Hybrid Genetic Algorithm with Filters to Image Enhancement
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Received on: 14/10/2012
Accepted on: 30/01/2013

ABSTRACT

Image enhancement is a useful and necessary part of image processing and its analysis. The quality of an image could be corrupted by different kinds of noises, added due to the undesired conditions or during the transmission.

In this paper, a Hybrid Genetic Algorithm with Filters (HGAF) is suggested for the removing of impulse noise from digital images. The new suggested algorithm HGAF uses popular (mean, median and min-max filters) and other proposed filters as fitness function for it in order to design eight proposed genetic filters. These eight proposed genetic filters are applied on several gray images corrupted by two types of noise (salt-and-pepper and gaussian noises) with different levels for comparison and to show the effectiveness of them by using the Peak Signal to Noise Ratio (PSNR) and Root Mean Square Error (RMSE). Also, proposed two methods of parents selection to compare between them and types of crossovers and mutations that are used.

Keywords: Image Enhancement, Genetic Algorithm, Filters, Noises, Digital Images.

1. Introduction

In the last few years, Evolutionary Computation (EC) solutions[8],have been applied to solve difficult optimization problems via simulated evolution. By repeatedly utilizing selection and reproduction principles to the population of individuals representing solutions to the problem, the evolutionary techniques evolve a satisfactory solution quickly and efficiently. Therefore, EC tools find applications in many problems ranging from telecommunication networks[3], to fuzzy learning[21], to modeling, and data mining[6], as well as image processing problems mostly related to gray-scale restoration[10], feature extraction, and coding. In this study, we intend to use genetic algorithm (GA) in image filtering and enhancement
applications. This choice is reasonable due to the fact that: (i) the intention of this experimentation is to obtain the globally optimal setting of the directional processing based vector filtering scheme considered, (ii) GAs are relatively easy to implement, (iii) the optimization problem defined over the vectorial inputs is complex, and (iv) GAs work well in noisy conditions[16] and [19].

Digital images are prone to impulse noise as a result of errors in the image acquisition, transmission, sensing and storage etc. Noise significantly degrades the image quality and cause great loss of information details in the image; thus, denoising is an essential step to improve the image quality. Image denoising has been widely investigated as an initial image processing method during the past four decades[18]. Random variations in the sensor readings make the recorded values different from the ideal ones, introducing errors and undesirable side effects in the subsequent stages of the image processing process[16]. These errors will appear on the image output in different ways depending on the type of disturbance in the signal. Image Noise is classified as Amplifier (Gaussian), Salt (maximum) and Pepper (minimum) (Impulse), Shot, Quantization (uniform), Film grain, on-isotropic, Speckle (Multiplicative) and Periodic noise[13] and [17].

2. Related work

Various filtering techniques have been proposed over the year, for removing impulse noise. It is well-known that linear filters could produce serious image blurring hence, non-linear filters have been widely exploited due to their much improved filtering performance, in terms of impulse noise attenuation and edge/details preservation[1]. Sandra S.N. and Ivan S.N.(2007)[22] proposed Partition Based Median (PBM) filter using genetic algorithm in training have demonstrated results in noise suppressing based on median filtering. With PBM filter, at each location, observed vector is classified into one of M exclusive partitions, and a particular filtering operation is then activated. Optimal weighting vector of each partition is derived by using genetic algorithm in training the filter over a reference image. The values of SNR of filtering Lena and cameraman images are corrupted by 20% Gaussian noise are 27.71% and 25.57% respectively. Jin H.H., Sung B.C. and Ung K.C.(2009)[14] proposed a method that uses (GA) to determine composite filters that remove different levels of impulse noise from an image. In these methods, the GA considers a set of possible filter combinations of a particular length, selects the best combinations among them according to a fitness value assigned to each combination based on a fitness function. Anisha K.K. and Wilsy M.(2011)[2] proposed a technique that used Fuzzy Genetic Algorithm (FGA) to find the optimal composite filters for removing all types of impulse noise from medical images without using deep knowledge about noise factors. Geoffrine J.M.C. and Kumarasabapathy N.(2011)[7] presented a new Decision Based median filtering algorithm to replace the impulse noise corrupted pixel by the median of the pixel scanned in four directions. The value of PSNR(dB) of cameraman image corrupted by 95% salt-and-pepper noise is PSNR=20.3. Vadivu S.and Jeeveraj E.(2011)[23] proposed Adaptive PDE-based Median Filter (APM Filter) to suppress the high-density fixed-value impulse noise. The value of PSNR(dB) of Lena image corrupted by 90% salt-and-pepper noise is 17.4%. Bhnam, B.S.(2011)[5] proposed genetic filters which are applied on several real images contaminated by two types of noise with different levels. The results show that the fifth genetic filter that depends on the median filter as an objective function and heuristic crossover and adding and subtracting mutation, gives the best results with RMSE=15.7243% and PSNR=24.1646% for Lena.bmp image and with RMSE=8.6197% and PSNR=29.4210% for girl.png image when add 0.05 salt-and-paper noise. Gupta S., Kumar R. and Panda S.K.(2012)[9] use PSNR as a fitness function of genetic algorithm to develop hybrid filter which uses various smoothing filters (both linear and non-linear) in a particular sequence to give an output as improved image with noise reduced.

