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Random-valued impulse noise removal using adaptive dual threshold median filter

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ABSTRACT

Noise detection and its removal is very important in the image processing. Detection of noise is very crucial and significant in random valued impulse noise because it does not hamper the image pixels uniformly. This paper presents a novel and unique concept of adaptive dual threshold for the detection of random valued impulse noise along with simple median filter at noise removal stage. Simulation results shows that an efficient noise detection leads to a superior quality of de-noised image as compared to existing adaptive threshold based image de-noising techniques. Proposed threshold computation is based on averaging of pixel values of window which enhances the PSNR of our system as compared to existing median filter based image de-noising methods.

1. Introduction

Image de-noising is an essential pre-processing step for image analysis. It refers to the process of recovering a good estimate of the original image from a corrupted one, without altering and changing useful information in the image such as discontinuities and edges [1,18]. During the acquisition or transmission of images, they are frequently corrupted by noise and this degrades the quality of an image along with other features like sharpness, edge, layer depth, etc. Hence noise detection and its removal is very important image processing task for many applications. Noise is generally modelled as Gaussian noise (Normal), Uniform noise and Impulse noise. Impulse noise is randomly distributed over the image and is of two types: Fixed Value Impulse Noise (FVIN) and Random Valued Impulse Noise (RVIN) [3]. Removal of RVIN is more important and complex since it corrupts the pixels with any magnitude in the available gray level [4].

Many algorithms have been proposed to remove the effect of RVIN [5–15], but most of them cause the blurring of edges in the image [2]. In image de-noising the noisy pixels are first detected and then gray levels of noisy pixels are modified by a locally computed approximate value [1]. Detection stage identifies the noisy and noise free pixels of the corrupted image. Proposed method utilizes windowing technique in noise detection stage. In this process, first of all, a test window is defined and central pixel of the window is checked with respect to some defined threshold for identifying the existence of noise. And after the detection of noisy pixel, noise removal part eradicates the noise from it. Quality of noise detection is very much dependent on the selection of threshold value. Most of the techniques compute a priori threshold for all the filtering windows depending on image details while some of the techniques also work in an adaptive manner where threshold value for each window is computed separately.

Filters are simple and efficient solution for the removal of noise, they fall in two categories: linear filter and non-linear filter [5]. Linear filters are low pass filters and tend to blur the edges and other details of image. On the other hand, non-linear filters remove the impulse noise without edge blurring and results in better image quality thereby causing more complexity in the system. Median filter [1] is a widely used non-linear filter in image de-noising due to its effectiveness and high computational efficiency. This conventional method modifies all the pixels of image by median of its surrounding pixels, irrespective of the existence/absence of noise. It leads to the loss of fine image details causing an edge jitter and streaking. At high noise densities simple median filter also results in some patches [2].

Lots of improvement in simple median filter has been proposed to make a trade-off between detail preservation and complexity. Most of them are the Tri-State Median Filter (TSMF) [7], the Multi-state Median Filter [8], the Centre Weighted Median Filter (CWMF)

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[9], the Rank-Order Mean Filter [10] and the Stack Filter [11]. However these filters are applied uniformly over the whole image, without considering whether the test pixel is a noisy pixel or not [6]. This might modify the image details and cause image quality degradation. In order to overcome this shortcoming, the switching scheme or the two-stage method has been introduced. The Basic Principle in this two stage scheme is that noisy pixels are detected first and filtered afterward, whereas uncorrupted pixels are left unchanged. Notable de-noising method based on this two-stage scheme are: Progressive Switching Median Filter (PSMF) [12], Luo-Iterative Median Filter (Luo) [13], Adaptive Switching Median Filter (ASMF) [14] and Adaptive Non-Local Switching Median Filter (ANSM) [15], etc. The performance may further improve by incorporating the sorting algorithm with median filter to sort the elements of window [16]. Recently some probabilistic methods are also investigated for image noise removal, like in de-noising of astronomical images (SAR images) [20–22] and layer depth de-noising [19], etc.

In the proposed method, we have improved the technique of noise detection by introducing the concept of two threshold values for detection of RVIN. It results in efficient detection and provides better quality of de-noised image. Dual threshold concept is already investigated by K.S. Srinivasan and D. Ebnezer in 2007 for the detection of FVIN [17]. Threshold computation of Srinivasan's method was based on the rearrangement of pixels in the window. In our method, thresholds are estimated by averaging process and provide brilliant quality of recovered image by using Simple Median [MED] filter for noise removal.

Rest of the paper is organized as follows: In Section 2, noise model for random valued impulse noise is discussed. Section 3 presents the important features of different median filter based de-noising methods. Section 4 furnishes proposed de-noising method. In Section 5, simulation results of proposed method on test images are given. Finally, a brief conclusion is presented in Section 6.

