A survey on Digital Image De-Noising Filters

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*Abstract:*Digital image processing is basically the use of computer algorithms to perform image processing on digital images. The main drawback in digital images is inheritance of noise while their acquisition or transmission. Removal of noise from the original signal is still a bottleneck for researchers. In digital image processing, de-noising is one of the important tasks. The main purpose of De-noising the image is to restore the detail of original image as much as possible. The criteria of the noise removal problem depends on the noise type by which the image is corrupting. This paper presents a review of some recent significant work in the field of Image De-noising. The briefintroduction of some popular approaches is provided and discussed.

*Keyword:*Digital image, Noise, Salt and Pepper Noise, Gaussian Noise, Filters.

INTRODUCTION

An digital image may be well-defined such as a two-dimensional function F(a, b).Where a and b are spatial (plane) coordinate, and the amplitude of F at any pair of coordinates (a, b) is called the intensity or gray level of the image at that point. When a, b and the amplitude values of are all predetermined discrete quantity, we will call the image as digital image. A digital image is collection of a finite number of elements, in which each element has a certain value and location. These elements of digital image are known as image elements, picture elements, pels, and pixels. They are arranged in a grid format with each pixel containing information about its color or intensity.Digital images play an important role both in daily life applications such as satellite television, magnetic resonance imaging, computer tomography as well as in areas of research and technology

The area of digital image processing refers to dealing with digital images by means of a digital computer.It involves the modification of digital data for improving the image qualities with the aid of computer. The processing helps in maximize the clarity, sharpness of image and details of features of interest towards extraction of information & further analysis.Image restoration is the process of elimination or decrease of degradations that are incurred while the images are being obtained. Poor quality of the image is the result of blurring as well as noise due to electronic and photometric sources. Blurring is the disturbance made in the image byreduction in bandwidth due to relative motion between the original picture and the camera.

TYPES OF DIGITAL IMAGES:

*Binary Image:*A binary image is a digital image that has only two possible values for each pixel. Binary images are also called bi-level or two-level. This means that each pixel is stored as a single bit—i.e., a 0 or 1. The namesblack-and-white,B&W, monochrome or monochromatic are often used.
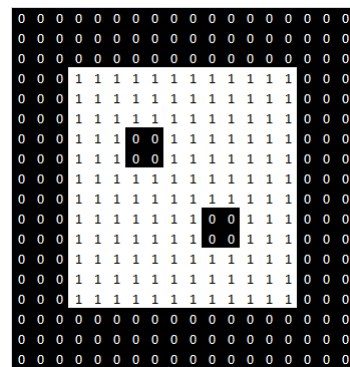

Fig 1: Binary Image

*Grayscale Image:*In grayscale image each pixel is shade of gray, which have value normally 0 [black] to 255 [white]. This means that each pixel in this image can be shown by eight bits that is exactly of one byte. Other grayscale ranges can be used, but usually they are also power of 2.

Fig 2: Grayscale Image

*RBG Image:*It is also referred to as a "True Color" image. The RGB color model is an additive color model in which red, green, and blue light are added together in various ways to reproduce a broad array ofcolors. RGB is a device-dependent color model. The main purpose of the RGB color model is for the sensing, representation, and display of images in electronic systems
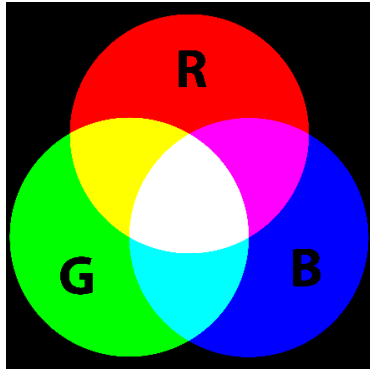
Fig 3: RGB Image

NOISE MODELS

Noiseispresent inimageeither inadditive or multiplicativeform.

AdditiveNoiseModel: Noisesignal thatisadditive innaturegetsaddedtothe originalsignal to producea corruptednoisysignal andfollowsthefollowingmodel:

$w(x,y) = s(x,y) + n(x,y)$

MultiplicativeNoiseModel: In thismodel, noisesignalgetsmultiplied to theoriginalsignal.Themultiplicative noisemodelfollows the followingrule:

$w(x,y) = s(x,y) \times n(x,y)$

where,$s(x,y)$istheoriginalimageintensityand$n(x,y)$ denotesthenoiseintroducedtoproducethecorrupted signal $w(x,y)$at(x,y)pixellocation.

TYPES OF NOISE:

*Salt and Pepper Noise:*Salt and Pepper is a form of bipolar noise. It is also known as Shot noise, Impulse noise, Spike noise, Data-Drop-Out noise.An image that contains impulsive noise will have dark pixels in bright regions and bright pixels in dark regions.It is digitized as extreme (pure white or black) values or saturated values. For an 8-bit image this means typically that a=0 (black) and b=255 (white).Different filters used to remove this noise are Minimum Filter, Maximum Filter, Mean Filter and Median Filter. Salt and pepper noise occurs in images under situations where quick transients, such as faulty switching take place. This type of noise can be caused by malfunctioning of analog-to-digital converter in cameras, bit errors in transmission, etc.

Fig 4: Salt and Pepper Noise

*Gaussian Noise:*Gaussian noise is statistical in nature.The standard model of Gaussian, noise is additive, independent at each pixel and independent of the signal intensity. Its probability density function equal to that of normal distribution, which is otherwise called as Gaussian distribution. Each pixel in noisy image is the sum of true pixel value and a random Gaussian distributed noise value. It is a major part of the read noise of an image sensor that is of the constant level of noise in the dark areas of the image. It arises in an image due to factors such as electronic circuit noise and sensor noise due to poor illumination and high temperature.

