be corrupted by noise with uniform distribution between 0 and 255. For the impulse noise detection, the median of the pixels in the filtering window is compared with the threshold value. If it reaches the noisy pixel replaced with the median value otherwise keep the original pixel.

In this section we discussed some of the techniques which are related 3x3 windows, especially in diagonal and neighborhood similarity based filters. However, there is a lot of scope in this area, to full fill this, we proposed algorithm that uses just 3 comparisons per window through diagonal sorting and hence lower number of computations leading to robustness can be achieved. Earlier algorithms use combinations of row, column and diagonal sorting which increases computational and hardware complexity. Also reduction in the operating speed due to more computations is observed.

3. Existing Approaches with Similarity Measures

In this section we discussed the existing methods especially in similarity measures like neighbor value, side by side pixels. The algorithm for lone diagonal sorting for color images is described here. For each channel of the color image (red, green and blue), here we discussed some of them.

3.1. Decision Based Approach

The decision based algorithm (DBA) [14,15] processes the corrupted image by first detecting the impulse noise. The detection of noisy and noise-free pixels is decided by checking whether the value of a processed pixel lies between the maximum and minimum values that occur inside the selected window. This is because the impulse noise pixels can take the maximum and minimum values in the dynamic range (0, 255). 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 or by its neighborhood values. Following are the steps for DBA:

Step 1) A 2-D window “S×Y” of size 3*3 is selected. Assume the pixel to be processed is P(X, Y).

Step 2) the pixel values inside the window are sorted, and, Pmin, Pmax and Pmed are determined as follows.

(a) The rows of the window are arranged in ascending order.

(b) The columns of the window are arranged in ascending order.

(c) The right diagonal of the window is now arranged in ascending order.

Now the first element of the window is the minimum value P_{min}, the last element of the window is the maximum value P_{max} , and the middle element of the window is the median value Pmed .

Step 3)

Case 1) The P(X,Y) is an uncorrupted pixel if P_{min}<P(X,Y)< Pmax, Pmin>0, and P_{max}<255; the pixel being processed is left unchanged. Otherwise, P(X,Y) is a corrupted pixel.

Case 2) If P(X,Y) is a corrupted pixel, it is replaced by its median value if $P_{min}<P_{med}< P_{max}$ and $0<P_{med}<255$.

Case 3) If $P_{min}<P_{med}< P_{max}$ is not satisfied or $255<P_{med}=0$, then P_{med} is a noisy pixel. In this case, the P(X,Y) is replaced by the value of neighborhood pixel value.

Step 4) Steps 1 to 3 are repeated until the processing is completed for the entire image.

3.2. Edge Preserving Approach

The edge preserving approach (EPA) [9,16] is composed of two components: efficient impulse detector and edge preserving filter. The former determines which pixels are corrupted by fixed-valued impulse noise. The latter reconstructs the noisy pixels by observing the spatial correlation and preserving the edges efficiently. Correlation-dependent filtering technique based on observing the sample correlations of six different directions. For each noisy pixel, the image filter detects edges in six directions first and estimates the intensity value of the pixel accordingly.

3.3. **Denosing approach for the removal of impulse Noise**

The algorithm for lone diagonal sorting for color images is described below. For each channel of the color image (red, green and blue), the following is implemented.

STEP 1: First the “red” array is selected among three channels.

STEP 2: A 2D window of size 3x3 in a 512x512 array is chosen. A_{ij} is assumed as the pixel being processed.

STEP 3: The leading diagonal elements (only three elements in this case) of the window size 3x3 is selected and sorted. Assume that the diagonal pixels being processed are D11, D22 and D33 If the diagonal element 0 < Dij < 255, then it is classified as a noise free pixel, and is left unchanged.
If the diagonal element Dij = 0 or 255 then it is classified as noisy pixel and the replacing technique is applied since the proposed algorithm aims to remove the noisy pixels such as salt(255) and pepper(0) in an effective manner.

