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Removal of salt-and-pepper noise in corrupted image using three-values-weighted approach with variable-size window[☆]

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ABSTRACT

The quality of a digital image deteriorates by the corruption of impulse noise in the record or transmission. The process of efficiently removing this impulse noise from a corrupted image is an important research task. This investigation presents a novel three-values-weighted method for the removal of salt-and-pepper noise. Initially, a variable-size local window is employed to analyze each extreme pixel (0 or 255 for an 8-bit gray-level image). Each non-extreme pixel is classified and placed into the maximum, middle, or minimum groups in the local window. The numbers of non-extreme pixels belonging to the maximum or the minimum group determines the centroid of the middle group. The distribution ratios of these three groups are employed to weight the non-extreme pixels with the maximum, middle, and minimum pixel values. The center pixel with an extreme value is replaced by the weighted value, thus enabling the noisy pixels to be restored. Experimental results show that the proposed method can efficiently remove salt-and-pepper noise (only for known extreme values of 0 and 255) from a corrupted image for different noise corruption densities (from 10% to 90%); meanwhile, the denoised image is freed from the blurred effect.

1. Introduction

Images are inevitably corrupted by impulse noise, caused by malfunctioning pixels in camera sensors, fault memory locations in hardware, transmission in a noisy channel, and bit errors in transmission. There are two types of impulse noise; salt-and-pepper noise and random valued noise. Salt-and-pepper noise can seriously corrupt the images where the corrupted pixel takes either the maximum or the minimum gray level. This noise can significantly deteriorate the quality of an image. The process to remove this kind of impulse noise efficiently is an important research task.

Many techniques have been proposed for the restoration of the images contaminated by salt-and-pepper noise [1,2,4–6,8–17,19,20,21]. The median and the mean filters were popular for the removal of salt-and-pepper noise due to their good denoising power and computational simplicity. However, when the noise density is over 60%, some details and edges of the original image cannot be restored well by the algorithms. This is because, the number of noise-free pixels are not sufficient to reconstruct the pixels (noisy pixels) corrupted by noise in a local window.

An adaptive median filter [10] selects the median value in an adaptive window for each pixel, thus enabling the noisy pixels to be removed. This method performed well at low noise densities. However, for high noise densities the window size has to be increased which may lead to a blur in the denoised image. In the modified switching median filters [3,20], the decision of an impulse noise pixel is based on a pre-defined threshold value. The major drawback of these methods is that defining a robust decision threshold becomes difficult. In addition, these filters did not take into account the local features because the details and the edges could not be adequately restored, in particular when noise density was high. A directional-weighted-median (DWM) filter [7] was proposed for the removal of random-valued impulse noise. This method analyzed the neighbor information of the center pixel in four directions to weight the pixels in a local window. A noise-corrupted pixel could be detected, and hence removed by the weighted median filter on the optimum direction. The experimental results showed that this method could be employed to remove the random-valued impulse noise, when the noise

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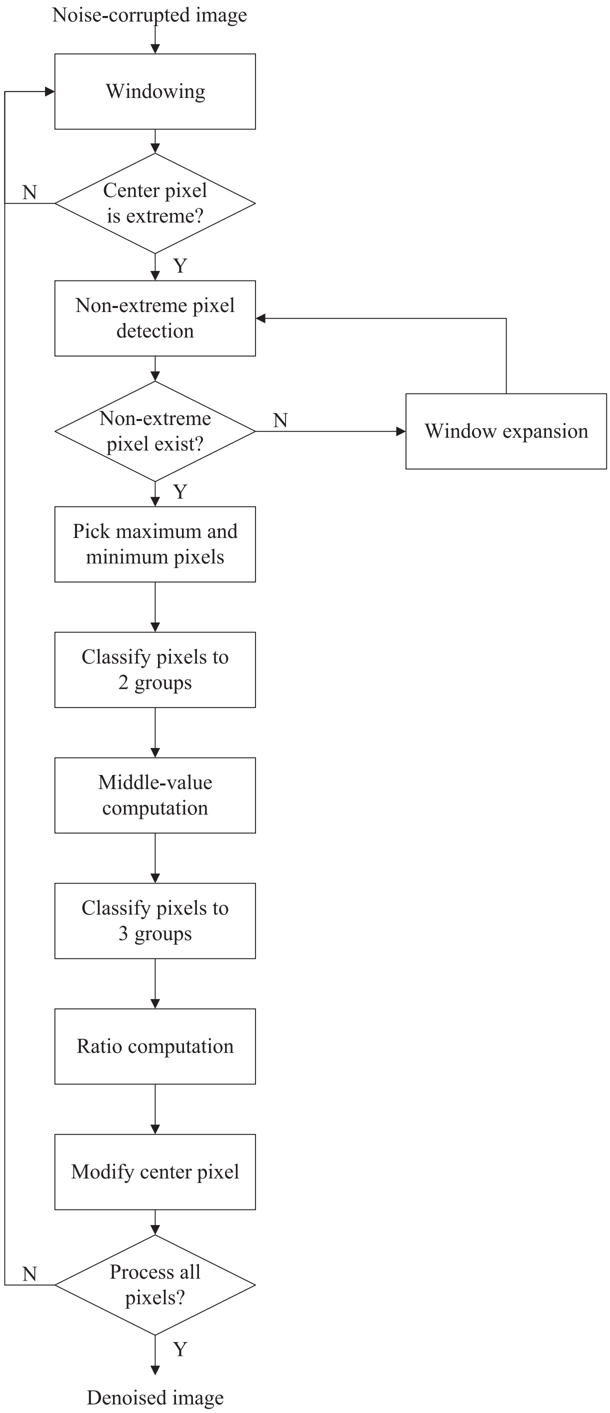