The objective of this study is to present a new proposed Hybrid Genetic Algorithm with Filters (HGAF) to remove the impulse noise from digital images. The HGAF uses popular (such as mean[9], median[4] and min-max filters[15]) and others proposed filters as fitness function of it in order to design eight proposed genetic filters. These eight proposed genetic filters are
applied on several gray images corrupted by two types of noise (salt-and-pepper and gaussian noises) with different levels for comparison and to show the effectiveness of them using the Peak Signal to Noise Ratio (PSNR) and RMSE.

This work is organized as follows: Section 3 deals with proposed Hybrid Genetic Algorithm with Filters (HGAF) for de-noising in the images. In section 4, finds fitness function of HGAF in order to design proposed genetic filters. Experimental results in Section 5. The results of filters[5] after and before developed them by HGAF is presented in Section 6. Section 7 shows the results of popular and proposed filters, but without applying HGAF. Section 8 puts forward the conclusions drawn by this paper and Future Research.

3. The Hybrid Genetic Algorithm with Filters (HGAF)

The HGAF has several fitness functions for removing noise from the image. These fitness functions are popular filters (mean, median, min-max filters) and other proposed filters (that will be explained later) in order to design eight proposed filters for removing noise from images. These genetic filters different from [5] about execute GA over all image as well as window. Also, proposed two methods of parent selected rather than parent selection randomly. These proposed genetic filters have been implemented by using MATLAB 7.10.0(R2010a). The performance of these proposed genetic filtering is analyzed and discussed. The simple and widely used objective image quality metrics are Root Mean Square Error (RMSE) and Peak Signal-to-Noise Ratio (PSNR) [11] and [12]:

\[
RMSE = \sqrt{\frac{1}{M \times N} \sum_{r=0}^{M-1} \sum_{c=0}^{N-1} [\text{Im}_{\text{new}}(r,c) - \text{Im}_{\text{old}}(r,c)]^2}
\]

\[
PSNR = 10 \log_{10} \left( \frac{L - 1)^2}{\frac{1}{M \times N} \sum_{r=0}^{M-1} \sum_{c=0}^{N-1} [\text{Im}_{\text{new}}(r,c) - \text{Im}_{\text{old}}(r,c)]^2} \right)
\]

Here Im_{old}(r,c) is the original image, Im_{new}(r,c) is an enhanced image, L is 255 and M and N are the total number of pixels in the horizontal and the vertical dimensions of the image.

The Steps of the HGAF as follows:

Step 1) Read original image and then add noise to it.
Step 2) Select a two dimensional window P of size 3×3. (consider each pixel in P as chromosome).
Step 3) Compute the fitness function for the window P using one of the popular (mean, median and min-max filters) or proposed filters (that will be explained later).
Step 4) Select the parent using one of the proposed methods:
  - **Method 1**: Select parent closer to the original pixel.
  - **Method 2**: Select parent closer to original window median.
Step 5) Apply crossover between fitness value and each point in window P and, then apply mutation.
Step 6) Compute RMSE of resulting window. Repeat steps from 3 to 6 until the stopping criterion is achieved. The stopping criteria taken is: optimum found or no increase in quality for 50 generations of window.
Step 7) Select the window that minimum RMSE and put it in an array (B). Repeat steps from 2 to 7 until all the windows in the entire image are processed.
Step 8) Compute RMSE and PSNR of the resulting image in B. Repeat Steps from 2 to 8 until the stopping criterion is achieved. The stopping criteria taken is: optimum found or no increase in quality for 50 generations of image.

Fig. 1 shows the flow control of the HGAF. Firstly, read the original image I!, corrupted image K and then, select a window P of size 3×3. After that, compute fitness function for the window P using one of the popular (mean, median and min-max filters) or proposed filters (that will be explained later). At each time, new two points are created in order to find new window by the crossover between each pixel in a window and the fitness value instead of each two pixels in a window that is used in [5]. Then, one of the pixels is selected using one of the proposed selection methods (select pixel closer to the original pixel or closer to original
window median) instead of random selection used in [5], and apply Mutation to avoid the local minima trapping of the algorithm. The RMSE is computed for the window. After the completion of the first iteration for the window, new window is created and the process continues until the stopping criterion is achieved. Then, a window that minimum RMSE is selected among 50 generation for window and put it in the array B. Repeat this process for each window until all the windows in the entire image are processed, then RMSE and PSNR are computed for the processed image. After the completion of the first iteration for the image, repeat this process for each window until the stopping criterion is achieved (number of generation for image) or old RMSE equal new RMSE (for the image) or old PSNR equal new PSNR. Finally, the image that minimum RMSE and maximum PSNR showed among 50 generation for image. This is another difference from [5] about execute the GA over the image as well as window.

