

Directional Correlation-Dependent Filtering Technique for Removal of Impulse Noise

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Abstract

This paper aims to obtain an integrated and consecutive original image from noisy image by a directional correlation-dependent filtering technique, for removing salt and pepper noise from corrupted images. A comparative study is made on the various image denoising methods and extensive experimental results demonstrate that directional correlation-dependent filtering algorithm can obtain better performances in terms of PSNR value compare to other impulse denoising techniques. The proposed algorithm can preserve edges very well while removing impulse noise and is very suitable to be applied to many real-time applications.

Keywords: Noise, Image denoising, Edges, PSNR

1. Introduction

Image is a function $f(x,y)$ where (x,y) are spatial co-ordinates and f is a intensity value or brightness value or gray level value at that particular spatial co-ordinate. If image is represented in discrete form for spatial co-ordinates is called digital image. The size of image is represented by $M \times N \times K$ where M is number of rows, N is number of columns and K is number of bits required to represent each pixel of an image. Real images are often degraded by some random errors [1, 19]; this degradation is called as noise. Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. The acquisition or transmission of digital images through many consumer electronics products such as digital cameras and digital television (DTV) is often interfered by impulse noise. It is very important to eliminate noise in the images before subsequent processing, such as image segmentation, object recognition, and edge detection.

The image $g(x,y)$ is a noisy image obtained by adding $\eta(x,y)$ noise to the original image $f(x,y)$, represented as $g(x,y) = f(x,y) + \eta(x,y)$. Noise can occur in still images or video sequences of DTV in various steps such as image acquisition, recording, and transmission. The standard television broadcast signals are often contaminated with impulse noise arising from various sources such as household electrical appliances and atmospheric disturbances. In order to get images and video sequences of high quality in digital cameras and DTV, it is very important to eliminate impulse noise in the images. For further uses of these images needs the noise is to be removed from those corrupted images by applying image denoising methods. Image denoising is a process of removing noise in a digital image. In order to remove the noise from an image we need to identify the noise-free and noisy pixels from an image. If the value of the pixel to be

processed lies in the image pixel intensity value 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. If a pixel is a noisy then it is smoothed by applying linear or non-linear noise removal techniques. Figure 1 shows original image along with 30% of pixels corrupted by Salt and Pepper noise.



Figure 1. Original and Corrupted Image with Impulse Noise

Recently, many image denoising methods have been proposed to carry out the impulse noise suppression [2–19]. Existing denoising techniques used for removal of salt and pepper noise from corrupted images. These can be grouped into two types i.e., linear and non-linear filtering techniques. New Impulse Detector (NID) approach [16] uses switching median filter, which obtains minimum absolute value of four convolutions by using one dimensional laplacian operators to detect noisy pixels. Differential rank impulse detector approach [5] compares signal samples within a narrow rank window by both rank and absolute value. Decision Based Algorithm (DBA) approach [8] involves removing the corrupted pixels by the median or by its neighboring pixel value according to the proposed decisions but it includes drawbacks as when noise level is high the image details and edges are not recovered satisfactorily. In this paper an efficient directional correlation-dependent filtering technique for removal of salt-and-pepper noise and also well in preserving edges with improved PSNR (db) value. The efficient edge preserving algorithm is efficient in preserving edges in a corrupted image after denoising process and with improved PSNR (db) value on both gray scale and color images.

The paper is organized as follows. The proposed method is in Section 2, Section 3 is on the experimental results followed by conclusions at Section 4.

2. Proposed Method

2.1 Efficient Edge Preserving Algorithm

Efficient Edge Preserving Algorithm on Gray Scale Images. An efficient edge preserving algorithm is applied on gray scale images of 8-bit representation. This method is used for removal of salt and pepper noise. It consists of two modules.

- Efficient Impulse Detector – in which we are determining which pixels are corrupted by fixed-valued impulse noise.
- Edge Preserving Filter – used to reconstruct the noisy pixels by observing the spatial correlation and preserving the edges efficiently. This method is efficient in terms of improved PSNR and IEF parameters even increase in noise ratio also.

