International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

# Salt & Pepper Noise Reduction using Cellular Automata

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***Abstract:****In order to reduce salt & pepper noise in an MRI image of brain, in this paper we make algorithm using 2-dimensional Cellular Automata (CA). Image processing with CA has improved digital image processing in several years. Salt & Pepper noise can corrupt a picture via image transmission (atmospheric disturbance) or faulty sensors in camera or a computer system through hardware.*

***Keywords:*** *Salt & pepper noise, median filter, Matlab, Cellular Automata, Periodic Boundary, noise density.*

## I. INTRODUCTION

Noise Filtering from a digital image is a challenge in images. Salt&Pepper noise is an impulse noise, we get this noise in an image often during processing, transmission and acquisition of images[1]. To remove Salt&Pepper noise from an image two filtering techniques can be used: Linear filtering technique and non-linear filtering technique. From many researches it was observed that linear technique for impulse noise removal does not give desirable effect and output. Median filter however was considered most effective for reduction of Salt&Pepper noise [2]. But if the density of noise in an image is >30%, it can destroy edges of this image. More variants of median filter were proposed , which are very desirable for removal of impulse noise from an image. But these software are highly complex, lack robustness and their computation cost is also high [3]. To overcome these constraints we introduce Cellular Automata. In a CA each cell in a regular grid can have a different state based on its neighboring cells, and transition rules. In Cellular automata cells are represented in a regular grid, with each cell in a state of its own. In every step the value of a cell is changed based on the value of its neighboring cells in the last step, giving rise to uniformity and locality.

In this paper, CA based algorithm is given for reduction of Salt & Pepper noise from an MRI image of brain with cancerous cells.

Manuscript published on November 30, 2019.
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The algorithm which is being proposed works fine with neighborhood conditions. In order for this algorithm , periodic boundary is added for all the boundary conditions which may take place in the given image. We make use of Wolfram's CA rule 30, in order to propose an efficient transition function in our algorithm (filter).This algorithm is tested on the MRI brain images with different noise densities and the output (resulting image) is clear.

## II. CELLULAR AUTOMATA

CA is a finite grid which works locally, in which the value of each cell is dependent on its previous value and the value of its neighbors. Any Cellular Automat can be represented theoretically as 5-tuple machine.

Cellular Automata= $\{L_r,N,Q,d,q_0\}$, where $L_r$ represents the CA grid, N represents the neighborhood, the finite set of state used in a CA are represented by Q, with $q_0$ being its initial state, and the rule(transition function) for a CA is represented by 'd'. For a one dimensional Cellular Automata, the rules are given below:

$$n=|N|s$$

$$d: Qn \longrightarrow Q$$

$$C_i^{t+1}= d(C^t_i,C^t_{i-1},C^t_{i+1})$$

Where, $C_i^{t+1}$ and $C^t_i$ are the $i^{th}$ cell's state in different time period(t and t+1)and the neighbors of this cell can be represented by $C^t_{i-1}$ and $C^t_{i+1}$(for time period t) and $C^{t+1}_{i-1}$ and $C^{t+1}_{i+1}$(for time period t+1), they will form a left and right neighbor of cell. In order to use Cellular Automata in a problem, the initial values of the cells in a grid of CA should be known, boundary conditions should be set and neighboring cells has to be taken care of.

In CA, when a particular cell is considered in a grid, it should have an initial value. The next state of this cell is determined by its value in the previous state and the value of its neighboring cells. In Cellular automata, various neighborhood structures are used and with the help of transition rules, we come to a final solution. In this paper, Extended Moore neighborhood concept will be used to achieve our goal Figure 1. The transition function of Moore neighborhood is represented as:

$$(C_{i,j})^{t+1}= d((C_{i,j})^t,(C_{i,j+1})^t,(C_{i+1,j+1})^t,(C_{i+1,j})^t,(C_{i+1j-1})^t,(C_{i,i-1})^t,(C_{i-1,i-1})^t,(C_{i-1,i})^t,(C_{i-1,i+1})^t)$$

| | | |
|---|---|---|
| NW | N | NE |
| W | C | E |
| SW | S | SE |

(i)

*Retrieval Number: D9004118419/2019©BEIESP*
*DOI:10.35940/ijrte.D9004.118419*
*Journal Website: www.ijrte.org*



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|---|---|---|---|---|
| NNWW | NWW | NN | NNE | NNEE |
| NWW | NW | N | NE | NEE |
| WW | W | C | E | EE |
| SWW | SW | S | SE | SEE |
| SSWW | SSW | SS | SSE | SSEE |

(ii)

**Figure 1: (i) Moore neighborhood, (ii) Extended Moore neighborhood**

### ADDING PERIODIC BOUNDARY

Whenever we apply transition rules to cells in a CA, the boundary cells are also included. In order to make the rules work properly for boundary cells, periodic boundary is added. In this paper, the cells added all are given the value of 0.

## III. PROPOSED WORK

In this paper a simple yet efficient filter based on 25 neighborhood (Figure 1(b)) Cellular Automata is presented in order to reduce Salt & Pepper noise from an image. Here each pixel will be replaced by $q_{med}$(median of the neighborhood values). Periodic boundary has already been attached with the image and now it is divided in identical CA cells matrix. For any cell in a CA takes 256 values as:-

$C^t_{(i,j)}$ ε {0, … , 255} (8-bit gray-scale, $2^8$=256).

