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Removal of high-density impulse noise based on switching morphology-mean filter

Chengbin Zhang, Kaifu Wang*

College of Aerospace Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

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ABSTRACT

In this paper, an effective switching morphology-mean filter is proposed to remove impulse noise from digital images. The proposed method consists of two stages. The first stage is to detect the impulse noise in an image. The second stage is to construct adaptive structuring elements and remove the impulse noise. In this stage, the "noise-pixels" are filtered out by using the morphology-mean filter, and the "noise-free pixels" are copied directly to the output image. The proposed filter uses the window of size 3×3 pixels. Simulation results show that the proposed method outperforms some existing algorithms for high-density impulse noise, both in vision and quantitative measurements. Moreover, our method can preserve effectively the details in an image, and has less processing time.

1. Introduction

During image acquisition and transmission, digital images are frequently corrupted by impulse noise. Impulse noise that is also known as salt-and-pepper noise is quantized into two extreme values, which are the minimum or maximum values in the dynamic range [1]. Even low density impulse noise can also change significantly the appearance of the image. Therefore, removing effectively the impulse noise and recovering reasonably the original information are crucial for impulse noise removal in images. To remove effectively impulse noise, many methods have been proposed [2–21]. Among these methods, the non-linear filters perform effectively.

The widely used median filter is simple and effective. However, with the increase of noise density, the performance of median filter is not good. Thus, many improved median filters have been proposed [6,7]. Although weighted median filter can improve the performance of median filter by using the information of the surrounding pixels, the high-density noise still affect the performance of weighted median filter [7]. The adaptive median filter also can improve the performance of median filter [8]. This is because the size of filtering window is adaptable to the local noise content. However, most of these filters are implemented uniformly across the image, and thus remove desirable details in an image. As a solution to this problem, the switching median filter has been introduced. The switching median filter consists of noise detection and noise removal stages. In noise removal stage, the pixels that are labeled noise-free in the detection stage remain unchanged and the noise pixels are altered differently. This condition enables the method to preserve most of the image details [9]. Therefore, there are some new impulse noise detectors have been proposed, such as using four convolutions, one minimum of four values, and a threshold comparison [9], unsymmetrical trimmed variants [10], and the local histogram [11]. Another example for switching median filter is adaptive switching median filter [12]. An efficient adaptive switching median filter (ASMF) [13] and a noise adaptive switching median filter have been proposed [14]. However, most of these filters use the median filter with increasing filtered window size in the noise removal stage, and the performance is still affected by high-density noise. Then, an improved switching median filter (ISMF) has been proposed by using the directional weighted median filter [15].

Although these switching-based filters perform better than the standard median filter due to the noise detection stage, they only use the local statistics within a small neighborhood of pixels for removing impulse noise and thus tend to damage image details at high density noise. The decision-based non-local means filter (DNLM) has been proposed [16]. However, the DNLM needs some parameters to be tuned, and more computation time. Then, the switching non-local means filter (SNLM) has been proposed to remove impulse noise by using the modified non-local means filter [17]. However, SNLM uses too big size filtering window, and thus makes the filtered image blur. Linear mean-median filter (LMMF) is a combination between mean and median filter has been proposed

* Corresponding author. Tel.: +86 25 84892003x8015.
E-mail address: kfwang@nuaa.edu.cn (K. Wang).