A. Efficient Impulse Detector

Let P_{ij} denote the current pixel at coordinate (i,j) and Y_{ij} denote its pixel value. For each pixel in an image, we define a 3 X 3 window centered on it first. Let $W_{i,j}$ represent the set of pixels within a 3 X 3 window centered on . Thus, it can be given as

$$W_{i,j} = \{P_{k,l} / i-1 < k < i+1 \text{ and } j-1 < l < j+1\} \quad (1)$$

Assume that $\text{Maxin}W_{i,j}$ and $\text{Minin}W_{i,j}$ are the maximum and minimum gray-scale values in the current working window $W_{i,j}$, respectively, and let $\text{Max}_{i,j}$ and $\text{Min}_{i,j}$ are the maximum and minimum gray-scale values in those previously processed windows from the first one ($W_{0,0}$) to ($W_{i,j}$) the current one. The relationships between them are given as follows.

$$\text{Max}_{i,j} = \begin{cases} \text{Max}_{i,j-1} & \text{if } \text{Max}_{i,j-1} > \text{Maxin}W_{i,j} \\ \text{Maxin}W_{i,j} & \text{otherwise} \end{cases} \quad (2)$$

Similarly

$$\text{Min}_{i,j} = \begin{cases} \text{Min}_{i,j-1} & \text{if } \text{Min}_{i,j-1} > \text{Minin}W_{i,j} \\ \text{Minin}W_{i,j} & \text{otherwise} \end{cases} \quad (3)$$

Based on this, we define two variables N_{\max} and N_{\min} , for efficient impulse detection. They are given as

$$N_{\max} = \begin{cases} \text{Max}_{ij} & \text{if } \text{Max}_{ij} = \text{Max}_{ij-1} \\ 255 & \text{otherwise} \end{cases}$$

similary

$$N_{\min} = \begin{cases} \text{Min}_{ij} & \text{if } \text{Min}_{ij} = \text{Min}_{ij-1} \\ 255 & \text{otherwise} \end{cases}$$

Where N_{\max} and N_{\min} can be treated as the estimated intensity values of “salt” and “pepper” noises, respectively, in those previously processed pixels ranging from $P_{0,0}$ to $P_{i,j}$. Based on this we can detect the noisy pixels by

$P_{i,j}$ = Noisy pixel If ($Y_{i,j} = N_{\max}$ or N_{\min})

Otherwise $P_{i,j}$ is a noise-free pixel.

B. Edge-Preserving Image Filter

The proposed edge-preserving image filter adopts a directional 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. For simpler representation, let a,b,c,d,e,f,g,h represent the intensity values of pixels, $P_{i-1,j-1}, P_{i-1,j}, P_{i-1,j+1}, P_{i,j-1}, P_{i,j+1}, P_{i+1,j-1}, P_{i+1,j}, P_{i+1,j+1}$ and the steps to calculate reconstructed value for noisy pixel are explained below.

- Find the six directional differences $D - D6$ as given below.

$$D1 = \text{Abs}(d - h) + \text{Abs}(a - e)$$

$$D2 = \text{Abs}(a - g) + \text{Abs}(b - h)$$

$$D3 = \text{Abs}(b - g) * 2$$

$$D4 = \text{Abs}(b - f) + \text{Abs}(c - g)$$

$$D5 = \text{Abs}(c - d) + \text{Abs}(e - f)$$

$$D6 = \text{Abs}(d - e) * 2$$

- Check whether the four pixels to be denoised later (e, f, g, and h) are equal to N_{\max} or N_{\min} , respectively. If yes, the pixel might be corrupted, and thus we do not consider the directional differences containing it by setting those differences to 512.

