ADVANCED EVOLUTIONARY IMAGE FILTERING

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1 Overview

Digital image noise filtering is an important pre-step of image processing algorithms. Capturing, transferring, or storing an image can damage it in various ways, ending in lost original information. Multiple noise models can be considered:

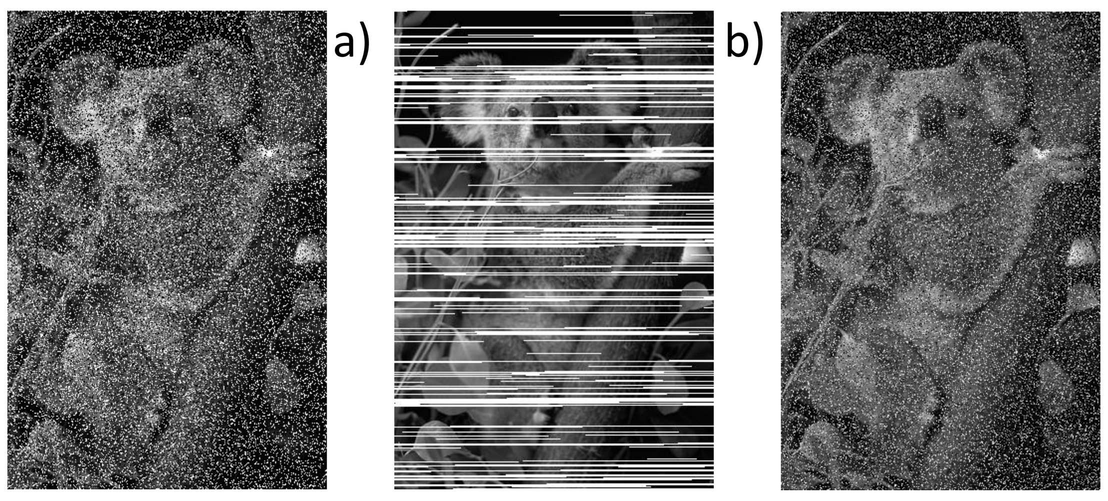

Figure 1: An image damaged by a noise of intensity of 30 % a) salt and pepper, damaged pixels are white or black; b) impulse burst, pixels are damaged in random sequences; c) random noise, damaged pixels can be any color.

2 Motivation and goals

Conventional image noise filtering methods such as popular median filters (MF) can yield unsatisfying results due to their weak edge preservation. Using CA for noise removal is therefore a promising alternative, especially if paired with the conventional methods in a meaningful way.

This work is motivated by an existing method using CA and evolutionary developed conditionally matching rules (CMR) for salt and pepper noise removal which proved to be an effective way to approach the problem.

Our goal is to further improve this method by modifying the right side of CMR and exploring its potential on other types of noise such as salt and pepper, impulse burst, or random noise.

3 The proposed CA setup

In our experiments, 2D CA with 255 states and 5-cell neighborhood were considered and evolved by means of:

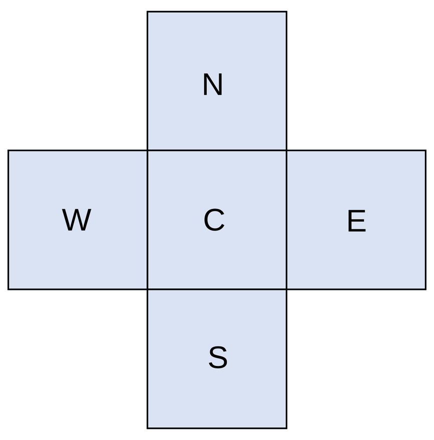

Figure 2: 2D CA von Neumann neighborhood

Modified Conditionally Matching Rules (CMRs):

A CMR is specified in a form of 5 conditions, evaluated for each cell in the neighborhood, followed by a function (func) that returns the next state value for the central cell that is acquired by this cell if all conditions of the CMR are satisfied. Among the set of possible functions are median, mean, minimum, maximum, major value, minor value, etc. A finite sequence of CMRs constitutes a trans. function.