Fig. 1. Block diagram of proposed system for image denoising.

147	137	147
139	157	177
162	179	188

a

147	137	147
139	**0**	255
162	179	188

b

147	137	147
139	**158**	255
162	179	188

c

Fig. 2. An example of three-values weighted pixel for a local analysis window, (a) original noise-free pixels; (b) center pixel is noisy; (c) center pixel is replaced by the three-values weighted pixel.

density was 60% high. Lu and Chou [11] proposed a modified DWM (MDWM) filter which can find a better edge direction and give an additional constraint on performing the switching median filtering. The experimental results showed that this method could significantly improve the performance of the DWM filter [7] by removing a greater quantity of background noise, while preserving the details of the original image. An iterative adaptive fuzzy filter using an alpha-trimmed mean was proposed by Ahmed and Das [2], which employed an adaptive, iterative, fuzzy filter for denoising images corrupted by the impulse noise. The detection of the noisy pixels had an adaptive fuzzy detector followed by denoising, using a weighted mean filter on the noise-free neighboring pixels. The experimental results showed that this method could operate in heavy noise densities. The proposed algorithm replaces the noisy pixel by trimmed median value when other pixel values, 0′s and 255′s are present in the selected window and when all the pixel values are 0′s and 255′s then the noise pixel is replaced by the mean value of all the elements present in the selected window. A modified decision based unsymmetric trimmed median filter [9] was proposed. This method replaces noisy pixels by trimmed median value when other pixel values, 0′s and 255′s are present in the selected window and when all the pixel values are 0′s and 255′s then the noise pixel is replaced by mean value of all the elements present in the selected window. Moreover, Li et al. [12] proposed estimating the noise density of a non-recursive local window for a noise-corrupted pixel, and then adaptively obtaining the weighted gray level means of a recursive or non-recursive filtering window to restore the current noise pixel according to the estimated noise density. The experimental results showed that this method could significantly improve the performance of noise suppression and image detail preservation. Zhang and Li [21] proposed an adaptive weighted mean filter for the removal of salt-and-pepper noise with heavy noise corruption. This method firstly determines the adaptive window size by continuously enlarging the window size until the maximum and the minimum values of two successive windows are equal, respectively. The noise candidate pixel was replaced by the weighted mean of the current window, while the noise-free pixels were left unchanged. The experimental results showed that this method could well restore a noisy image with a high noise density. Li et al. [13] proposed an image block-based noise detection rectification method, for estimating the noise density of an image, and presented a global image information-based noise detection rectification method for the removal of impulse noise. The experimental results showed that this method could dramatically improve the denoising effect. Liu et al. [14] proposed a weighted mean filter with a two-phase noise detector for image denoising. In the first phase, a rank-ordered difference method was employed for detecting the noise candidates. Therefore, a minimum edge pixels difference was utilized as the second phase to identify the edge pixels from the noise candidates. This preserves the edges and improves the detection accuracy. Consecutively, a weighted mean filter was iteratively performed to remove the impulse noise. This performance outperforms many state-of-the-art denoising methods. Based on the above findings, the method to improve