A ROBUST OPTIMAL MORPHOLOGICAL FILTER TO REMOVE IMPULSE NOISE IN IMAGES

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Image smoothing is a primary step to remove noise and sharpens the important edge features in the image. The present paper proposes a new Optimal Morphological Filter (OMF) for noise removal in the image. The impulsive noise take gray level values as minimum or maximum from the dynamic gray level range. Optimal notations are proposed in this paper to eliminate the noise pixels corrupted by low and high gray level values in two stages. The method also adopted median and is compared with obtained optimal notation values from local neighborhood of the image to preserve important image features. Different grayscale noise images are tested and visual results show the performance of the proposed algorithm.

Keywords: Image Smoothing, Edge Features, Impulse Noise, OMF, Median.

1. INTRODUCTION

Digital images are often corrupted by different types of noise, namely, additive white Gaussian noise, impulse noise and mixed (Gaussian and impulse) noise. Images are often corrupted by impulse noise caused by transmission errors, faulty memory locations or timing errors in analog-to-digital conversion. Salt-and- pepper noise is one type of impulse noise which can corrupt the image, where the noisy pixels can take only the maximum and minimum values in the dynamic range. Hence, image smoothing is one of the most common and important image processing operations in image and video processing applications. Linear filters were the primary tools for many of the signal and image processing applications, because of the availability of systematic theory for design and analysis [1]. If images are corrupted by Additive White Gaussian Noise (AWGN) linear filters show very good performance [2]. However, linear filters cannot cope with nonlinearities of the image formation model and cannot take into account the nonlinearities of human vision. Furthermore, human vision is very sensitive to high-frequency information. Image edges and image details (e.g., corners and lines) have high frequency content [3] and carry very important information for visual perception. Filters having good edge and image detail preservation properties are highly suitable for digital image filtering. Most of the digital images require low-pass filtering [4]. Low pass filtering tends to blur edges and destroy lines, edges, and other fine image details. These reasons have led researchers to the use of nonlinear filtering techniques for image processing applications.

An important non linear filter that will preserve the edges and remove impulse noise is standard median filter [5] [6] [7]. Median filter replaces every pixel by its median value from its neighborhood and often removes desirable details in the image. Specialized median filters such as weighted median filter [8], center weighted median filter [9] and Recursive Weighted Median Filter (RWMF) [10] were proposed to improve the performance of the median filter by giving more weight to some selected pixel in the filtering window. When the noise level is over 50%, the edge details of the original image will not be preserved by the median filter [11]. But they are still implemented uniformly across the image without considering whether the current pixel is noise free or not. Therefore, a noise-detection process to discriminate between uncorrupted pixels and the corrupted pixels prior to applying nonlinear filtering is highly desirable. Some of the decision based algorithms, such as Adaptive Median Filter [12], Signal Dependent Rank Ordered Mean Filter [13], a Difference Type Noise Detector [14], Detail Preserving Filter [15], High Probability Noise Removal Filter [16] have been published in the literature. All these algorithms first detect the noisy pixels and remove it by applying either standard median filter or its variants. These filters are effective in removing low to medium density impulse noise. Recently, a decision based algorithm (DBA) [17] has been proposed to remove high density salt and pepper noise, in which, the corrupted pixels are replaced by either the median value of the window or neighborhood pixel, in contrast to other existing algorithms that use only median value for replacement of corrupted pixels. In this paper a new algorithm is presented which improves the performance of removing of impulse noise.

The present paper organized as follows: Section 2 describes the noise model which is considered in this paper. Section 3 and Section 4 discusses the proposed method and results. Conclusions are given in Section 5.
2. Impulse Noise Model

The Salt and Pepper (SP) noise is also called as fixed valued impulse noise will take a gray level value either minimal (0) or maximal (255) (for 8-bit monochrome image) in the dynamic range (0-255). It is generated with the equal probability. In the case of salt and pepper noise, the image pixels are randomly corrupted by either 0 or 255. That is, for each image pixel at location \((i, j)\) with intensity value \(I_{i,j}\), the corresponding pixel of the noisy image will be \(I'_{i,j}\) in which the probability density function of \(I'_{i,j}\) is

\[
\rho(x) = \begin{cases} 
  p/2 & \text{for } x = 0 \\
  1-p & \text{for } x = O_{i,j} \\
  p & \text{for } x = 255 
\end{cases}
\]

where \(p\) is the noise density.

3. Optimal Morphological Filter (OMF)

The proposed OMF first detects impulse noise in the image. The corrupted and uncorrupted pixels in the image are detected by checking the pixel value against the maximum and minimum values in the mask selected. Let \(I\) denote noise image and for each pixel \(I[x, y]\) denoted as \(I_{x,y}\). A sliding window of size \((2L+1) \times (2L+1)\) centered at \(I_{x,y}\) is defined as shown in Fig. 1.

\[
\begin{array}{ccc}
I_{x-1,y-1} & I_{x-1,y} & I_{x-1,y+1} \\
I_{x-1,y} & I_{x,y} & I_{x+1,y} \\
I_{x+1,y-1} & I_{x+1,y} & I_{x+1,y+1}
\end{array}
\]

Fig.1: 3X3 Mask

The pixels corrupted by low and high gray values are eliminated using the following optimal notations.

\[
PE = \max \left[ \bigvee_{j=1}^{3} \min \left\{ I_{i,j,j=1-3} \bigvee \bigvee_{j=1}^{3} \min \left\{ I_{i,j,j=1-3} \right\} \right\} \right] \quad (1)
\]

\[
SE = \min \left[ \bigvee_{j=1}^{3} \max \left\{ I_{i,j,j=1-3} \bigvee \bigvee_{j=1}^{3} \max \left\{ I_{i,j,j=1-3} \right\} \right\} \right] \quad (2)
\]

The Optimal equation (1) computes the maximum of all row and column minimums, which eliminates the pixels corrupted by low intensity (pepper noise). The optimal equation (2) computes minimum of all row and column maximums. This eliminates the pixels corrupted by high intensity value (white noise). The algorithm also adopted median to check whether PE and SE are corresponding image pixel or not. The below Algorithm describes entire procedure.

**Algorithm:**

1. Read the Image \(I\).
2. Read the pixels from the sliding window and store in \(M\).
3. Compute the PE and SE using Optimal equations (1 & 2).
4. Check the PE and SE with the Central pixel and Median(\(M\))
   - if \((PE \geq I_{i,j} \geq SE)\)
     - \(res(i,j) = I_{i,j}\).
   - elseif \((PE \leq M \leq SE)\)
     - \(res(p,q) = M;\)
   - else
     - \(res(i,j) = \text{abs}(PE+SE)/2)\)
   - end if
5. Repeat the steps 2 to 4 on entire image.
6. Display the resultant Image
7. Stop

4. Results

The proposed algorithm has been applied on standard noise images (Lena, Cameraman, Mandrill and Woman) and the results are shown in below Fig.2.
5. CONCLUSIONS

A new approach, Optimal Morphological Filter, is presented to remove impulse noise. The proposed OMF performs well on gray scale noisy images. The experimental results show that the proposed filter restores the fine details, such as lines and corners efficiently. The proposed algorithm performance can be further improved by using statistical parameters to apply for the images corrupted up to 90%. OMF algorithm shows better results when compared with standard noise filters.

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Fig. 2: (a), (c), (e) and (g) are Original Noise Images and (b), (d), (f) and (h) are Corresponding Resultant Images