Data Fusion Approach for Image Noise Removing

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Abstract

Noise is any undesired information that contaminates an image. The noise removal is thus a prerequisites to facilitate later image processing and analysis tasks. Data fusion, on the other hand, is the process of combining data from multiple sources such that the resulting entity or decision is in some sense better than that provided by any of the individual sources. In this paper we present a new method for image noise removal by fusing number of images transmitted through different noisy channels. The proposed method is compared with the traditional methods of noise removal. The results show that the fusion method gave superior results in compared with the traditional method

1. Introduction

One of the primary concerns of digital image preprocessing is to increase image quality and to moderate the degradations introduced by the sensing and acquisition devices. Digital image enhancements techniques increase subjective image quality by reduce noise. Some of the basic techniques for image noise removal work by convolute the noisy image with a specific kernel (e.g. mean filter), other techniques based on statistical measures which are order statistic filters or non-linear filters (e.g. median filters), mean filter blur an image edge, while the results of median filter are sometimes unpredictable.

Image fusion is the process that produces a single image from a set of input images. The fused image should contain “complete” information (as defined by a given application), than any individual input. Image data fusion commonly used in surveillance systems, object tracking, digital watermarking, steganography, and multifocuse video image fusion. One of the very rare applications of image fusion is noise removal. In this work we combine image fusion techniques with image noise removal techniques, so that we introduce a new method for noise removal. This method fuse a number of images transmitted through different noisy channels in order to obtain a clear image.

Several techniques for noise reduction have been developed. Most of these techniques deal with one source image. In this work we will focus on fusion technique for image filtering. A previous work suggested using image fusion approach for X-ray images [CHE05]. The fusion step is based on wavelet transform, the fused images generally reveals more detail information; however, background noise often gets amplified during the fusion process.

The proposed method uses the mode (one of the central tendency statistical measures) as the main tool for removing noise, which we find that it is very suitable for this situation. The proposed method is more edge preservation than other noise removal methods, besides; its results are almost predictable.

2. Noise

Noise is any undesired information that contaminates an image. Noise appears in images from a variety of sources. The digital image acquisition process which converts optical images into a continuous electrical signal that is then sampled is the primary process by which noise appears in digital images. At any step in the process there are fluctuations caused by natural phenomena that add a random value to the exact brightness value for a given pixel [UMB98]. On the other hand, if the image is transmitted through a transmission channel, this image may be contaminated by noise during transmission process.

2.1 Type of Noise

In typical images the noise can be modeled with either a Gaussian (Normal), uniform, or salt-and-pepper (impulse) distribution. The shape of the distribution of these noise types as a function of grey levels can be modeled as a histogram and can be seen in Figure (1). In Figure (1.a) we see that the bell-shaped curve of the Gaussian noise distribution, which can be analytically described by:

$$Histogram_{Gaussian} = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(g-m)^2/2\sigma^2} \quad \text{........(1)}$$

where g = *grey level*
m = *mean (average)*
σ = *standard deviation*

Figure(1.b) shows the Uniform distribution, which can be analytically described by:

$$Histogram_{Uniform} = \begin{cases} \dfrac{1}{b-a} & \text{For a} \quad \text{g} \quad \text{b} \\ \\ 0 & \text{Otherwise} \end{cases} \qquad \ldots\ (2)$$

$$Where \qquad mean = \frac{a+b}{2}$$

$$variance = \frac{(b-a)^2}{12}$$

With the uniform distribution, the grey level values of the noise are evenly distributed across a specific range, which may be the entire range (0 to 255 for 8-bits), or a smaller portion of the entire range.

In the salt-and-pepper model there are only two possible values, *a* and *b*, and the probability of each is typically less than 0.1 - with a number greater than this the noise will dominate the image. For an 8-bit image, the typical value for pepper noise is 0 and for salt-noise, 255.