- If at least one of $D1$ and $D2$ is equal to 512, and $P_{i+1,j+1}$ is noise-free, then obtain extra directional difference to improve image quality.

$$D7 = \text{Abs}(a - h) * 2$$

If at least one of D_4 and D_5 is equal to 512, and $P_{i+1,j-1}$ is noise-free, then obtain extra directional difference to improve image quality.

$$D_8 = \text{Abs}(c - f) * 2$$

- Find the minimum value among those directional differences and denote it as D_{\min} . The minimum directional difference has the strongest correlation and probably has an edge in its direction. Hence, the reconstructed value of the corrupted pixel is estimated as follows:

$$Y_{ij} = \begin{cases} (a + d + e + h)/4 & \text{if } D_1 = D_{\min} \\ (a + d + g + h)/4 & \text{if } D_2 = D_{\min} \\ (b + g)/2 & \text{if } D_3 = D_{\min} \\ (b + c + f + g)/4 & \text{if } D_4 = D_{\min} \\ (c + d + e + f)/4 & \text{if } D_5 = D_{\min} \\ (d + e)/2 & \text{if } D_6 = D_{\min} \\ (a + h)/2 & \text{if } D_7 = D_{\min} \\ (c + f)/2 & \text{if } D_8 = D_{\min} \end{cases}$$

- If D_{\min} is equal to 512, it means that $P_{i,j+1}, P_{i+1,j-1}, P_{i+1,j}, P_{i+1,j+1}$ are all corrupted. In this case, no edge is considered. Here, we employ the two previously denoised pixels, $P_{i-1,j+1}$ and $P_{i,j-1}$ and take the mean of them as the reconstructed value. Then $Y_{i,j} = (c+d) / 2$



Figure 2. Efficient edge preserving Algorithm applied on Lena image corrupted with 10% noise



Figure 3. Efficient Edge Preserving Algorithm Applied on Lena Image Corrupted with 40% Noise

C. Efficient edge preserving algorithm on Color Images

Color is a property of enormous importance to human visual perception, but historically it has not been particularly used in digital image processing. Humans detect colors as combinations of the primary colors red, green and blue. In RGB model, a particular pixel may have associated with 3D vector (r,g,b) which provides the respective color intensities, where (0,0,0) is black, (k,k,k) is white, (k,0,0) is pure red, and so on – here k is the quantization granularity for each primary (256 is common).

D. Efficient edge preserving algorithm for Color images

The following steps are applied in order to remove Impulse noise from color images. First introduce the Impulse noise into the color image.

- Separate the red content, green content and blue content corrupted pixel intensity values from a color image by keeping each color content as a separate image. If $F(x,y)$ is a color image then $F(x,y,1)$ refers to red content pixels, $F(x,y,2)$ refers to green content pixels and $F(x,y,3)$ is blue content pixel values from a color image.
- On each separate image $F(x,y,1)$, $F(x,y,2)$ and $F(x,y,3)$ apply the efficient edge preserving algorithm discussed in order to remove the impulse noise in 2.5.
- From the restored images $F(x,y,1)$, $F(x,y,2)$ and $F(x,y,3)$ obtain the restored color image $F(x,y)$.



Figure 4. Restored Color Image after Applying Efficient Edge Preserving Algorithm Applied on Color Image

3. Results and Discussions

The efficient edge preserving algorithm compared with DBA [5, 15] and Median filters [7, 17], in terms of PSNR value obtained after denoising process. To verify the characteristics and performances of various denoising algorithms, a variety of simulations are carried out on the five well-known 512×512 8-bit gray-scale test images: Lena, Leaf, Einstein, water Lillies and vegetables. All the, images are corrupted by salt-and-pepper noise, where 255 represents the “salt” noise and 0 represents the “pepper” noise with equal probability. A wide range of noise ratios varied from 10% to 90% with increments of 10% is tested and the results are given in Figure 2 and Figure 3. Totally, two popular denoising methods are compared in terms of objective testing and subjective testing: 1) standard median filter of size 3×3 (MF) and 2) Decision based method. The Median filter brings out blurry restored images and other methods are not good enough with regard to edge preservation. In contrast, efficient edge preserving method can remove noise efficiently while preserving edges very well, and it can produce visually pleasing images. The efficiency of the efficient edge preserving method is compared with various functions stated below.