For Moore Neighborhood as we have already defined:

$$(C_{i,j})^{t+1}= d((C_{i,j})^t,(C_{i,j+1})^t,(C_{i+1,j+1})^t,(C_{i+1,j})^t,$$
$$(C_{i+1j-1})^t,(C_{i,j-1})^t,(C_{i-1,j-1})^t,(C_{i-1,j})^t,(C_{i-1,j+1})^t)$$

And, $(N_{(i0,j0)})_{Moore}=\{(i_0,j_0) : |i-i_0| <= r ,|j-j_0| <= r\}$,

where $N_{(i0,j0)Moore}$ represents the value of neighboring pixels in a Moore neighborhood. With the addition of more neighboring values in the above mentioned formulas we can obtain formula for extended Moore neighborhood in the same fashion.

### a. APPLYING CA TO NOISY CELLS

In this paper as already discussed a fixed neighborhood size of 5 x 5 is used, where r=1. Here, we take four deviation values for the Cellular Automata Cell values, $q_{med}$ as already discussed, $q_{std}$ as standard deviation of the values of neighborhood cells, $q_{min}$ =0(represents salt error) and $q_{max}$=255(represents pepper noise)

**Step 1.**

Convert the image into gray-scale

**Step2.**

Detection of Salt & Pepper noise:

1.We will check the cells with values higher or equal to $q_{max}$ and values lower or equal to $q_{min}$.

2. The cells with the value lower than $q_{max}$ and higher than $q_{min}$ will remain unchanged.

3. The cells with noise (values higher or equal to $q_{max}$ or, lower or equal to $q_{min}$) are given a unique value num.

$$C^{t+1}_{(i,j)} = \{C^t_{(i,j)}\ if\ q_{min} < C^t_{(i,j)} < q_{max}$$

$$C^{t+1}_{(i,j)} = \{num\ if\ q_{min} \geq C^t_{(i,j)} \geq q_{max}$$

**Step 2.**

Reduction of Salt & pepper noise:

1. Check the values of the CA cells.
2. The values which are equal to num should be replaced by new value based on the neighborhood cells of the CA.

$$C^{t+1}_{(i,j)} = \{ (N_{(i,j)} \times q_{med}) + ((1 - N_{(i,j)}) \times C^t_{i,j}) + x\ q_{std}\ if\ C^t_{(i,j)} = num$$

Where the value for ‘x’ being the adjusting parameter varies from 0.01 to 0.2.

This algorithm can provide more noise reduction for varying noise densities (10%− 90%).

## IV. EXPERIMENTAL RESULTS

In this paper we have taken an MRI of brain having cancer as an input image. We will put our algorithm through test for 20%, 40%, 60% and 80% of noise density in the original image. MatlabR2019b has been used for our algorithms and output is obtained.

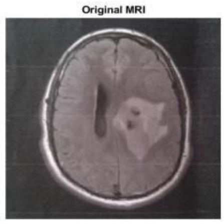


**Fig I: Original Image**

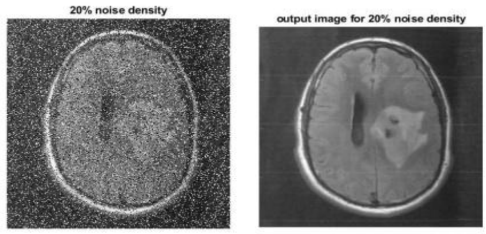


**Fig II: a) Image with 20% noise density. b) Restored image**

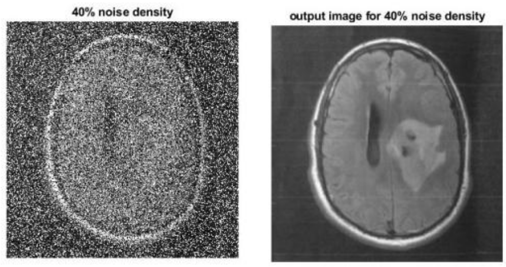


**Fig III: a) Image with 40% noise density. b) Restored image**

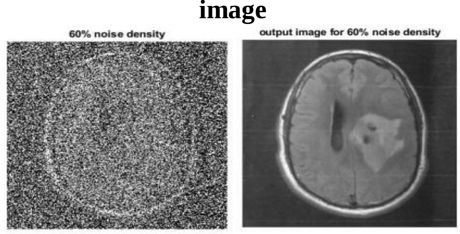


**Fig IV: a) Image with 60% noise density. b) Restored image**

Retrieval Number: D9004118419/2019©BEIESP
DOI:10.35940/ijrte.D9004.118419
Journal Website: www.ijrte.org



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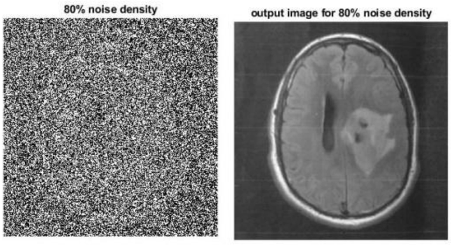


**Fig V: a) Image with 80% noise density. b) Restored image**

## V. CONCLUSION

The algorithm which is presented in this paper is simple and effective to reduce Salt & Pepper noise. It has proved effective even with the image of higher than 50% of noise density. Improvements are need of the hour and hence the proposed algorithm can also be improved if many other Cellular Automata rules are used.

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