The Gaussian model is most often used to model natural noise processes, such as those occurring from electronic noise in the image acquisition system. The salt-and-pepper type noise is typically caused by malfunctioning pixel elements in the camera sensors, faulty memory locations, or timing errors in the digitization process. Uniform noise is useful because it can be used to generate any other type of noise distribution. Visually, the Gaussian and uniform noisy images appear similar, but the image with added salt-and-pepper is very distinctive.

2.2 Noise Removal Basic Technique

All image acquisition processes are subjected to noise of some type, so there is little point in ignoring it; the ideal situation (no noise) never occurs in practice. Noise cannot be predicted accurately because of its random nature, and cannot even be measured accurately from a noisy image, since the contribution to the grey levels of the noise can't be distinguished from the pixel data. However, noise can sometimes be characterized by its effect on the image, and is usually expressed as a probability distribution with a specific mean and standard deviation [PAR97].

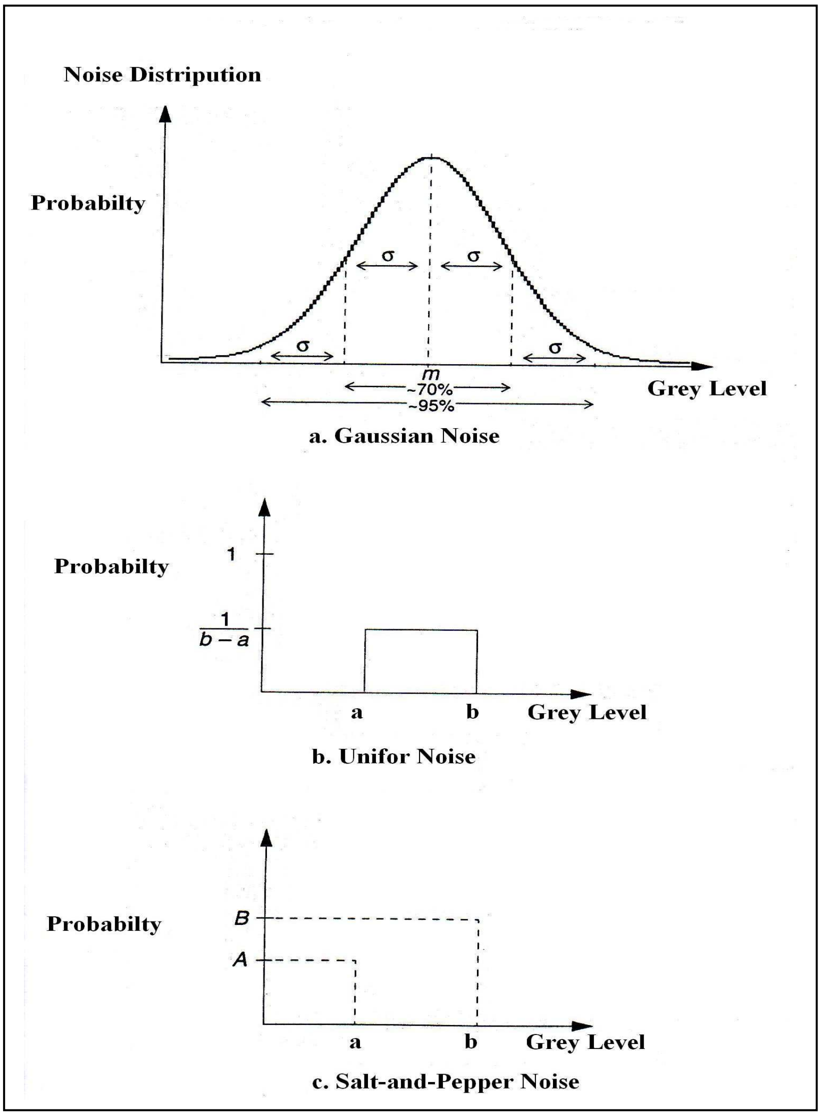


Figure (1) Noise distribution

2.2.1 Linear Filtering

Convolution can be used to carry out linear filtering of an image. It's known as liner filtering because it uses the convolution to perform a linear weighted sum. The nature of the filter is determined by our choice of kernel coefficients.

