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REGULAR PAPER

A hybrid image restoration approach: fuzzy logic and directional weighted median based uniform impulse noise removal

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Abstract In this paper, a hybrid image restoration technique based on fuzzy logic and directional weighted median is presented. The proposed technique consists of noise detection and fuzzy filtering processes to detect and remove uniform (random-valued) impulse noise while preserving the image details efficiently. In order to preserve image details such as edges and texture information, a two-stage robust noise detection is presented in this paper. Pixels detected as noisy by both the noise detection stages are considered for noise removal by the fuzzy filtering process, which utilizes the direction based weighted median to construct fuzzy membership function, which is the main contributing factor in noise removal and detail preservation. Extensive experimentation shows that the proposed technique performs significantly better than state-of-the-art filters based on peak signal-to-noise ratio, structural similarity index measure and subjective evaluation criteria.

Keywords Fuzzy logic · Fuzzy filter · Impulse noise · Image restoration · Weighted median

1 Introduction

Images can be corrupted with impulse noise during any of the acquisition, pre-processing, compression, transmission, storage and/or reproduction phases of processing [1]. Image processing techniques have enormous applications ranging from space exploration to medical diagnosis. Since many image processing techniques cannot work well in noisy environment,

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therefore a pre-processing step became important before application of any image processing technique. As a pre-processing step, we will focus on fuzzy logic and median based image restoration techniques to restore images corrupted with impulse noise. The main task in image restoration is to remove the impulse noise and preserve edges and texture information. Non-linear filtering techniques provide satisfactory performance for restoring the images than the linear filtering techniques because impulse noise is highly non-linear in nature.

A number of non-linear approaches have already been proposed for the impulse noise removal. For example, Tukey [2], Astola et al. [3], and Pitas et al. [4] have utilized the median filter to remove impulse noise from the degraded images. To preserve texture and edge information, several variations of median filters have been proposed, e.g., *minimum-maximum exclusive mean* (MMEM) filter [5], *detection-estimation-based filter* (DEBF) [6], *multistage median filter* [7], *weighted median filter* (WMF) [8], *center weighted median* (CWM) filter [9], *noise adaptive soft-switching median filter* (NASM) [10] and *a new directional weighted median filter for removal of random valued impulse noise* (DWM) [11] to achieve a much-improved filtering. Machine learning is a relatively recent research area with vast scope in many applications [21–23]. Many filters based on machine learning techniques have been proposed for removing impulse noise. For instance, the *histogram-based fuzzy filter* (HFF) [12], Lee et al.'s *novel fuzzy filter* (NFF) [13], *genetic-based fuzzy image filter* (GFIF) [14], *detail preserving fuzzy filter for impulse noise removal* (DPFF) [15], *fuzzy impulse noise detection and reduction method* (FIDRM) [16], *fuzzy random impulse noise reduction method* (FRINRM) [17], Nemanja et al.'s *universal impulse noise filter based on genetic programming* [18] and *histogram-based fuzzy color filter for image restoration* (HCF) [19] are examples of the most recent filters. Most of the median and machine learning based filters are mainly developed for images corrupted with pure impulse noise (salt and pepper) except FIDRM, DWM, FRINRM, HCF and Nemanja et al.'s method, which are recently proposed methods for random-valued impulse noise reduction.

In this paper, we propose a fuzzy logic and directional median based hybrid impulse noise detection and reduction method. The proposed technique consists of robust impulse noise detection process and DBWM-based fuzzy filtering process to remove impulse noise and preserve image details such as edges and texture information. The main contributions of the proposed technique include

- Using the direction based weighted median (DBWM) for constructing the fuzzy membership function in fuzzy filtering process removes noise and preserves the image details such as thin lines and sharp corners quite effectively.
- A robust two-stage fuzzy logic and direction-based impulse noise detector is used so that the false detection rate can be minimized.
- Removal of uniform as well as mixed (salt and pepper, uniform) impulse noise.
- The proposed technique filters impulse noise and preserves image details without any training which is required in [14] and [18].

The rest of the paper is organized as follows: impulse noise model is elaborated in Sect. 2. In Sect. 3, we explain proposed system architecture. Experimental results are presented in Sect. 4. These results are discussed in detail, and are compared to those obtained by other state-of-the-art filters. Conclusions drawn from the present work and recommendations for the future work are given in Sect. 5.

2 Impulse noise models

In contemporary literature two major impulse noise models are used which are as follows: