Adaptive Four-dot Median Filter for Removing 1-99% Densities of Salt-and-Pepper Noise in Images

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ABSTRACT

In order to accelerate denoising and improve the denoising performance of the current median filters, an Adaptive Four-dot Median Filter (AFMF) for image restoration is proposed in this article. AFMF is not only very efficient and fast in logic execution, but also it can restore the corrupted images with 1–99% densities of salt-and-pepper noise to the satisfactory ones. Without any complicated operation for noise detection, it intuitively and simply distinguishes impulse noises, while keeping the noise-free pixels intact. Only the uncorrupted pixels of the four-dot mask in adaptive filtering windows are used for the adoption of candidates for median finding, whatever filtering window size is. Furthermore, the adoption of recursive median filters leads to denoising performance improvement and faster filtering. The simple logic of the proposed algorithm obtains significant milestones on the fidelity of a restored image. Relevant experimental results on subjective visualization and objective digital measure validate the robustness of the proposed filter.

KEYWORDS

Image Denoising, Image Restoration, Impulse Noise, Median Filter, Salt-and-pepper Noise

1. INTRODUCTION

During digital images acquisition as for malfunctioning pixels in camera sensors or image transmission in a noisy channel, these digital images are inevitably corrupted by impulse noise. One type of the impulse noise also known as salt and pepper noise is quantized in two extreme values, which are minimum or maximum values in a digital image (0 or 255 for an 8-bit gray-level image) (Gonzalez & Woods, 2002). Impulse noise, even with low noise density, can destroy the appearance of the image significantly. Therefore, how to efficiently remove the impulse noise from the corrupted images is an important research task. It is well known that if the noise is non-additive, linear filtering fails, so most of the methods use a nonlinear approach to get better results (Hamza & Krim, 2001; Ibrahim, Kong & Ng, 2008; Chaux, Duval, Benazza-Benyahia et al., 2008).

Median filters are the most popular non-linear rank ordered filters that provide excellent results in the removal of impulse noise than averaging filters due to their perfectness, computational efficiency and simplicity. However, the standard median filter was defined to process all pixels of the image equally, including the “uncorrupted pixels”. This will result in loss of fine details of the image. So, the
standard median filter is only effective at low noise density. Thus, many variations and improvements of median filter have been proposed, such as weighted median filter (Dong & Xu, 2007) and center-weighted median filter (Ko & Lee, 1991) and so on. One of the improvements of median filter is adaptive median filter (AMF) (Yuan & Tan, 2006). In AMF, the filtering window size of the median filter is made adaptable to the noise content. Small window size is used at pixel locations with low noise density in order to keep the image details better. Larger size is applied at pixel locations with higher noise density in order to remove the noise more successfully. These filters started with a smaller window size at first, and increased the size one by one until certain conditions are met. In these filters, however, when the numbers of noise affected image pixels are large, i.e., noise density is high, a spatial filter with large window size (variants of median filter) would be needed and this would offer more effective noise removal, but at the same time maybe blur the image features and the boundaries. As an example, AMF performs well at low noise density, but in case of high noise density window dimension has to be increased, which may lead to blurring of image details. Another type of the median based methods is the switching median method, which consists of two stages. The first stage is to detect the “noise pixels” and the second one is to remove the noise. In the switching method, only “noise pixels” are processed, and the “noise-free pixels” are kept unprocessed. This enables the method to preserve most of the image details and boundaries. Among the recently proposed switching-based filtering methods are directional weighted median filter (Dong & Xu, 2007), difference-type noise detection based cost function-type filter (Yuan, Tan & Sun, 2007), second-order difference analysis based median filter (Dang & Luo, 2007), switching median filter (SMF) with boundary discriminative noise detection (Ng & Ma, 2006), opening closing sequence filter (Deng, Yin & Xiong, 2007), fast switching median filter (Srinivasan & Ebenezer, 2007), efficient edge-preserving filter (Chen & Lien, 2008) and switching-based filter employing non-monotone adaptive gradient method (Yu, Qi, Sun et al., 2010). The main problem as to the decision-based or switching median filter is that they cannot be used well owing to difficulty in defining a robust decisive measure arising out of right thresholding during decision making operation (Pok & Liu, 1999). Furthermore, the noisy pixels are replaced by some median value in their neighborhood without taking into account local content like probable presence of edges, contours, and so on. Thus, when the noise density is high, image details and edges are not fully restored while denoising. (Chan, Ho & Nikolava, 2005) proposed a two-phase algorithm to cope with this problem. In the first phase, using an AMF for the classification of noisy and noise-free pixels and in the second phase, by application of a specialized regularization method to the noisy pixel, the method was found to be successful in preserving the edge and suppression of noise, but this method had some problem due to more processing time and larger window size (Srinivasan & Ebenezer, 2007).

So, the authors propose an adaptive four-dot median filter (AFMF) to efficiently remove impulse noise from digital images and to accelerate denoising speed at the same time in this article. The proposed method uses an adaptive, switching and recursive median filter to fulfill the adaptive four-dot median filter, it is simple and efficient to remove impulse noise from images more quickly, and can preserve the details inside the image.

This article is organized as follows. Section 2 is the related works. Section 3 describes the proposed method. Section 4 presents the simulation results and discussions. Section 5 is the conclusion.

2. RELATED WORKS

The related works of the median filter are briefly described below. (Srinivasan & Ebenezer, 2007) proposed a switching median filtering algorithm, namely decision-based algorithm (DBA). In DBA, denoising is performed using fixed window dimension of 3x3. If the pixel’s intensity is 0 or 255 for an 8-bit gray-level image, it is processed, otherwise it is left unaltered. At high noise density, the median value of the window will be again either 0 or 255, so the changed pixel is again a noisy pixel. Thus, DBA considers neighboring pixels for replacement. However, repeated placement of neighboring
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