The ***mean filter*** is a low pass linear filter which is most commonly used in spatial domain. When all the coefficients of a mask are equal, we can multiply these type of masks by $\frac{1}{N}$ where N is the sum of the mask coefficients, as example, if the entire mask coefficients are equal to 1, then by multiplying it by $\frac{1}{9}$, now, the coefficient sums to one, so convolution with them will not result in an overall brightening of the image.

On the other hand, convolution with these kernels is equivalent to computing the mean gray levels over the neighborhood defined by the kernel, for this reason, these kernels are called mean filter . The mean filter works best with Gaussian or uniform noise, this filter blurs an image edge or details while mitigating the noise effects [EFF00], [UMB98].

2.2.2 Non-Linear Filtering (or, Order Statistical Filters)

Convolution is not the only way of carrying out spatial filtering. Non-Linear techniques also exit. A number of these are known collectively as "order statistic filter "or "Rank filters ". Typically, these filters operate on small sub images, windows, and replace the center pixel value (similar to the convolution process). Order statistics is a technique that arranges the neighborhood of a given pixel in sequential order , based on grey level value (from smallest to largest grey- level value) and this ordering is used to select a value at particular position, to use it as a new value for the center pixel.

The order statistic filters have the advantage of not being kernel-based. Also, they work very well with salt-and-pepper noise. The order filters are non-linear, so their results are sometimes unpredictable [UMB98].

The most useful of the order filters is the ***median filters***, in which we place the grey levels from the neighborhood in a list, and sort the list into ascending order, that forces the noisy values to migrate to the end of the list and therefore do not affect the selection of a new pixel value, then we select the middle pixel value from the ordered set as our output value [UMB98] [EFF00]. The median filter is particularly good at removing certain types of noise, which is the impulse noise. Median filter is one of the better edge preservation smoothing filters [NIB 86].

The main disadvantage of the median filter is that it is not specific, any structure that occupies less than half of the filters neighborhood will tend to be eliminated [PIT00].

The midpoint noise removal filter technique takes the greater and the smaller values in a sub image (window) and replaces the center position of this window with the average of these two values.

2.4.3 Adaptive Filters: Minimum Mean Square Error Filter

Adaptive filters performance depends on the accuracy of the estimation of certain signal and noise statistics, namely the signal mean and standard deviation and the noise standard deviation. The estimation is usually local, that is, relatively small windows are used to obtain the signal and noise characteristics [PIT00].

Most adaptive filters compute local gray level statistics within the neighborhood of a pixel and base their behavior on this information. The classic example is the Minimum Mean Square Error Filter (MMSE filter), this filter computes

$$g(x,y) = f(x,y) - \frac{\sigma^2 n}{\sigma^2(x,y)}\left[f(x,y) - \bar{f}(x,y)\right] \quad \text{……. (4)}$$

where $\sigma^2 n$: is the estimate of noise variance

$\sigma^2(x,y)$: Local variance – gray level variance computed for the neighborhood centered on (x,y) (in the window under consideration).

$\bar{f}(x,y)$: Local mean – gray level mean in the neighborhood (in the window under consideration) .

The adaptive filter will work as below*:*

1. with no noise in the image. The noise variance equals zero, and the equation will return to the original unfiltered image, i.e., $g(x, y) = f(x, y)$.
2. in supposedly homogeneous regions of an image (area of fairly constant value such as background regions), noise will be the sole cause of variations in gray levels, thus $\sigma^2(x,y) = \sigma^2 n$, and the original equation is reduced to the mean filter, i.e.,

   $g(x, y) = \bar{f}(x,y)$.
3. in the vicinity of edges (heterogeneous regions) we expect $\sigma^2(x,y)$ to dominate local noise variance (the local variance is much greater than the noise variance) resulting in a small ratio of variances ($\sigma_n^2 / \sigma^2_{(x, y)} \approx 0$), thus the filter returns a value close to the unfiltered image data, i.e.

   $g(x, y)=f(x, y)$

This is desired since high local variance implies high detail (edges), and an adaptive filter tries to preserve the original image detail. Thus, the adaptive MMSE filter preserves edges, although it does not filter the noise in edge regions.

3. Image Data Fusion

Image fusion is defined as the process of combining two or more different image into a new single image retaining important feature from each image with extended information content. For example, IR and visible images may be fused as an aid to pilots landing in poor weather.

The technology of image fusion was developed with the development of technology of computer, communication, sensor and material. Originally, image fusion resolved the problem of information overlapping of images, and now, the research of image fusion include image registration, the display and analysis of fused image, reconstruction on anatomical information and functional; information [YUL04].

3.1 Image Fusion Requirements

A complete image fusion technique must satisfy a number of requirements, from which are[FIO05]:

a. the fusion process should preserve all relevant information in the fused image.
b. since the fused image may be taken at different time, the data must be smoothed and cleaned of parts that have been changed in time.
c. noise must be filtered to preserve spikes in the geometry.
d. gaps between the scans must be reduced as much as possible.

3.2 Image Fusion Types

There are two main approaches to image fusion which are [KAN07]:

a. Direct fusion: in direct fusion the pixel values from the source image are summed up to form the pixel of the composite image at that location.
b. Multi resolution fusion: multi resolution fusion uses wavelet transform for representing the source image at multi scale. There are three levels in multi resolution fusion scheme namely pixel based fusion, area based fusion, and region based fusion.

In our proposed method for image fusion we follow the direct fusion approach and we deal with the fused images using the pixel based level.

3.3 Image Fusion Applications

In recent years, there has been a growing interest in using multi sensor data fusion in order to increase the capability of the intelligent machines and systems. For this reason, multi sensor data fusion has been used in many applications, from which are:

a. Surveillance systems: the fusion of tracking and classification information in multi camera surveillance environment will result in greater robustness, accuracy and temporal extent of interpretation of activity within the monitored scene. Tracking accuracy can be greater enhanced by combining information from several cameras with overlapping views. Not only will this provide more observations, but will ensure the object remains tracked for longer intervals and provide some protection from occlusion [REM02].

b. Medical field: image data fusion can be used in medical field to improve the ability of nuclear medicine practitioners to accurately localize sites of abnormal signals by combining digital visual images with planner scintigraphic images [PUT04].

c. image watermarking : where the image fusion principles is used for problem of robust logo watermarking , in which the logo embedded in the image for copy protection or robust tagging applications [KUN04]

d. volumetric reconstruction of large outdoor areas : to build realistic 3D models that match the physical word as accurately as possible, the 3D reconstruction of very large outdoor environments is performed by combining several kinds, of data such as : ground and aerial laser range scan, tracking data, ground, aerial , and satellite images [FIO05]

4. Image Fusion for Noise Removing (The Proposed Method)

Fusion rules play an essential role in noise removal by image fusion. There are two commonly adopted classes of fusion rules, pixel _based rules and region _based rules. For pixel based fusion rules, the value of the fused pixels is determined by the corresponding pixel of the source image. Region _based fusion rules use the corresponding pixels of the source images as well as their surrounding pixels to define the fused pixel. In this work, a pixel based fusion algorithm is employed to remove the noise

The general procedure of the proposed technique for noise removal can be described as follows:

When a number of images are transmitted through a noisy channel(s), those images will be contaminated with noise. Since noise is distributed randomly, so at any specific pixel location of the source images, the corresponding pixels have a very small probability to be noise contaminated.