The following graph depicts restoration results in PSNR(db) for Leena image in which noise density is introduced from 10% to 90%.

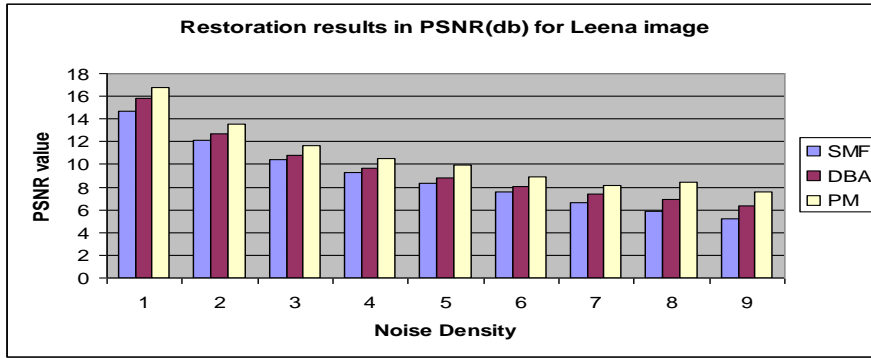


Figure 5. Graph for Comparisons of Restoration Results in PSNR (db) for Image “Lena”

The following graph depicts restoration results in PSNR(db) for five reference images Lena, Leaf, Einstein, water Lillies and vegetables images in which noise density is introduced from 10% to 90% with efficient edge preserving method along with SMF and DBA approaches.

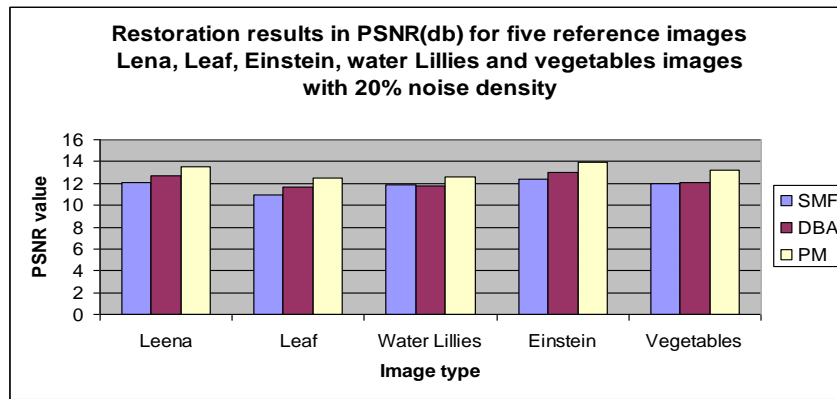


Figure 6. Comparisons of Restoration Results in PSNR (db) for Five Reference Images

4. Conclusions

The efficient edge preserving denoising algorithm for removing salt-and-pepper noise, detects the impulse noise efficiently while preserving the edge details very well. The experimental results demonstrate that, efficient directional correlation-dependent filtering technique performs much better than other existing techniques (SMF, NID, DBA...etc.,) in terms of both quantitative evaluation and visual quality. Particularly, it removes the noise from corrupted images efficiently. The efficient edge preserving algorithm is efficient in terms of PSNR values. An efficient edge-preserving algorithm for impulse noise removal is modified by improving the time complexity by reducing the directional vectors based on four neighbor pixels concept, diagonal neighbors, pixels already denoised and pixels to be denoised. The efficient edge preserving method brings out restored image with preserved edges; the improved method also brings out restored image with preserved edges but increases PSNR value, and produces visually pleasing images.

Acknowledgements

The authors would like to express their gratitude to chairman K.V.V. Satya Narayana Raju, MLC and chairman, K.Sasikiran Varma, Managing Director GIET for providing advanced research lab facilities through Srinivasa Ramanujan Research Forum GIET.

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