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Cellular automata-based approach for salt-and-pepper noise filtration

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ABSTRACT

Application of cellular automata (CA) to digital image processing has achieved considerable attention in last several years. CA are now employed in noise filtration of digital images; particularly many CA-based impulse noise filters have been proposed. Salt-and-pepper noise is a special kind of impulse noise and is introduced in an image during transmission over transmission media by external noise sources like atmospheric disturbances, or due to corrupted hardware memory locations or fault in camera sensors. In this paper, we present five salt-and-pepper noise filters based on modifications of outer totalistic cellular automata (OTCA) with the adaptive neighborhood. Use of OTCA model makes the proposed filters computationally simple on one hand and the use of adaptive neighborhood help the filters to provide efficient noise filtration at varying noise densities on the other. Comparative analysis of these filters followed by comparison with several standard and CA-based filters in terms of peak signal to noise ratio (PSNR) and structural similarity (SSIM) index is presented.

1. Introduction

Digital images find tremendous use in a wide variety of areas and the increase of digital image use may be attributed to rapid growth of information technology, which has facilitated gradual replacement of traditional form of text data with image data in many applications (Thepade et al., 2017). Digital images sometimes carry sensitive information as in case of health-care medical reports that take the form of digital images. Noise in image processing generally refers to unwanted data that conceal or distort the information carried in digital images. Images may get corrupted by different types of noise during different stages of image processing like image acquisition due to malfunctioning of the sensors in a digital camera, or during encoding and transmission, when the images are transferred over noisy transmission lines. It becomes immensely vital to remove this noise because presence of noise may lead to misleading information carried in digital images and adversely affect the subsequent decisions to be taken on the basis of this information. Computer vision systems are also sensitive to presence of noise in digital images and fail to produce appropriate results if the digital image is not filtered for noise (Qadir and Shoosha, 2018). As such, image restoration has become one of the most investigated fields of image processing where the original image is recovered from the noisy image (Singh et al., 2018). Different types of noise like Impulse, Gaussian, or Speckle noise may corrupt digital images. There are two types of impulse noise, salt-and-pepper noise and random valued noise. For images corrupted by salt-and-pepper noise, the noisy pixels can take only the maximum and minimum values in the dynamic range (Sahin et al., 2014). Random valued noise on the other hand, may assume any value in the dynamic range. Although, many linear and non-linear filters have been proposed in literature but they tend to perform poor as the noise densities increase in the digital images. Lack of adaptability in these filters to varying densities of noise has paved way for the application of CA to noise filtration. In last few years, many CA-based noise filtration algorithms have been proposed. Many of these filters use variations of totalistic cellular automata (TCA) while others are based on fuzzy cellular automata (FCA).

Linear filters, like average filter (AF), for removing of impulse noise are not satisfactory (Sahin et al., 2014) because their denoising performance deteriorates with increase in noise density and these filters, in addition to noise, remove useful information from the images as well. One of the most popular non-linear filters is the median filter (MF) which results in effective filtering when the noise density in an image is low. MF provide better detail

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