The fusion approach has been applied on the mean, median and midpoint filters by taking all the corresponding pixels in the different source images and applying the filter on these pixels.

A new filter has been proposed in this work that is the **Mode** filter which computes the resulted pixel by taking the corresponding pixels in the source images and consider the resulted pixels value equals to the value of higher frequently occurred pixels value. Thus when the mode of those pixels is calculated, the noisy pixels will be less frequent than the original pixels, so the mode of those pixels will be definitely the original pixels rather than the noisy pixels.

Algorithm (1) describes the operation steps of the mode noise removal filter:

Algorithm (1) : Noise removal using image fusion
Input: number (N) of source images corrupted by noise with different ration. Output : a clear image
Step1: for all source N images do Step2 : for all pixels coordinated I and j do Step 3: read the source images (image 1 to N) Step4: put the pixel (i,j) of all the source images in a vector. Step 5: calculate the frequency of each pixel value in the vector. Step6: obtain the pixel which is most frequent (that represents the mode). Step7: replace pixel (i,j) of the output image by the mode.

5. Evaluation Criteria

In this work, three evaluation criteria are used. These criteria can be used to measure the amount of error in the reconstructed (manipulated) image. The three evaluation measures are:-

1.The Root_Mean_Square_Error is computed by taking the square root of the squared error divided by the total number of pixels in the image.

$$Root\_MSE = \sqrt{\frac{1}{N^2}\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[\hat{I}(r,c)-I(r,c)\right]^2} \quad \text{……….(5)}$$

Where I(r,c)=the original image

$\hat{I}$ (r,c)= the reconstructed image

The smaller the value of the error metric, the better the reconstructed image represents the original image.

2.The SNR metrics consider the reconstructed image $\hat{I}$ (r,c) to be the signal and the error to be "noise", the root_SNR is defined as:

$$Root\_SNR = \sqrt{\frac{\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[\hat{I}(r,c)\right]^2}{\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[\hat{I}(r,c)-I(r,c)\right]^2}} \quad \text{…………….(6)}$$

With the signal to noise ratio (SNR) metrics, a larger number implies a better result.

3.The peak _SNR is defined as:

$$peak\_SNR = 10\log_{10}\frac{(L-1)^2}{\frac{1}{N^2}\sum_{r=0}^{N-1}\sum_{c=0}^{N-1}\left[\hat{I}(r,c)-I(r,c)\right]^2} \quad \text{……..(7)}$$

Where L is the number of gray levels.

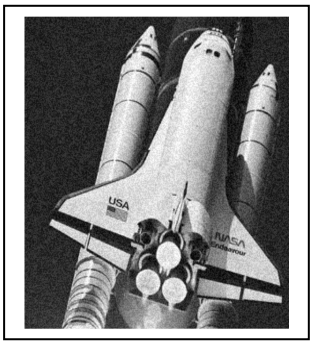
In this measure a larger number implies a better result.

6. Results and discussion

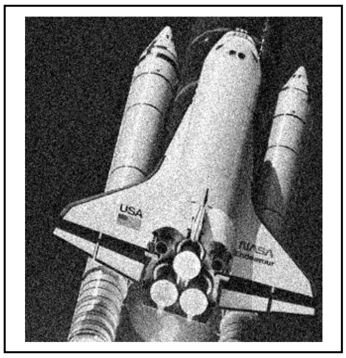
The fusion approach for image noise removing has been tested on images with different corruption ratio with the three noise types (uniform, Gaussian and impulse). The original image, the corrupted images and the resulted images after applying the noise removing are shown in the figures below.

Figure (2) shows the original image and the noisy image which contaminated with uniform noise, Gaussian noise and impulse noise respectively. The corruption ratio in all the corrupted images equals to 9%. Figures 3, 4, and 5 show the result of applying the fusion filters on the images b, c, and d in figure (1) respectively.

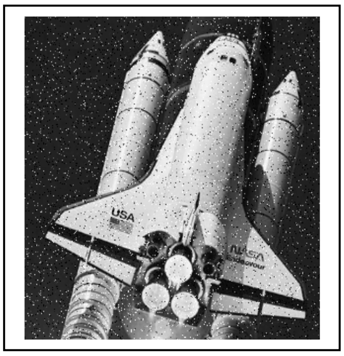
a)



b)



c)



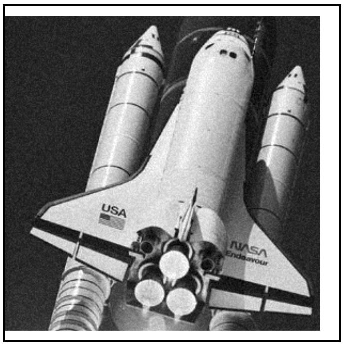
d)

Figure (2) a) the original image b) corrupted image with uniform noise c) corrupted image with Gaussian noise d) corrupted image with impulse noise

a)

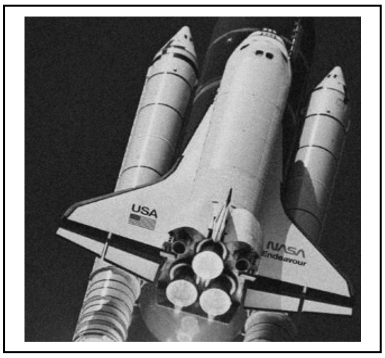
b)

c)

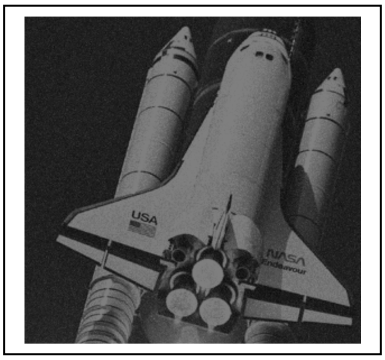


d)

Figure (3) The Result Of Applying The Fusion Approach Using a) Mean, b) Midpoint c) Median and d) Mode Filters On Image b in figure 2

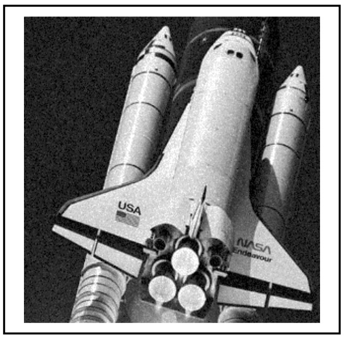


a)



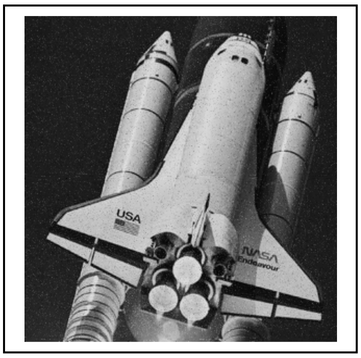
b)

c)

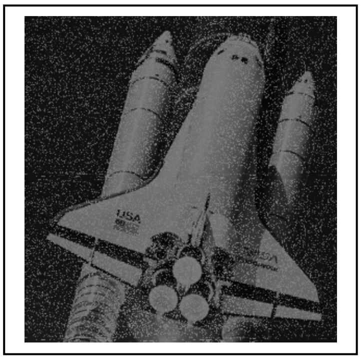


d)

Figure (4) The Result Of Applying The Fusion Approach Using a) Mean, b) Midpoint c) Median And d) Mode Filters On Image c In Figure 2



a)



b)

c)

d)

Figure (5) The Result Of Applying The Fusion Approach Using a) Mean, b) midpoint c) median and d) mode filters on image d in figure 2

The following tables show the comparison between the different methods of noise removal using the traditional filters. These filters had been applied onto the corrupted images with corruption ratio range between 5% and 10%. The average values of the evaluation criteria are as in the tables 1, 2 and 3:

Table (1) The Results Of The Evaluation Criteria After Applying The Traditional Filters For One Image Corrupted By Uniform Noise

Criteria / filter	Root_MSE	Root_SNR	Peak_SNR
Mean	16.153	7.922	23.654
Mid_point	20.722	6.138	21.801
Median	15.106	8.564	24.547

Table (2) The Results Of The Evaluation Criteria After Applying The Traditional Filters For One Image Corrupted By Gaussian Noise

Criteria / filter	Root_MSE	Root_SNR	Peak_SNR
Mean	17.274	7.365	23.382
Mid_point	22.091	5.718	21.246
Median	16.759	7.675	23.645

Table (3) The Results Of The Evaluation Criteria After Applying The Traditional Filters For One Image Corrupted By Impulse Noise (Salt And Pepper)

Criteria / filter	Root_MSE	Root_SNR	Peak_SNR
Mean	17.254	7.354	23.392
Mid_point	36.294	3.535	16.934
Median	12.787	10.049	25.995

The following tables show the comparison among the different methods of noise removal using the fusion filters. These filters had been applied to the corrupted images with corruption ratio range between 5% and 10%. The average values of the evaluation criteria are as in the tables 4, 5, 6 and 7:

Table (4) The Results of The Evaluation Criteria After Applying The Fusion Filters For Ten Images Corrupted By Uniform Noise

Criteria / filter	Root_MSE	Root_SNR	Peak_SNR
Mean	14.285	8.165	25.032
Mid_point	59.451	1.197	12.647
Median	7.267	17.9	30.902
Mode	9.676	13.422	28.416

Table (5) The Results Of The Evaluation Criteria After Applying The Fusion Filters For Ten Images Corrupted By Gaussian Noise

Criteria / filter	Root_MSE	Root_SNR	Peak_SNR
Mean	14.837	7.852	24.703
Mid_point	56.336	1.341	1.311
Median	8.043	16.178	3.002
Mode	13.238	9.752	25.693

Table (6) The Results of The Evaluation Criteria After Applying The Fusion Filters For Ten Images Corrupted By Impulse Noise (Salt And Pepper)

Criteria / filter	Root_MSE	Root_SNR	Peak_SNR
Mean	15.493	7.463	24.328
Mid_point	63.339	1.178	12.097
Median	1.295	99.395	45.879
Mode	1.749	73.671	43.274

Table (7) The Results Of The Evaluation Criteria After Applying The Fusion Filters For Ten Images Corrupted By A Mixed Of Gaussian And Uniform Noise

Criteria / filter	Root_MSE	Root_SNR	Peak_SNR
Mean	14.413	8.090	24.955
Mid_point	58.846	1.225	12.736
Median	7.091	18.343	31.115
Mode	9.415	13.781	28.653

The values in the above tables have shown that the mode and median filters in the fusion filters gave the best results and that both methods give an excellent results when applied to images contaminated by salt_and_pepper noise.

7. Conclusion

In this work an Image Fusion approach have been applied for image noise removal problem. Three traditional filters are exploited to use the fusion approach. These filters are Median, Mean and Midpoint. Also a new filter is proposed which is named **Mode** filter. This filter found to be the most suitable for image fusion noise removal approach. The four filters have been applied for images that are corrupted with the three noise types (Uniform, Gaussian and Impulse) with different corruption ratio.

The image fusion filters are compared with the traditional method and the results show that the image fusion approach is better in noise removing problem than the traditional filters according to the three evaluations criteria (Root_MSE, Root_SNR and Peak_SNR).

From the experiment results we concluded that median and the mode filters are better than the other filters when they applied to fused noisy images.

Results also show that the proposed method (the **Mode** filter) and median filter are better than the other filters when applied to a number of images corrupted by a mixed noise types (e. g. Gaussian and uniform).

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