STEP 4: Each diagonal pixel is checked for salt and pepper noise (0 or 255) and replaced with the either of the other values which are noise free. In the above case the D_{11} is 0, D_{22} is 27 and D_{33} is 255.

STEP 5: Sorting of the three diagonal elements is performed in the ascending order sorting result comes as 0,27,255 and middle element called as median value (in this case 27) is replaced for the diagonal element D11 and D33 which are pepper and salt noises respectively.

3.4. Polynomial filter[11,17]

In this filter, first we consider a $(2L_f+1)x(2L_f+1)$square region centered about an impulse pixel (i_0,j_0) with $f_{i0j0}=1$ The pixels in the region can be categorized into two classes good pixels ($f_{ij}=0$) and impulse pixels ($f_{ij}=1$). Only good pixels are used by the PA filter, which models the local region using a 2-D polynomial. For simplicity, we shift the position of the center pixel (i_0 , j_0) to (0,0) and normalize the square region so that its top-left and bottom-right corners are located at (-1,-1) and (+1,+1), respectively: $y_{pq}=x_{ij}$ where *ypq* is the pixel value under the new coordinate and we have $p=(i-i_0)/L_f$ and $q=(j=j_0)/L_f$, Then the approximation polynomial can be denoted as $\widehat{y_{pq}} = \sum_{n=0}^{K}\sum_{n=0}^{K=m} c_{mn} \quad p^m \quad q^n$, where $\{C_{mn}|$ m=0,….K; n==0,…m=K$\}$is a set of coefficients, and *K* is the order of the polynomial. The calculated value of *y pq* can be used to estimate the value of *xi j* :*xi j* := *ypq* The set of coefficients $\{C_{mn}\}$ should be well selected so that the good pixels in the local region are best approximated under the condition of the least squared error. The squared error is calculated as $E = \sum_{i=-L_f}^{L_f}\sum_{j=-L_f}^{L_f}\left(1-f_{ij}\right)(x_{ij} = \widehat{x_{ij}})^2$ By solving these equations, the value of each c_{mn} can be obtained. Finally, the center pixel $x_{i0\ j0}$ is replaced by the estimated value: $X_{i0j0}=j_{00}=c_{00}$ As a special case, the zero order PA filters has only one coefficient c_{00} and the solution is simply

$$c_{00} \frac{\sum_{i=-L_f}^{L_f}\sum_{i=-L_f}^{L_f}(1-f_{ij})x_{ij}}{\sum_{i=-L_f}^{L_f}\sum_{i=-L_f}^{L_f}(1-f_{ij})}$$

That is, c_{00} equals the average value of the good pixels in the square region. Therefore, the zero-order PA filter can also be viewed as a noise free neighborhood mean filter

4. Sorensen Filter

The main challenge in impulse noise removal is to suppress the noise as well as to preserve the details (edges). This paper presents a simple & effective way to remove the impulse and random noises from the digital image. The first step is to detect the impulse and random noise from the image as shown in Fig 1. In this stage, based on the only intensity value, the pixels are roughly divided into two classes, which are "noise-free pixel" and "noise-pixel". Then the second stage is to eliminate the impulse and the random noise from the image. The proposed filter operates on impulse noise densities without jeopardizing image fine details and textures. The proposed filter does not require any tedious tuning or time consuming training of parameters as well. No priori threshold is to be given. Instead, the threshold is computed locally from image pixels values in a 3x3 window using weighted statistics. More precisely, the diagonal weighted value and the Sorensen weighted deviation are estimated in the current 3x3 window. The weights are the values of the distance between three diagonal values divided by sum of diagonal value of pixels in a given window. A result is that impulse noise does not corrupt the determination of these statistics from which the Threshold is derived. Noise-free pixels are relatively easy to be selected by utilizing the decision. A limit for window is set to contain a minimum number of pixels avoids loss of image details.

