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ORIGINAL PAPER

Linear cellular automata-based impulse noise identification and filtration of degraded images

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Abstract
In this paper, four impulse noise filters based on modifications of linear cellular automata (LCA) are proposed and evaluated. Each of these filters make use of an adaptive neighborhood to provide efficient noise filtration at varying noise densities. The LCA model works asynchronously and makes the proposed filters computationally efficient. Peak signal to noise ratio and structural similarity (SSIM) index metrics are used to provide objective analysis of the proposed filters.

Keywords Salt-and-pepper noise · Impulse noise · Cellular automata · Structural similarity index · Peak signal to noise ratio

1 Introduction

Digital images have become an effective medium for communicating different types of information concerning a wide variety of areas including industrial processes, health-care, social networking, remote sensing, and education. Use of smart phones and other portable devices with cameras has made capturing of digital images easier than ever [2]. Noise generally refers to unwanted data that distort and hide the original information carried in digital images. In extreme cases, noise change or distort the semantics of information carried in digital images to an extent that human or computer vision systems fail to recognize the original image content. Therefore, it becomes immensely important to filter out this noise from the images. The presence of noise in digital images can affect the appropriateness of results produced by computer vision systems [20].

Most of the impulse noise filters proposed in literature tend to perform poor as the noise densities increase in the digital images. Lack of adaptability to varying levels of noise have paved way for the application of cellular automata (CA) to noise filtration. In the last decade, various CA-based impulse noise filters have been proposed. Information about the type of noise in digital images plays a significant role in the subsequent image de-noising process [4]. The presence of noise can be detected based on appearance of the image, and hence, impulse noise is measured based on the brightness quality [12]. Most of the detection algorithms are based on the assumption that noise free images consist of locally smoothly varying areas separated by edges and a noise pixel takes a gray value substantially larger or smaller than those of its neighbors. The median-based impulse noise detectors and filters are not able to make distinction between fine lines and impulses and as such result in removal of such fine lines. Most linear filters like the average filter (AF) are not effective for filtering impulse noise from digital images [24] because de-noising capabilities of these filters deteriorate considerably and remove original image information in addition to the noise data.

Filters, such as arithmetic filters (AF), median filters (MF), center weighted median filter (CWMF) and weighted median filter (WMF), process all pixels in the noise corrupted image, and, as such, there is some loss of original information because of processing the uncorrupted pixels. Therefore, different filters are proposed that first try to identify the corrupted pixel and process the pixel only if the pixel is labeled corrupted. Switching median filter (SMF) [28] is based on MF that filters identified corrupted pixels only. Adaptive Center weighted Median Filter (ACWMF) [16] was proposed to filter images with small contamination ratio. A rough estimate of the corruption ratio is calculated to compute a central weight in an adaptive manner. The problem with this filter is the introduction of unwanted smoothing artifacts after noise

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