For example a trans. function of just 2 modified CMR:

1) ≤ 65 = 0 ≥ 202 ≤ 11 ≤ 109 → median
2) ≥ 150 = 0 ≠ 0 ≤ 54 = 0 → min

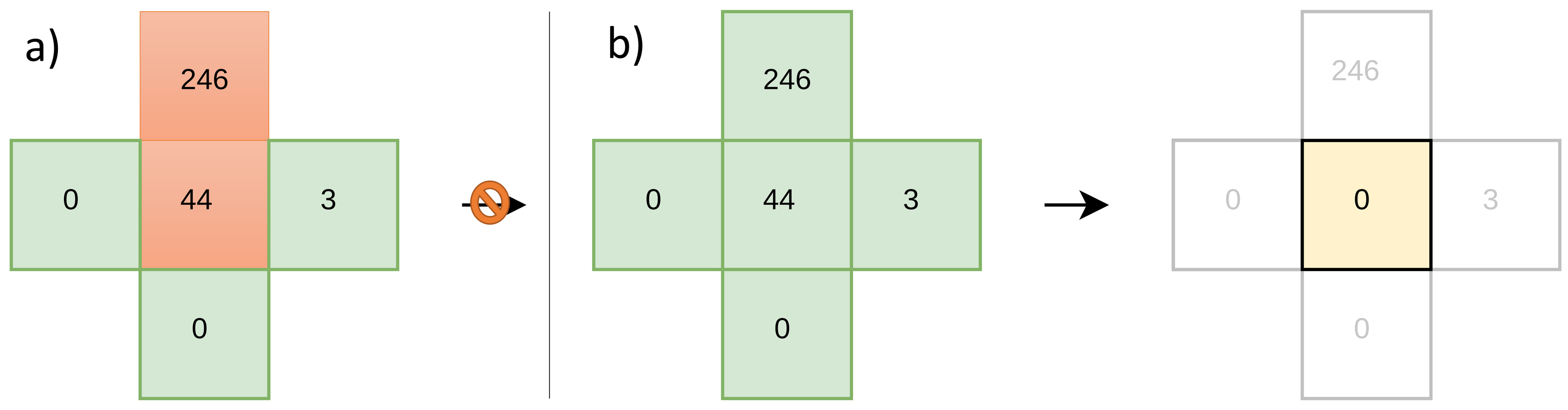

Figure 3: Conditions matching and CMR evaluation on the given neighborhood for a) first CMR, b) second CMR from example.

The CMRs are evaluated sequentially, the first matching rule is used to determine the next cell state. If no CMR is matched, the value does not change. In this example, the next state value for the central value is calculated as the minimum of the values from the neighborhood.

4 Evolutionary system setup

A (μ, λ)-Evolution Strategy (ES) was applied with the settings of (4, 8)-ES with elitism and 2500 generations.

Evolution parameters setup:

- noise intensity: 10-90 %
- noise type: salt and pepper, impulse burst, random
- CA steps: 1-6
- CMR count: 5, 10, 15, 20, 30, 40, 50
- set size of possible functions: 4, 8

in 30 independent runs for each setup.