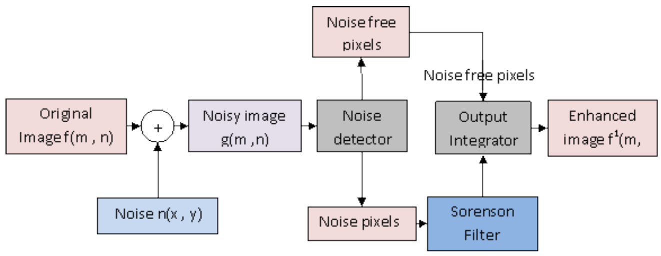

Figure 1. System structure

4.1. Sorensen Filter Algorithm

In an image contaminated by random-valued impulse noise, the detection of noisy pixel is more difficult in comparison with fixed valued impulse noise, as the gray value of noisy pixel may not be substantially larger or smaller than those of its neighbors. Due to this reason, the conventional median-based impulse detection methods do not perform well in case of random valued impulse noise. The numerical Threshold value is defined a priori or chosen after many data dependant tests. The literature shows that an optimal threshold in the sense of the mean square error can be obtained for most real data. However, Threshold suitable for a particular image is not necessarily adapted to another one. To overcome this problem, the following algorithm is proposed. Consider an image of size $M \times N$.

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Algorithm 1 Sorensen approach	
S	Read the input image and insert Random Valued Impulse Noise into the image.
S	Construct a matrix from the whole image so that pixel values of order 3×3 can be stored which is also known as image resolution. $\begin{bmatrix} 255 & 0 & 0 \\ 0 & 243 & 0 \\ 0 & 0 & 1 \end{bmatrix}$
S	Now compute the pixel values present at the diagonals from the 3×3 matrix. $\begin{bmatrix} 255 \\ 243 \\ 1 \end{bmatrix}$
S	Compute the Sorensen distance value by using the diagonal values[18] Sorensen distance= $D_{i,h} = \dfrac{\sum_{j=1}^{p} \lvert a_{ij} - a_{hj} \rvert}{\sum_{j=1}^{p} a_{ij} + \sum_{j=1}^{p} a_{hj}}$

S	Read each pixel intensity value from 3×3 matrix
	For i=1 to M
	For j=1 to N
	begin
	If pixel intensity value=255 then
	that pixel intensity value is replaced with the Sorensen distance as follows
	pixel(i,j)=Dih
	else if pixel value=0 then
	also that pixel intensity value is replaced with the Sorensen distance as follows
	pixel(i,j)= Dih
	else
	there is no change in the pixel intensity value and as follows
	pixel(i,j)=pixel(i,j)
	end

S	Restore the image with calculated pixel intensity values.

4.2. Experimental Results

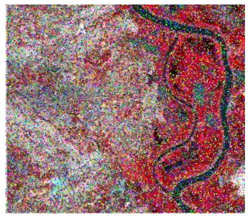
In this section, the proposed algorithm is evaluated and compared with some other existing techniques. Extensive experiments are conducted on four standard grayscale test images and four standard color test images with distinctly different features, corrupted by simulated with impulse noise at different power levels. The parameters of each method have been set according to the values given by their respective authors in the corresponding referred papers.

Visual Quality:

In Fig. 2, the output images are processed with the proposed and other state- of-the-art image denoising algorithms. The fragments of the color remote sensing images are corrupted by impulsive noise. Although there is no consensual objective way to judge the visual quality of a denoised image, two important criteria are widely used: the conservation of image edges and the visibility of processed artifacts. The proposed algorithm (MSMF) generally outputs smoother surfaces in homogeneous regions, and preserves sharper edges in detailed regions.