Figure (1): Flow control of the Hybrid Genetic Algorithm with Filters HGAF

4. Find Fitness Function of HGAF In order to Design Proposed Genetic Filters

The HGAF is hybrid with many filters most of them popular and others proposed. These filters are used as fitness function of HGAF. The popular filters are used mean, median, and min-max filters, after hybrid them with HGAF called: Genetic mean filter, Genetic median filter and Genetic min-max filter respectively. The proposed filters are elucidated as follows:

- **Proposed Genetic Mean Filter**

  Assume that the pixel being processed is \( P_x \) and the window_noise is \( P \) as \( 3 \times 3 \) from the image _noise_ K. In this proposed filter, \( P_x \) will be replaced by the mean of the subset of the sorted window \( S_w \) according to the conditions that are early determined. Fig.2 shows the proposed genetic mean filter to find the fitness value. The algorithm of this filter to find the fitness value \( F \) for window \( P \) as follow:

```plaintext
The algorithm of the proposed genetic mean filter:
Begin
    \( P_x = P(5) \);
    \( S_w = \) Sort the window_noise (P);
    Find fitness(F) for window(P) as the following:
    Case: \( P_x > \text{max}(P) \) ; then \( F \) is the mean of last three pixel of \( S_w \) as : \( F = (S_w(7) + S_w(8)) / 3 \)
    Case: \( P_x < \text{min}(P) \) ; then \( F \) is the mean of first three pixel of \( S_w \) as : \( F = (S_w(1) + S_w(2)) / 3 \)
    Case: median(P) < \( P_x \leq \text{max}(P) \)
    \( F = \) median(3) \( / 3 \)
    Case: \( \text{min}(P) \leq P_x \leq \text{median}(P) \)
    \( F = P(5) \)
otherwise
end
```
Where $P$ is the window noise as $3 \times 3$, $P_x$ is the pixel being processed, $F$ is the Fitness value, $S_w$ is the window noise $3 \times 3$ after been sorted ascending, $\max(P)$ is the maximum pixel of $P$, $\min(P)$ is the minimum pixel of $P$ and $\text{median}(P)$ is the median pixel of $P$.

![Flow chart to find the fitness value](chart.png)

**First Proposed Genetic Median Filter**

In this proposed filter, instead of replaced $P_x$ with mean, here it will replaced by the median of the subset of the sorted window $S_w$ according to the conditions that are early determined. The algorithm of this filter is is explained below:

**The algorithm of the first proposed genetic median filter:**
Begin
$P_x = P(5)$
$S_w = \text{Sort window (P)}$
Find fitness($F$) for window($P$) as the following:
Case: $P_x > \max(P)$
$F = \text{median}(S_w (7), S_w (8), S_w (9))$
Case: $P_x < \min(P)$
$F = \text{median}(S_w (1), S_w (2), S_w (3))$
Case: $\text{median}(P) < P_x < \max(P)$
$F = \text{median}(S_w (6), S_w (7), S_w (8))$
Case: $\min(P) < P_x < \text{median}(P)$
$F = \text{median}(S_w (2), S_w (3), S_w (4))$
Otherwise
$F = \text{median}(P)$
end

**Second Proposed Genetic Median Filter**

The idea of this filter is same as of the first proposed genetic median filter but different of it by first two conditions to find the fitness value and as follows:
Case: $P_x > \max(P)$
$F = \max(P)$
Case: $P_x < \min(P)$
$F = \min(P)$

**First Proposed Genetic Midrange Filter**

This proposed filter use the midrange metric [20]to find the fitness value of the window $P$. The algorithm of this filter is explained below:

**The algorithm of the first proposed genetic midrange filter:**
Begin
Find fitness($F$) for window($P$) as the following:
$F = (\max(P) + \min(P))/2$
end
• Second Proposed Genetic Midrange Filter

Also, this filter uses midrange metric but, for sorted window after first and last pixel of it are excepted. This algorithm is as follows:

The algorithm of the second proposed genetic midrange filter:

Begin
Sw = Sort window (P)
Find fitness(F) for window(P) as the following:
Case: Px > max(P)  F= max(P)
Case: Px < min(P)  F=min(P)
Otherwise  F=(Sw (3)+Sw (7))/2
End

5. Experimental Results

The eight proposed genetic filters have been tested on images belonging to different types. Lena.bmp (256×256) , Flower.jpg (128×128) , Girl.png (416×512) and cameraman.tif (256×256) are gray-scale images. These images are of different sizes and corrupted by two different types of noises : salt-and-pepper and gaussian noises at different noise densities 0.05 and 0.1. Tables 1, 2, 3 and 4 show the values of PSNR and RMSE of these filters when apply the first method of parents selection closer to original pixel , arithmetic crossover and bit inverse mutation.

Table(1): Results of Genetic Filters (Arithmetic Crossover and Bit Inverse Mutation) when apply Parents Selection Method closer to original pixel with adding 0.05 salt & pepper noise.

| IMAGES          | Lena.bmp | Flower.jpg | Girl.png | Cameraman.tif |
|-----------------|----------|------------|----------|---------------|
| FILTERS         | RMSE     | PSNR       | RMSE     | PSNR          | RMSE     | PSNR       | RMSE     | PSNR          |
| Genetic mean filter | 10.1286  | 28.0198    | 9.9728   | 28.1545       | 5.9783   | 32.5992    | 14.1149  | 25.1373       |
| Proposed genetic mean filter | 8.8288   | 29.2128    | 7.1453   | 31.0504       | 4.8966   | 34.3328    | 12.4685  | 26.2145       |
| Genetic median filter | 8.7121   | 29.1702    | 7.6697   | 30.3452       | 4.9703   | 34.2276    | 12.4755  | 26.2097       |
| First proposed genetic median filter | 8.7793   | 29.2616    | 7.4775   | 30.6557       | 4.9227   | 34.2990    | 12.3153  | 26.3219       |
| Second proposed genetic median filter | 8.8752   | 29.2755    | 7.2960   | 31.0291       | 4.8906   | 34.3435    | 12.5401  | 26.1648       |
| Genetic min-max filter | 21.8617  | 21.3371    | 24.0658  | 20.5028       | 11.5986  | 26.8427    | 23.9634  | 20.5398       |
| First proposed genetic midrange filter | 18.3924  | 22.8380    | 20.6779  | 21.8207       | 15.5941  | 24.2716    | 23.6914  | 20.6390       |
| Second proposed genetic midrange filter | 11.3045  | 27.0657    | 11.5724  | 26.8624       | 6.4541   | 31.9341    | 16.1548  | 23.9648       |

Table(2): Results of Genetic Filters (Arithmetic Crossover and Bit Inverse Mutation) when apply Parents Selection Method closer to original pixel with adding 0.1 salt & pepper noise.

| IMAGES          | Lena.bmp | Flower.jpg | Girl.png | Cameraman.tif |
|-----------------|----------|------------|----------|---------------|
| FILTERS         | RMSE     | PSNR       | RMSE     | PSNR          | RMSE     | PSNR       | RMSE     | PSNR          |
| Genetic mean filter | 10.7286  | 27.5200    | 11.1344  | 27.1975       | 5.8475   | 31.4201    | 16.6539  | 23.7005       |
| Proposed genetic mean filter | 9.2014   | 28.8537    | 8.6873   | 29.9331       | 5.2196   | 33.7781    | 13.1699  | 25.7391       |
| Genetic median filter | 9.3488   | 28.7157    | 8.1275   | 29.3516       | 5.2201   | 33.7772    | 13.0177  | 25.8401       |
| First proposed genetic median filter | 9.3707   | 28.6953    | 8.1485   | 29.9092       | 5.2114   | 33.7917    | 13.2328  | 25.6978       |
| Second proposed genetic median filter | 9.3300   | 28.7332    | 8.5527   | 29.4887       | 5.1800   | 33.8441    | 13.2119  | 25.7115       |
| Genetic min-max filter | 23.6167  | 20.6664    | 33.7000  | 17.5782       | 9.9353   | 28.1872    | 30.9108  | 18.3286       |
| First proposed genetic midrange filter | 19.7313  | 22.2277    | 23.2641  | 20.4054       | 18.7181  | 22.6856    | 26.1207  | 19.7911       |
| Second proposed genetic midrange filter | 10.3883  | 27.7999    | 10.2055  | 27.9541       | 6.7640   | 31.5267    | 14.4331  | 24.9436       |
Hybrid Genetic Algorithm with Filters to ...

Table(3): Results of Genetic Filters (Arithmetic Crossover and Bit Inverse Mutation) when apply Parents Selection Method closer to original pixel with adding 0.05 gaussian noise.

| FILTERS                  | Lena.bmp | Flower.jpg | Girl.png | Cameraman.tif |
|--------------------------|----------|------------|----------|---------------|
| GENETIC MEAN FILTER      | RMSE     | PSNR       | RMSE     | PSNR          |
| Proposed genetic mean    | 13.8403  | 25.9593    | 14.9385  | 24.8931       | 9.7134 | 28.3836 | 16.3376 | 23.8670 |
| First proposed genetic median filter | 17.7009  | 23.1670    | 17.2591  | 23.3904       | 16.2141 | 23.9330 | 19.7179 | 22.2336 |
| Second proposed genetic median filter | 17.8375  | 23.1041    | 17.2577  | 23.3911       | 16.2707 | 23.9027 | 19.7387 | 22.2244 |
| GENETIC MIN-MAX FILTER   | 22.5160  | 21.1585    | 22.1364  | 21.2286       | 16.2470 | 23.9154 | 23.3000 | 20.7837 |
| First proposed genetic midrange filter | 13.3629  | 25.6128    | 14.1353  | 25.5166       | 8.5388 | 29.5028 | 16.2376 | 23.9070 |
| Second proposed genetic midrange filter | 14.3421  | 24.9986    | 14.2793  | 25.1222       | 12.0712 | 26.4958 | 17.3727 | 23.3334 |

Table(4): Results of Genetic Filters (Arithmetic Crossover and Bit Inverse Mutation) when apply Parents Selection Method closer to original pixel with adding 0.1 gaussian noise.

| FILTERS                  | Lena.bmp | Flower.jpg | Girl.png | Cameraman.tif |
|--------------------------|----------|------------|----------|---------------|
| GENETIC MEAN FILTER      | RMSE     | PSNR       | RMSE     | PSNR          |
| Proposed genetic mean    | 18.4188  | 22.8256    | 18.6634  | 22.7110       | 16.6345 | 23.7106 | 21.4230 | 21.5132 |
| First proposed genetic median filter | 27.6218  | 19.9729    | 27.1737  | 19.4477       | 26.8086 | 19.5659 | 28.9469 | 18.8988 |
| Second proposed genetic median filter | 27.7170  | 19.2759    | 27.4755  | 19.3519       | 26.7587 | 19.5815 | 28.9850 | 18.8873 |
| GENETIC MIN-MAX FILTER   | 27.7512  | 19.2652    | 27.4644  | 19.3554       | 26.8371 | 19.5616 | 28.9283 | 18.9044 |
| First proposed genetic midrange filter | 27.6318  | 19.3026    | 27.8239  | 19.2424       | 26.7701 | 19.5778 | 28.9943 | 18.8845 |
| Second proposed genetic midrange filter | 27.9281  | 19.2100    | 29.5877  | 18.7086       | 20.8256 | 21.7588 | 30.7507 | 18.3737 |
| GENETIC MIN-MAX FILTER   | 16.6645  | 23.6950    | 18.3648  | 22.8511       | 13.2426 | 25.6913 | 21.2963 | 21.5647 |
| First proposed genetic midrange filter | 22.0168  | 21.2757    | 22.1833  | 21.2103       | 20.9825 | 21.6937 | 24.2764 | 20.4271 |

Tables 5,6,7 and 8 show the values of PSNR and RMSE when apply the second method of parents selection closer to original window median , same type of crossover and mutation and corrupted these images by 0.05 and 0.1 salt-and-pepper noise and Gaussian.

Table(5): Results of Genetic Filters (Arithmetic Crossover and Bit Inverse Mutation) when apply Parents Selection Method closer to original window median with adding 0.05 salt & pepper noise.

| FILTERS                  | Lena.bmp | Flower.jpg | Girl.png | Cameraman.tif |
|--------------------------|----------|------------|----------|---------------|
| GENETIC MEAN FILTER      | RMSE     | PSNR       | RMSE     | PSNR          |
| Proposed genetic mean    | 8.1834   | 29.8721    | 6.8370   | 31.4335       | 4.8765 | 34.3686 | 11.5509 | 26.8785 |
| First proposed genetic median filter | 7.8656   | 30.2437    | 6.3039   | 32.1386       | 4.1032 | 35.8683 | 11.5893 | 26.8496 |
| Second proposed genetic median filter | 8.3351   | 29.7126    | 6.9045   | 31.3482       | 4.9990 | 34.1531 | 11.7347 | 26.7414 |
| GENETIC MIN-MAX FILTER   | 7.8182   | 30.2686    | 6.1833   | 32.3064       | 4.1412 | 35.7883 | 11.5377 | 26.8884 |
| First proposed genetic midrange filter | 7.8200   | 30.2666    | 6.0612   | 32.4796       | 4.0164 | 36.0540 | 11.5036 | 26.9115 |
| Second proposed genetic midrange filter | 13.4554  | 25.5529    | 16.4314  | 23.8173       | 7.0887 | 31.1194 | 20.3737 | 21.9494 |
| GENETIC MIN-MAX FILTER   | 15.0881  | 24.5581    | 16.9458  | 23.5495       | 14.7382 | 24.7619 | 18.8795 | 22.6110 |
| First proposed genetic midrange filter | 7.9380   | 30.1366    | 6.3237   | 32.1114       | 4.4210 | 35.2204 | 11.4448 | 26.9587 |
Table 6: Results of Genetic Filters (Arithmetic Crossover and Bit Inverse Mutation) when apply Parents Selection Method closer to original window median with adding 0.1 salt & pepper noise.

| FILTERS                  | IMAGES          | RMSE  | PSNR  | RMSE  | PSNR  | RMSE  | PSNR  | RMSE  | PSNR  |
|--------------------------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Genetic mean filter      | Lena.bmp        | 8.9821| 29.0632| 8.0354| 30.0307| 5.9371| 32.6594| 12.1966| 26.4060|
| Proposed genetic mean filter | Flower.jpg   | 8.4254| 29.5700| 6.8720| 31.3891| 4.3070| 35.4474| 12.1649| 26.4286|
| Genetic median filter    | Girl.png        | 8.4749| 29.2363| 7.9497| 30.1238| 5.2126| 33.5222| 12.4801| 26.2064|
| First proposed genetic median filter | Cameraman.tif | 8.2360| 29.8165| 7.3188| 30.8420| 4.3676| 35.3260| 12.3008| 26.3321|
| Second proposed genetic median filter |                | 8.8018| 29.7113| 7.3632| 30.7894| 4.2831| 35.4957| 12.2902| 26.3397|
| Genetic min-max filter   | Lena.bmp        | 14.6285| 24.8268| 17.1880| 23.4263| 9.6898| 28.4045| 21.9497| 21.3022|
| First proposed genetic midrange filter | Flower.jpg     | 18.3303| 22.8674| 20.4284| 21.9261| 18.0466| 23.0029| 20.7982| 21.7703|
| Second proposed genetic midrange filter | Girl.png       | 8.6747| 29.3657| 7.5194| 30.6071| 5.4560| 33.3933| 12.0309| 26.5249|