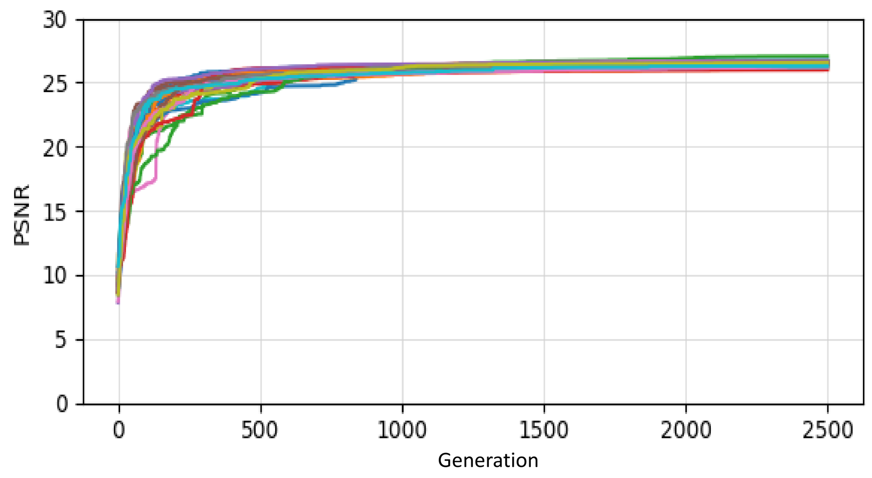

Figure 4: 210 runs of (4, 8)-ES on salt-pepper noise with intensity 50 %, 3 steps of CA, 8 functions.

Each experiment was evaluated on a dataset of 24 images.

5 Experimental Results

Two highest quality filters were determined for each noise type as well as one filter capable of filtering any of the considered noises. Proposed filters were then compared with existing methods by PSNR (peak signal-to-noise ratio) on the same dataset. The higher the PSNR value, the higher quality of the filtered image.

1. Filters comparison

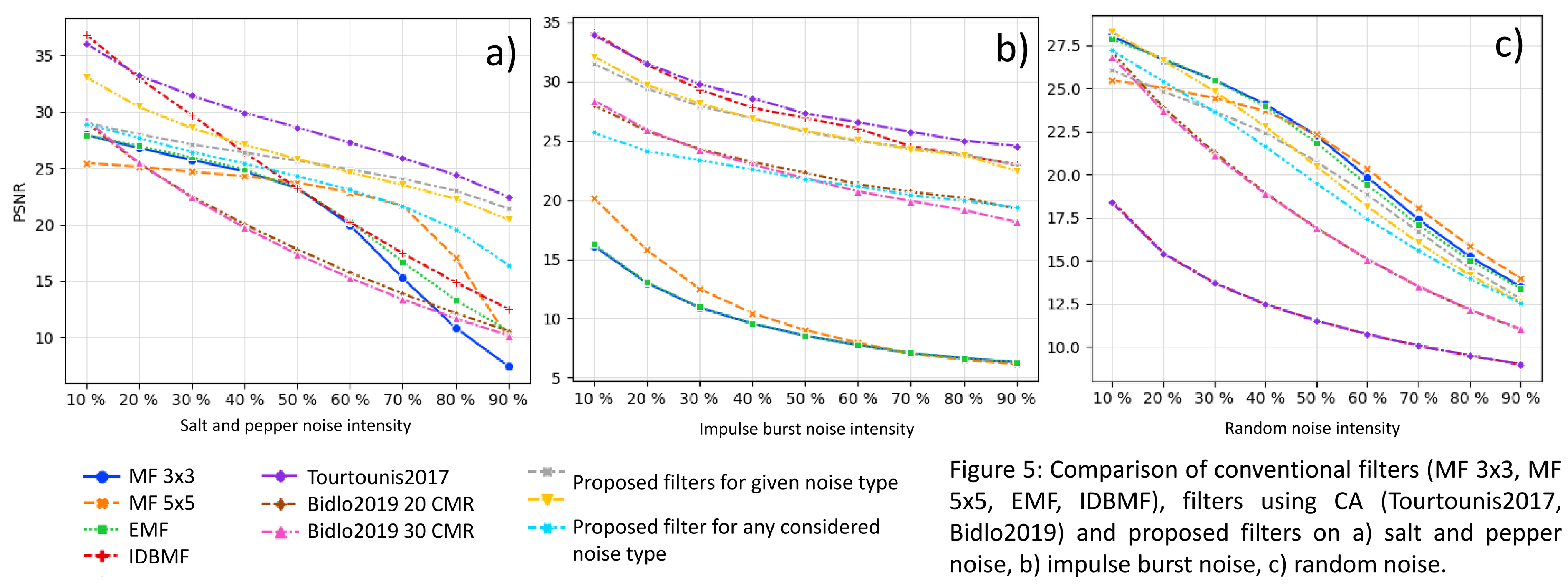

Figure 5: Comparison of conventional filters (MF 3x3, MF 5x5, EMF, IDBMF), filters using CA (Tourtounis2017, Bidlo2019) and proposed filters on a) salt and pepper noise, b) impulse burst noise, c) random noise.