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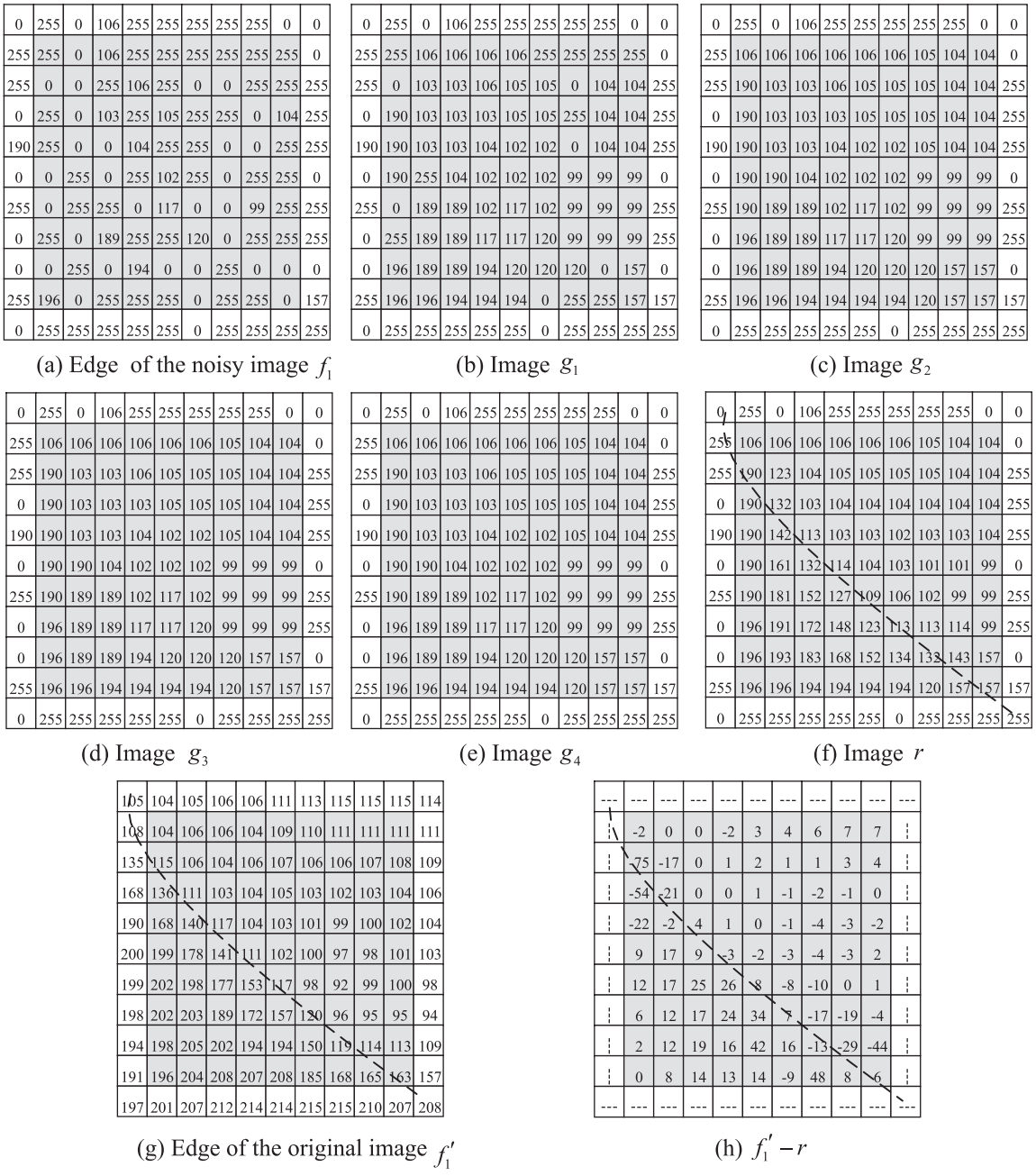

(a) Edge of the noisy image f_1 (b) Image g_1 (c) Image g_2

(d) Image g_3 (e) Image g_4 (f) Image r

(g) Edge of the original image f_1' (h) $f_1' - r$

Fig. 1. Results of the image edge.

[18]. However, the performance is affected by high density noise. An improved median filter (IMF) has been proposed by using the minimum absolute value of four convolutions obtained by one-dimensional Laplacian operators [19]. These methods improve the performance of median filter, but require some parameters to be tuned and more processing time. Moreover, there are some new efficient methods have been proposed to remove high density impulse noise, such as fuzzy filtering techniques [20] and the total variation method [21].

Another famous non-linear filter is morphological filter. Morphological filters have been tried for high density impulse noise removal. However, the performance is not very effective [22]. This is because that the structuring element used in morphological filters classically has a fixed shape and size, which have serious disadvantages such as creating artificial patterns or removing significant details. To remove the impulse noise without losing the details of an image, morphological filter with the spatially-variant structuring element has been proposed [23]. However, the performance is affected by high-density noise due to the use of fixed structuring element at noisy pixels. So, by carefully selecting structuring element sizes and shapes, it is possible to build morphological filters to remove features according to their sizes, orientations, and shapes.

Moreover, morphological basic operator value is the extreme value of the image in the window defined by structuring element. Therefore, using the fixed shape and the increasing size of structuring element cannot remove effectively the high density impulse noise. Inspired by the switching-based method, only the noise-free pixels are involved in the extreme value operation in the filtering window, then so called point-wise adaptive structuring elements are constructed. Since image between the adjacent pixel