Table 7: Results of Genetic Filters (Arithmetic Crossover and Bit Inverse Mutation) when apply Parents Selection Method closer to original window median with adding 0.05 gaussian noise.

| FILTERS                  | IMAGES          | RMSE  | PSNR  | RMSE  | PSNR  | RMSE  | PSNR  | RMSE  | PSNR  |
|--------------------------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Genetic mean filter      | Lena.bmp        | 11.2991| 27.0699| 10.2814| 27.8897| 9.3407| 28.7232| 13.9085| 25.2652|
| Proposed genetic mean filter | Flower.jpg     | 17.5843| 23.2283| 17.0502| 23.4962| 15.9309| 24.0860| 19.3453| 22.3993|
| Genetic median filter    | Girl.png        | 16.5435| 23.7582| 16.2113| 23.9345| 15.1108| 24.5451| 18.6007| 22.7402|
| First proposed genetic median filter | Cameraman.tif | 17.6711| 23.1856| 16.9178| 23.5639| 15.9530| 24.0740| 19.2896| 22.4243|
| Second proposed genetic median filter |                | 17.6047| 23.2182| 17.0569| 23.4928| 15.9652| 24.0673| 19.3128| 22.4139|
| Genetic min-max filter   | Lena.bmp        | 20.7287| 21.7994| 20.2403| 22.0065| 17.2702| 23.3849| 20.9837| 21.6932|
| First proposed genetic midrange filter | Flower.jpg     | 9.7490| 28.3516| 9.1837| 28.8704| 7.3681| 30.7837| 12.8914| 25.9248|
| Second proposed genetic midrange filter | Girl.png       | 13.0488| 25.8194| 12.2525| 26.3663| 11.4783| 26.9333| 15.4458| 24.3546|

Table 8: Results of Genetic Filters (Arithmetic Crossover and Bit Inverse Mutation) when apply Parents Selection Method closer to original window median with adding 0.1 gaussian noise.

| FILTERS                  | IMAGES          | RMSE  | PSNR  | RMSE  | PSNR  | RMSE  | PSNR  | RMSE  | PSNR  |
|--------------------------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Genetic mean filter      | Lena.bmp        | 17.7095| 23.1667| 17.1011| 23.4703| 16.8050| 23.5756| 19.6339| 22.2707|
| Proposed genetic mean filter | Flower.jpg     | 27.6352| 19.3015| 27.1800| 19.4458| 26.3726| 19.7078| 28.6329| 18.9993|
| Genetic median filter    | Girl.png        | 25.8607| 19.8780| 25.7937| 19.9005| 25.1478| 20.1208| 27.4052| 19.3741|
| First proposed genetic median filter | Cameraman.tif | 27.5812| 19.3185| 27.3939| 19.3777| 26.4041| 19.6974| 28.6926| 18.9754|
| Second proposed genetic median filter |                | 27.6135| 19.3084| 27.3763| 19.3833| 26.4849| 19.6708| 28.6509| 18.9381|
| Genetic min-max filter   | Lena.bmp        | 25.5581| 19.9802| 27.8815| 19.2245| 26.5049| 19.6408| 28.7115| 19.8639|
| First proposed genetic midrange filter | Flower.jpg     | 14.0050| 25.2052| 13.3167| 25.6429| 12.7254| 26.0371| 16.5894| 23.7342|
| Second proposed genetic midrange filter | Girl.png       | 21.2543| 21.5819| 20.9059| 21.7254| 20.3734| 21.9405| 22.5599| 21.0640|

Tables 9 and 10 show the results when apply the second method of parents selection, heuristic crossover, add and sub mutation and corrupted these images by 0.05 salt & pepper noise and gaussian respectively. Fig.3 show the best results of second proposed genetic median filter and first proposed genetic midrange filter.
### Table 9: Results of Genetic Filters (Heuristic Crossover and Add and sub Mutation) when apply Parents Selection Method closer to original window median with adding 0.05 salt & pepper noise.

| IMAGES          | Genetic mean filter | Proposed genetic mean filter | Genetic median filter | First proposed genetic median filter | Second proposed genetic median filter | Genetic min-max filter | First proposed genetic midrange filter | Second proposed genetic midrange filter |
|-----------------|---------------------|-----------------------------|----------------------|-------------------------------------|--------------------------------------|------------------------|---------------------------------------|----------------------------------------|
| FILTERS         | RMSE                | PSNR                        | RMSE                 | PSNR                                | RMSE                                | RMSE                   | RMSE                                 | PSNR                                   |
| Lena.bmp        | 7.4961              | 30.6341                     | 6.0287               | 32.5263                             | 3.8975                               | 36.3150                | 10.9701                              | 27.3266                                |
| Flower.jpg      | 7.1642              | 31.3823                     | 6.1238               | 32.9044                             | 3.7803                               | 36.5803                | 10.6643                              | 27.7766                                |
| Girl.png        | 7.7241              | 30.3738                     | 6.0778               | 32.4559                             | 4.1591                               | 36.1789                | 11.4024                              | 26.9908                                |
| Cameraman.tif   | 7.0841              | 30.4190                     | 5.7375               | 32.9563                             | 4.0019                               | 36.0854                | 11.4241                              | 26.9744                                |