2. CMR representation

Each filter is represented by modified CMRs:

$c_{i,j-1}(t-1)$	$c_{i-1,j}(t-1)$	$c_{i,j}(t-1)$	$c_{i+1,j}(t-1)$	$c_{i,j+1}(t-1)$	$c_{i,j}(t)$
= 0	≥ 23	= 0	≥ 99	≤ 38	W
≠ 0	≤ 251	≤ 7	= 0	≥ 93	N
≤ 112	≥ 146	= 0	≠ 0	≠ 0	median
≠ 0	≤ 253	≥ 250	≤ 242	≤ 253	median
≠ 0	≠ 0	= 0	≥ 44	≥ 18	median
= 0	≤ 220	≥ 236	≠ 0	≠ 0	median
= 0	≠ 0	= 0	= 0	≠ 0	W
≤ 216	≠ 0	≥ 240	= 0	≤ 19	N
≤ 206	≥ 21	≥ 255	≤ 119	≤ 198	S
≠ 0	≤ 250	= 0	≠ 0	≠ 0	median
≥ 42	≥ 21	= 0	= 0	≠ 0	S
= 0	≤ 87	= 0	≠ 0	= 0	E
≠ 0	≠ 0	≥ 255	≠ 0	≠ 0	min
= 0	≤ 175	= 0	≠ 0	≥ 21	S
≠ 0	≠ 0	= 0	≤ 255	≤ 77	N

Table 1: Table representation of a proposed filter for salt and pepper noise removal, that is used in the example of filtering an image damaged by noise of 90 % intensity. N, W, E and S functions refer to state values of the cells from the neighborhood.

6 Conclusions

The results show significant improvement from the original method by modifying the CMRs on all considered noises. The proposed method is capable of developing high-quality image noise filters for all the considered noise models.

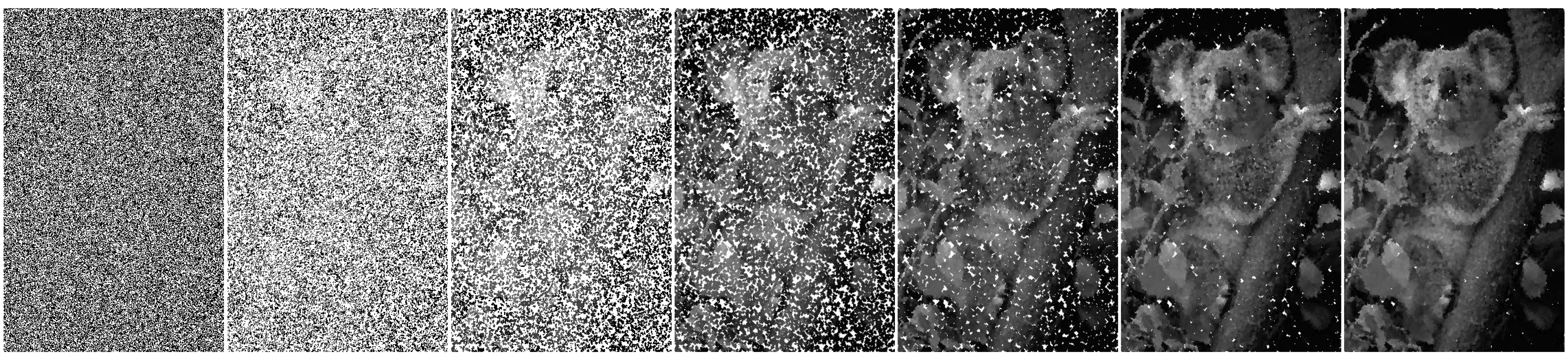

Figure 6: An example of salt and pepper noise of 90 % intensity removal by CA with an experimentally gained filter utilizing the proposed method in 6 steps. First image from the sequence refers to the corrupted non-filtered image.