Image Noise Reduction Based on Cellular Automata Filter

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Abstract

We present a new formulation that makes improvements. in color or grey scale in an automatic and adaptive fashion. It does not need user intervention, except to point the pattern of noise to be removed and choice of a couple of parameters. The formulation uses a neighborhood with sizes and format adapted to the features of the image on reconstruction. It glides the image finding the pattern of noise and replacing it by the relevant characteristics of neighborhood to carry out the local restoration. In this way the overall aspect can be dramatically improved because new features are not used but reproduction is performed based on the image content. We demonstrated through experiments and comparison with other common used techniques that this procedure produces excellent results for the problem of restoring true color images and also for look up table images.

1. Introduction

Image transmission is today used in all multimedia systems, from satellites to cellular phones. But the original appearance and final product after broadcast do often not have the same high quality of the input image. The final image can be affected for noise contaminating the original data in different ways such as over-the-air transmission or compression-stored-decompression noise. To reduce the degradation related to noise of any kind, a preprocessing or filtering step could be applied [1-4]. There has been a lot of effort in designing efficient noise suppression filters. An averaging filter would give good effect only in very homogenous fields. A common approach is the median filter [3], which presents better results than the average filter [2] in removing outlier values in the filtering process without blurring the image. Others approaches are Gabor filter [1], morphological [5], unsharp masking [2-4], out-of-range filtering [3] and homomorphic filters [6]. In this paper we will present a new formulation for image noise elimination. The next section introduces this formulation and section 3 describes the test and results.

2. Cellular Automata Filter Formulation

A cellular automaton (CA) is a collection of cells that assumes *n* possible states (the pixels colors) which are usually updated simultaneously and iteratively. A cell state is affected by neighboring cell states and its global evolution is driven by these local iterations. When a pixel is identified as noised its state is changed to the state of one of its random neighbor. In two dimensions, 2dCA, two common neighborhoods are used: 8 pixels square neighborhood also called Moore, and 4 pixels North-East-South-West shaped, named as von-Neumann neighborhood in CA theory. Both of those can be defined with different edges, r.

Boundary conditions describe how the CA iterates. It can be periodic or reflected. Reflected boundary condition is here used; in this, the cell at the rightmost edge of the grid is assumed to have a neighbor on its right that is the same as on the left and similarly for the other edges.

In this work, the knowledge of the positions of the corrupted pixels are stored before the first iteration. In the iterative process, corrupted pixels are randomly updated with uniform probability. As can be seen on figures 1 and 2, the image quality has been highly improved when such filter was applied. In `http://visual.ic.uff.br/reconstruction.html` the performance on others images is investigated and compared with others approaches considering the quality of the results [7].

3. Tests and Comparison

This section presents a comparison of salt and pepper noise reduction efficiency comparing 2dCA and Median filter [3]. Comparison for others types of degradation can be seen on [7]. Figure 1 shows a tested image with 75% of degradation and its reconstruction after application of 2dCA and median filters (this considering the best possible results by the use of median filter that is with radius of 4). The performance of the proposed algorithm is evaluated by means of 3 fidelity evaluators in table 1, where images with different degradation levels are used [7]. The first measure of the resulting image's fidelity is the root mean square error e_{rms} between the filtered image $d(x,y)$ and the original image $f(x,y)$, both of size NxN:

$$e_{rms} = \left(\Sigma_{x=i}^{N} \Sigma_{y=i}^{N} [e(x,y)]^{2} \right)^{0.5}$$

where $e(x,y) = (f(x,y) - d(x,y))$. Smaller e_{rms} means better restored image (or closer to the original). The second measure is the root signal-to-noise ratio of the processed image, given by

$$SNR_{rms} = \left(\Sigma_{x=i}^{N} \Sigma_{y=i}^{N} [d(x,y)]^{2} / \Sigma_{x=i}^{N} \Sigma_{y=i}^{N} [e(x,y)]^{2} \right)^{0.5}$$

Better resulting image correspond to higher signal-to-noise ratio. The main difficulty with using e_{rms}, and SNR as measure of image quality is that in many instances these values do not match the quality perceived by the human visual system [3]. The values of PSNR match better the human visual system:

$$PSNR = 20 \log (2^{m}-1)/(N^{2} SNR)$$

where m is grey level. Best result possible using median filter is e_{rms} = 9274.3; SNR_{rms}=7.3 and PSNR = 22.8. These show that the superiority of CA formulation is not only visually but also numerically.

4. References

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[7]http://visual.ic.uff.br/reconstruction.htm

Fig. 1 Lena image with 70% salt e pepper noise (left), reconstructed with Newman r=1 (center) and median filter best possible result (right).

Fig. 2 Diamantina color image with 70% salt e pepper noise (left), reconstructed with Newman r=1 after 14 iterations (center) and reconstructed with Moore r=1 after 12 iterations (right)

Table 1- Errors for different level of degradation considering restoration by CA formulation

CA results Lena image	e_{rms}			SNR			PSNR		
	0.2	0.5	0.7	0.2	0.5	0.7	0.2	0.5	0.7
Newman r = 1	10397.7	16131.5	19366.6	7.2	4.6	3.9	34.8	30.2	27.8
Newman r = 2	10891.1	16933.9	20343.1	6.8	4.4	3.7	32.6	28.0	25.9
Moore r = 1	10544.5	16408.1	19755.2	7.1	4.5	3.8	33.8	29.3	27.1
Moore r = 2	11405.9	17686.6	20873.6	6.5	4.2	3.6	30.9	26.8	24.9