### Table 10: Results of Genetic Filters (Heuristic Crossover and Add and sub Mutation) when apply Parents Selection Method closer to original window median with adding 0.05 Gaussian noise.

| IMAGES          | Genetic mean filter | Proposed genetic mean filter | Genetic median filter | First proposed genetic median filter | Second proposed genetic median filter | Genetic min-max filter | First proposed genetic midrange filter | Second proposed genetic midrange filter |
|-----------------|---------------------|-----------------------------|----------------------|-------------------------------------|--------------------------------------|------------------------|---------------------------------------|----------------------------------------|
| FILTERS         | RMSE                | PSNR                        | RMSE                 | PSNR                                | RMSE                                | RMSE                   | RMSE                                 | PSNR                                   |
| Lena.bmp        | 9.4241              | 28.6460                     | 8.0454               | 30.0199                             | 7.0732                               | 31.1385                | 12.2270                              | 26.3844                                |
| Flower.jpg      | 16.2065             | 23.9449                     | 14.9517               | 24.6370                             | 14.4530                             | 24.8559                | 17.6273                              | 23.1815                                |
| Girl.png        | 16.0065             | 24.0449                     | 14.7742               | 24.7407                             | 14.3630                             | 24.9859                | 17.5173                              | 23.2615                                |
| Cameraman.tif   | 15.9208             | 24.0915                     | 14.8995               | 24.6673                             | 14.2797                             | 25.0364                | 17.6055                              | 23.2178                                |

![Image of original and restored images](image-url)

**Figure (3):** (a,b,c,d) original image. (e,f,g,h) Noise 0.05 salt and pepper image. (i,j,k,l) restored by second suggested proposed median filter. (m,n,o,p) Noise Gaussian image. (q,r,s,t) restored by first suggested proposed midrange filter.
6. Results of Filters [5] After and Before Developed them by HGAF

The filters in [5] have been developed them according to HGAF. Tables 11 and 12 show the results of these filters [5] after developed by HGAF and apply the second method of parents selection. Table 13 shows the results of the best genetic filters according to the [5].

Table (11): Results of Genetic Filters [5] when apply Parents Selection Method closer to original window median with adding 0.05 salt & pepper noise.

| IMAGES        | Lena.bmp          | Flower.jpg         | Girl.png          | Cameraman.tif       |
|---------------|-------------------|--------------------|-------------------|--------------------|
| FILTERS       | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   |
| First genetic filter | 7.6211 | 30.4904 | 5.8951 | 32.7210 | 4.0645 | 35.9508 | 11.0557 | 27.2590 |
| Second genetic filter | 7.8412 | 30.2431 | 6.4056 | 31.9996 | 4.0740 | 35.9303 | 11.3209 | 27.0532 |
| Third genetic filter | 7.8862 | 30.1934 | 5.9349 | 32.6625 | 4.0974 | 35.8806 | 11.4959 | 26.9199 |
| Fourth genetic filter | 7.7889 | 30.3525 | 5.9107 | 32.1504 | 3.9298 | 36.2434 | 11.9842 | 27.3814 |
| Fifth genetic filter | 7.6739 | 30.4305 | 5.9480 | 32.1934 | 3.9285 | 36.2457 | 11.3450 | 27.0347 |

Table (12): Results of Genetic Filters [5] when apply Parents Selection Method closer to original window median with adding 0.05 gaussian noise.

| IMAGES        | Lena.bmp          | Flower.jpg         | Girl.png          | Cameraman.tif       |
|---------------|-------------------|--------------------|-------------------|--------------------|
| FILTERS       | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   |
| First genetic filter | 9.4409 | 28.6306 | 8.1624 | 29.8945 | 7.0858 | 31.1231 | 12.3443 | 26.3015 |
| Second genetic filter | 15.8932 | 24.1066 | 15.2472 | 24.4670 | 14.3330 | 25.0041 | 17.8863 | 23.0804 |
| Third genetic filter | 16.0560 | 24.0180 | 15.2792 | 24.4488 | 14.3794 | 24.9760 | 17.9120 | 23.0679 |
| Fourth genetic filter | 9.3987 | 28.6694 | 7.8949 | 30.1838 | 7.0036 | 31.2244 | 12.2575 | 26.3627 |
| Fifth genetic filter | 15.1111 | 24.2621 | 14.2457 | 25.0571 | 13.8402 | 25.3080 | 17.2644 | 23.3878 |
| Sixth genetic filter | 15.6621 | 24.2338 | 14.6664 | 24.8043 | 13.8422 | 25.3067 | 17.2617 | 23.3891 |

Table (13): Results of the best Genetic Filters according to the [5].

| IMAGES        | Lena.bmp          | Flower.jpg         | Girl.png          |
|---------------|-------------------|--------------------|-------------------|
| FILTERS       | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   |
| First genetic filter | 20.0148 | 22.0750 | 17.4941 | 22.8968 | Adding 0.05 gaussian noise |
| Fourth genetic filter | 20.0805 | 22.1016 | 17.6183 | 22.9115 | Adding 0.05 gaussian noise |
| Fifth genetic filter | 15.7243 | 24.1646 | 8.6197 | 29.4210 | Adding 0.05 salt & pepper |

7. Results of the popular and proposed filters but without apply HGAF

The mean, median, min-max and proposed filters have been tested on these images but, without HGAF. Tables 14 and 15 show the results of these filters without HGAF.