Original Image

Impulse Noise Image (0.2)



Sorensen filtered Image

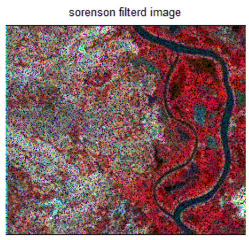


Fig 2 Sorensen original and filter images

Computational Time:

It is also important to evaluate the various denoising algorithms from a practical point of view: the computational time. In evaluating the computational complexity of our algorithm, we consider the spatial stages.

PSNR and MSE Comparisons:

The designed filter was tested using several noise conditions. The original image is corrupted by mixer of salt and pepper noise. Here we conducted set of experiments to see the performance of the proposed framework quantitatively and visually. To do a quantitative comparison, we simulated noisy images by adding white impulsive noise with various standard deviations to remote sensing test images. These noisy images were then denoised using several algorithms and the MSE, PSNR results were calculated. For visual comparisons, real noisy images were used. The simulated results are shown in Fig 3 and 4. Table 1 and 2 shows Performance evaluation of different filtered images at different noise level for Remote sensing image.

Table 1. performance evaluation with different filtered approaches

PSNR	10%	20%	30%	40%	50%
Denoising approach	36.4288	32.5153	30.5311	29.5730	27.9126
Polynomial approach	35.4288	31.5153	29.5311	27.5730	25.9126
DBA	34.4288	29.5153	27.5311	24.5730	22.9126
EPA	34.4288	30.5153	28.5311	25.5730	23.9126
Proposed	33.4288	28.5153	25.5311	23.5730	21.9126

Table 2. performance evaluation with different filtered approaches

MSE	10%	20%	30%	40%	50%
Denoising approach	1170.60	1980.60	2999.70	3666.50	4767.40
Polynomial approach	1290.60	2120.60	3109.70	3966.50	4967.40
DBA	1335.60	2320.60	3309.70	4266.50	5167.40
EPA	1375.60	2400.60	3409.70	4286.50	5207.40
Sorensen approach	1385.60	2439.60	3439.70	4309.50	5217.40

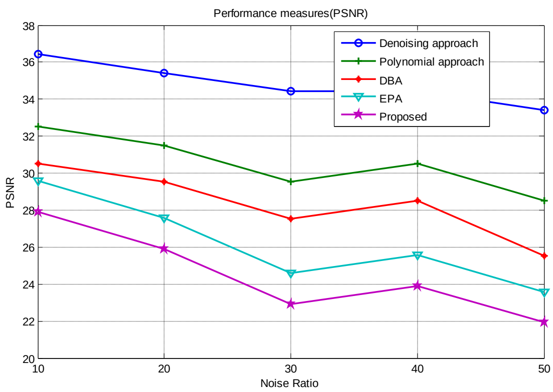


Figure 3 Noise ratio vs PSNR

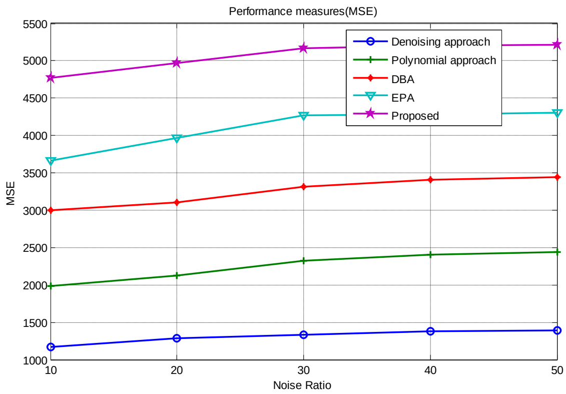


Figure 4 Noise ratio vs MSE

5. Conclusions

A novel Sorensen filtering operator for removing mixed noise from digital images is presented. The fundamental superiority of the proposed operator over most other operators is that it efficiently removes impulse noise from digital images while preserving thin lines and edges in the original image. Extensive simulation results verify its excellent impulse detection and detail preservation abilities by attaining the highest PSNR and lowest MSE values across a wide range of noise densities. Thus rampant loss of image is reduced without jeopardizing image fine details.

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