2. Impulse noise model

In Random valued impulse noise (RVIN), noise is dispersed uniformly. RVIN may take any value in the dynamic range of [0, 255]. At any pixel location (i,j), let $Y_{i,j}$ be the gray level of original image Y and $X_{i,j}$ be the gray level of noisy image and [n_{min}, n_{max}] be the dynamic range of image gray levels. For 8-bit images, $n_{min} = 0$ and $n_{max} = 255$. An image contaminated by RVIN with probability p can be described as follow:

$$X_{ij} = \begin{cases} n_{ij} & \text{with probability} \quad p \\ Y_{ij} & \text{with probability} \quad 1-p \end{cases} \quad (1)$$

where n_{ij} denotes the uniformly distributed random number in [n_{min}, n_{max}], that is n_{ij} can be any number between n_{min} and n_{max} [15]

3. Median filter based de-noising methods

Median filter is one of the most important non-linear filters which are used to remove RVIN. In this filter, the value of corrupted pixel in noisy image is replaced by the median value of the corresponding window. Median value is the value in the middle position of any sorted sequence [1].

Consider that the gray levels of any pixel value, in any window (w_x) of size $n \times n$ are represented by $x_1, x_2, x_3, \cdots, x_n$ and it becomes $x_{i1} \geqslant x_{i2} \geqslant x_{i3} \ldots \geqslant x_{in}$ after sorting it in descending or in an ascending order

$$M_x = \text{Median}(w_x) = \begin{cases} x_{i(n+1)/2}; & n \text{ is odd} \\ \frac{1}{2}\left[x_{i(\frac{n}{2})} + x_{i(\frac{n}{2})+1}\right]; & n \text{ is even} \end{cases} \quad (2)$$

Various median filter based image de-noising methods have been proposed in literature, many of them are application oriented. Some of the significant methods have been explained below.

3.1. Switching median filter (SWM)

A switching median (SWM) filter is a two steps scheme. In the first step, each pixel is checked whether it is a noisy or not. A pixel is said to be contaminated by noise if the absolute difference between the median value in its neighborhood and the value of the current pixel itself is greater than a given threshold. If the said condition is satisfied, a simple median filter is applied in the second phase, if not then the current pixel is said to be noise free and will remain unchanged. Consider an image X corrupted by an impulse noise and $X_{i,j}$ be the gray level value of the noisy image at position (i,j). Let W be the square window covering this pixel of size $(2L+1) \times (2L+1)$, where L is an integer greater than zero. The output $Z_{i,j}$ of switching median filter is given by

$$Z_{i,j} = \begin{cases} m_{i,j}, & if\,|m_{i,j} - X_{i,j}| > \text{Threshold} \\ X_{i,j}, & \text{otherwise} \end{cases} \quad (3)$$

where $m_{i,j}$ is the median value in the window W and Threshold is a fixed parameter [14]. Here the value of threshold is either defined a priori or selected after many data dependant tests.

3.2. Adaptive Switching Median Filter (ASWM)

The Adaptive Switching Median Filter is an improvised version of SWM filter. Here Threshold is not a priori choice but computed locally from image pixels. Now in every filtering window, weighted means are iteratively estimated. Then the weighted standard deviation is calculated and Threshold is determined. This filter provides improved results since impulse noise does not corrupt the statistics

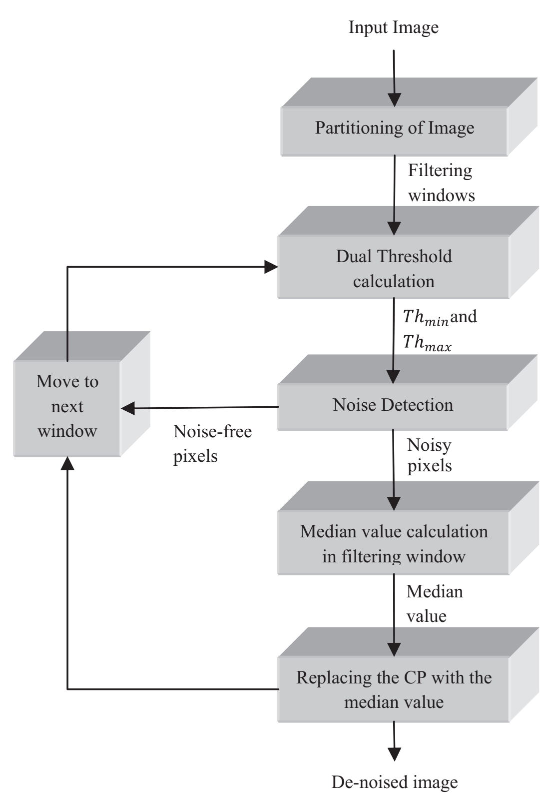

Fig. 1. Block diagram representation of proposed image de-noising method.

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