Table (14): Results of the popular and proposed filters but without apply HGAF when adding 0.05 salt-and-pepper noise.

| IMAGES        | Lena.bmp          | Flower.jpg         | Girl.png          | Cameraman.tif       |
|---------------|-------------------|--------------------|-------------------|--------------------|
| FILTERS       | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   | RMSE   | PSNR   |
| Mean filter   | 13.8549 | 25.2987 | 14.5215 | 24.8906 | 11.3605 | 27.0229 | 16.8242 | 23.6121 |
| Proposed mean filter | 8.6552 | 29.3853 | 9.4747 | 28.5995 | 5.7046 | 31.6033 | 12.5393 | 25.6745 |
| Median filter | 9.9840 | 28.0863 | 7.7745 | 31.5132 | 6.0343 | 30.0155 | 13.6428 | 24.8097 |
| First proposed median filter | 8.8893 | 29.0165 | 7.6789 | 30.4248 | 5.7002 | 35.7662 | 12.5929 | 25.4918 |
| Second proposed median filter | 29.9467 | 18.6038 | 34.0187 | 17.4964 | 30.1055 | 18.3568 | 32.4782 | 17.8990 |
| Min-max filter | 10.8994 | 27.1789 | 9.1443 | 25.0613 | 8.5577 | 28.9259 | 14.6972 | 23.7692 |
| First proposed midrange filter | 38.5114 | 16.4190 | 43.3233 | 15.3964 | 38.9701 | 16.3162 | 43.0043 | 15.4606 |
| Second proposed midrange filter | 9.7307 | 28.3679 | 9.9656 | 28.1608 | 5.9160 | 32.6902 | 13.9029 | 25.2687 |
Table 15: Results of the popular and proposed filters but without apply HGAF when adding 0.05 gaussian noise.

| IMAGES     | Mean filter | Proposed mean filter | Median filter | First proposed median filter | Second proposed median filter | Min-max filter | First proposed midrange filter | Second proposed midrange filter |
|------------|-------------|----------------------|--------------|------------------------------|------------------------------|---------------|-------------------------------|-------------------------------|
| RMSE       | 22.4704     | 22.3535              | 18.3641      | 21.8583                      | 27.3912                      | 22.1953       | 19.6234                       | 19.7346                       |
| PSNR       | 21.0986     | 21.1439              | 22.8514      | 21.3385                      | 19.3786                      | 19.9316       | 22.7573                       | 22.2262                       |
| RMSE       | 22.6779     | 22.6496              | 17.6395      | 21.8207                      | 27.3797                      | 20.5826       | 22.2753                       | 21.9548                       |
| PSNR       | 21.0188     | 21.8471              | 23.2011      | 21.3534                      | 19.3822                      | 21.2292       | 21.5033                       | 21.3002                       |
| RMSE       | 21.7612     | 21.8471              | 16.9573      | 20.8650                      | 27.5456                      | 20.9696       | 17.7681                       | 17.8175                       |
| PSNR       | 21.3771     | 21.3429              | 23.5437      | 21.7424                      | 19.3298                      | 20.5374       | 23.1380                       | 23.1139                       |
| RMSE       | 23.1832     | 23.0623              | 19.9604      | 23.2772                      | 28.1117                      | 23.9456       | 24.3834                       | 24.5819                       |
| PSNR       | 20.8273     | 20.8728              | 22.1274      | 20.7922                      | 19.1531                      | 19.1339       | 20.3889                       | 20.3185                       |

8. Conclusions & Future Research

1. The girl.png is suitable for HGAF in comparison with cameraman.tif.
2. Method 2 of selection (the parents selection method closer to original window median) gives better results of all filters in comparison with method 1 (the parents selection method closer to original pixel).
3. The heuristic crossover and add and sub mutation is much suitable than other crossovers and mutations.
4. The filters in [5] after developed by HGAF and apply the second method of parents selection closer to original window give better results in comparison with [5].
5. The second proposed genetic median filter gives better results as well as the perceived image quality in comparison with other filters and filters in [5] after development by HGAF when the images are corrupted by salt-and-pepper noise. But when corrupted them by gaussian noise, the better is first proposed genetic midrange filter. Experiments conducted show that the HGAF is much better than the popular and proposed filters without HGAF as well as filters in [5] for removing impulse noise from these images along with image detail preservation in terms of PSNR and RMSE. The proposed algorithm is faster since it uses a small window of size 3×3. The success of optimization strongly depends on the chosen parents selection method, crossover and mutation strategies as well as fitness function (selection popular and proposed filters).
   As future work, the proposed method can be used in applications such as impulse noise removal from satellite, medical and color images. Also, corrupt the images with other types of noises with high density and removing impulse noise by the HGAF.
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