Impulse Noise Removal: A comparative Study

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Abstract

The project is aimed at comparing performance of filters for pulse noise removal in images. 22 filters ([1-18]) were implemented on a Matlab platform and tested in terms of:

- False alarms errors
- Missing errors
- Estimation errors due to false alarms and missing
- Visual quality

The comparison results are presented in form of tables in which the filters are sorted in descending order of the quality.

Filters

The tested filters are divided into classes:

Order statistics based filters

A histogram based adaptive weighted-median filter [2]
A multiple-median related filter. [3]
Generalized trimmed mean filter [4]
Image block estimation using a block around the median [5]
Rank order filter for smoothing and sharpening with automatic parameter selection [9]
A recursive minimum-maximum filter [10]
Intensity spread based impulse detector for adaptive median [11]
Similarity based recursive impulse detector and adaptive weighted-median filter [12]
Adaptive α-trimmed and Lpq filters for smoothing an sharpening [13]
An adaptive median filter with impulse detector based on gaussian kernel smoothing [14]
An adaptive rank-conditioned median (RCM) filter [15]
An optimal nonlinear extension of linear filters based on distributed arithmetic [16]
Minimum-maximum exclusive mean filter to remove impulse noise from highly corrupted images [18]
Modified Intensity spread based impulse detector for adaptive median filter [19]
Robust moving average estimation for impulse noise filtering [21]
Robust KNN filter for impulsive noise suppression [22]

Morphological filters

Generalized morphological filters [17]

Nonlinear image restoration filters

Rank order mean filter and fuzzy impulse noise classifier [1]
A fuzzy filter for image corrupted by impulse noise [6]
Adaptive impulse noise removal using 2D polynomial approximation and
Median based impulse detector [7]
Restoration of impulse noise corrupted images using long range correlation [8]
Fuzzy filter algorithm using a relaxation algorithm [20]

Testing procedure

The filters were implemented using MATLAB 5.2 and tested for two types of impulse noise: random valued noise and “pepper&salt” noise on three test images

Test Images referred to as image1, image2 and image3 from left to right

2. For each image, its performance for four impulse noise probabilities: 0.05; 0.1; 0.2 and 0.4.
3. For each noise probability, 10 independent tests were performed and the final value of the comparison criteria for each probability are obtained as the average of these runs..
4. Two types of impulse noise model: random valued impulse noise and salt & pepper impulse noise.
5. In case of a filter working different local window, three window size where used: 3x3, 5x5 and 7x7 pixels.

Test results

Numerical evaluation:
According to obtained test results filters were ranked, from the best (rank 1) to the worst (rank 22) for each of three performance factors:

- Probability of false alarms
- Probability of missing noise impulses
- Standard deviation of estimation error for false alarms and missing errors.

For the convenience of filter comparison, obtained filter ranks were summed up and the filters were then sorted according to their average ranks. Obtained results are summarized in the table. Filters identified by their corresponding number in the list of references; filter #0 is median 3x3 filter

Random valued noise	**2 , 1, 14, 21, 16, 10, 6, 13, 11, 7, 22, 15, 0, 4, 8, 18, 19, 12, 3, 9, 5, 17, 20**
"Pepper& salt" noise	**2 ,18 ,14 ,1 ,16 ,7 ,0 ,21 ,6 ,10 ,13 ,4 ,8 ,11 ,15 ,22 ,12 ,19 ,3 ,9 ,5 ,20 ,17**

Evaluation by visual quality

In therms of visual quality (noise removal and preservation of fine details) the filters were divided into three groups:

1. Best (noise is substantially suppressed and much of the fine details are preserved).
2. Good (the noise is substantially suppressed but a certain most of the fine details are blurred).
3. Worst..

The comparison results are summarized in the tables.

For image 1

Noise Probability (**random valued noise**)	**Best**	**Good**	**Worse**
0.05	**14,22,1,6**	**2,4,12,13,15 ,18,21,16,7,8**	**3,5,9,10,19,17,20,20,11,0**
0.1	**14,1,6**	**4,21,22,16,7,8,13**	**2,3,5,9,10,11 ,15,18,19,17,20 ,12,0**
0.2		**14,6,8**	**2,3,4,5,9,10,11,12,13,15,18,19, 21 ,22,17,1,16,7,20,0**
0.4			**2,3,4,5,9,10,11,12,13,22,17,1,1 6,7 ,20,0,14,15,18,19,21**

For image 2

Noise Probability (**random valued noise**)	**Best**	**Good**	**Worse**
0.05	**14,1**	**2,10,6**	**3,4,5,9,11,12,13 ,15,18,19,21,22 ,17,16,7,8,20,0**
0.1		**2,10, 14,6**	**3,4,5,9,11,12,13 ,15,18,19,21,22 ,17,1,16,7,8,20,0**
0.2		**14,6**	**2,3,4,5,9,10,11,12,13,15,18,19,21,0 ,22,17,1,16,7,8,20**
0.4			**2,3,4,5,9,10,11,12,13,22,17,1,16,6,8,14, 15,18,19,21,7,20,0**

For image 3

Noise Probability (**random valued noise**)	**Best**	**Good**	**Worse**
0.05	**2, 14,1,6**	**10,13,15,18,21,22,16,7,8, 4,0**	**3,5,9,11,12,19 ,17,20**
0.1	**1**	**2,9,0, 14,18,21,22,16,6,7,8,4**	**3,5,10,11,12,13 ,15,19,17,20**
0.2		**14,1,16,6,7,8**	**2,3,4,5,9,10,11,12,13,15,18 ,19,21 ,22,17,20,0**
0.4		**6**	**2,3,4,5,9,10,11,12,13,22,17 ,1,16,8 ,14,15,18,19,21,7,20,0**

For image 1

Noise Probability ("Pepper&salt" noise)	Best	Good	Worse
0.05	14,18,1,6,8	2,4,9,12,13,15,21,22, 16,7	3,5,10,11,19,17 ,20,0
0.1	1,6,8	2,9,14,18,21,22 ,16,7,12	3,5,10,11,13 ,15,19,17,4,20,0
0.2		18,6,7,8,12	2,3,4,5,9,10,11,13,17, 1,16,20,0 , 14,15,19,21,22
0.4		18,8	2,3,4,5,9,10,11,12,13, 17,1,16,6,20,0 , 14,15,19,21,22,7

For image 2

Noise Probability ("Pepper&salt" noise)	Best	Good	Worse
0.05	2, 14,1	6	3,4,5,9,10,11,12 ,13,15,18,19,21 ,22,17,16,7,8,20,0
0.1		2,1,6	3,4,5,9,10,11,12, 13,22,17,16,7,8,0, 14,15,18,19,21,20
0.2		6	2,3,4,5,9,10,11,12,13, 22,17,16,7,8 ,20,14,15,18,19 ,21,1,0
0.4			2,3,4,5,9,10,11,12,13, 22,17,16,6,7,8 ,14,15,18,19,21,1,20, 0

For image 3

Noise Probability ("Pepper&salt" noise)	Best	Good	Worse
0.05	2,1,6	9,13,15,18,21,22,16,7 ,4,12,8,20,0	3,5,10,11, 14,19,17
0.1	6	2,9,18,21,1,16,7 ,12,8,0	3,4,5,10,11,13, 14,15,19,22,17,20
0.2		2,18,6,7,8,12,1	3,4,5,9,10,11 ,13,17,16,20,0 , 14,15,19,21,22
0.4		18,6	2,3,4,5,9,10,11,12,13, 17,1,16,7,20,0 , 14,15,19,21,22,8

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