Fig 5: Gaussian Noise

*Speckle Noise:*Speckle noise is multiplicative noise. It is a single dependent form of noise whose magnitude is related to the value of the original pixel. Speckle noise is a type of granular noise that commonly exists in and causes degradation in the image quality. Speckle noise tends to damage the image being acquired from the active radar as well as synthetic aperture radar (SAR) images. Due to random fluctuations in the return signal from an object in conventional radar that is not big as single image-processing element Speckle noise occurs.

Fig 6: Speckle Noise

FILTERS FOR SALT AND PEPPER NOISE:

Robust 2-State Filter: Robust 2-State Filter [1] removes salt and pepper noise in grey scale image in two steps. In first step, the center pixel is identified and checked whether it is effected by noise or not. In second step, the surrounding pixels are identified and checked for noise in the selected window. The minimum, maximum and median values in the selected window are computed. If the center pixel is identified as noisy, then it is replaced with the mean value else left unchanged. If the processing pixel is corrupted pixel, then there are two possible cases: whether all pixels of window are extreme values (0 or 255) or not. In first case, pixel value is replaced with the mean of the elements of window. In second case, the value is replaced by the median value of the remaining pixels.This filter shows stable and consistent performance for low to high noise density. It removes 90% variance noise effectively and preservers edge and image details.

Kriging Interpolation Filter: This filtering technique [2] is based on Kriging Interpolation. Kriging is a statistical technique to estimate unknown valuesat specific point in space by using data values from known locations. Kriging filter is superior for Gaussian Noise [8]. Thus, here it is applied to deal with salt-pepper noise problem in grey scale images. A sequential search is done by using k*k window size to determine non-noising pixels only. This approach is different as in the earlier researches the noisy pixels are detected and their values are replaced with a suitable value. The noisy pixels are represented as absent. The non-noisy pixels are processed through Kriging Interpolation and the value of each absent (noise) pixel is computed.
This filter shows higher PSNR (Peak Signal to Noise Ratio) and lesser MSE (Mean Square Error) value as compared to other techniques. It suppresses high density noise (upto 90%) efficiently without loss of edges and detailed information.

Robust Statistics Based Filter: This filter [3] is based on the Robust Statistics. It overcomes various difficulties of classical and other recent techniques. Like linear filtering techniques work under the assumption of wide-sense stationary signal and noise which isn't true for natural images. Non-Linear filtering techniques fail to remove impulse noise in higher frequency region such as edges.In this technique, initially the noisy pixels are identified as impulse noise effects only some pixels in the image. The minimum, maximum and median values are computed from the selected window. If the pixel value is within the min-max value range, then it is retained, else it is required to replace. Another pixel value is selected from the window within the min-max value range and it is further processed using Robust Influence Function and estimating equations. This filter suppresses the impulse noise from low to medium density and preserve fine details satisfactory. It requires less computational time.

Decision Based Technique: This filter [4] is a Decision based technique. It utilizes previously processed neighboring pixel values to get better image quality instead of using only previously pixel value. In this a sliding window is used and its minimum, maximum and median values are computed. In this, initially pixels are identified as corrupted and uncorrupted by checking the pixel value against the min-max value of the window selected. Then the value of uncorrupted is replaced by median pixel value or mean of the neighborhood processed pixel (if median itself is noisy).This filter is also applied on color image (RGB color space). It is simply applied to R-, G- and B-plane individually and then combined to form the restored color image.
It requires less computational time as compared to Adaptive Median filter and other techniques. It gives better PSNR and Structural Similarity (SSIM) index values compared to AMF and other techniques.

FILTERS FOR GAUSSIAN NOISE:

Probor Filter: Probor Filter [5] is based on Fuzzy Technique and basically perform averaging operation. It is divided into two sub-filter. The first sub-filter classifies the pixels which requires correction using 2D distance with color couple. In this large weights are assigned to neighborhood pixels having similar color as the center and small weights to different to colors. Then distances are calculated using Euclidean formula. After that activation of degree in calculated by difference between sum and product of weights. This rule is commonly known as the 'Probor rule'.
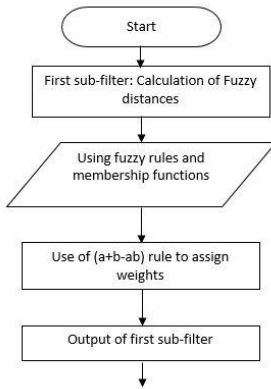
Fig 7: Flow chart of first sub-filter

The second sub-filter performs correction function by calculating mean of differences. It reduces noise without destruction of fine details of image and noise suppression.
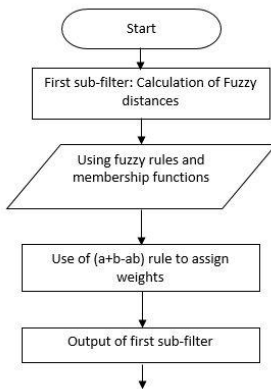

Fig 8: Flow chart of second sub-filter

This results a better mean square error value. This filter can be used as a preprocessing step for edge detection of Gaussian corrupted digital images.

Fuzzy Tri-State Filter: Fuzzy Tri-State filter [5] is a non-linear filter. This filter first determine whether pixel is corrupted or not, before applying filtering technique by using fuzzy logic. This is performed by Asymmetrical triangular Median (ATMED) filter, Asymmetrical Triangular Moving Average (ATMAV) filter and Median filter. If the pixel is corrupted, its value is replaced by the output of other filters based on a threshold. The decision about noised pixel is done by Gaussian detector. It results the best possible visual output as compare to others. It preserves image details and effectively suppresses the Gaussian noise.
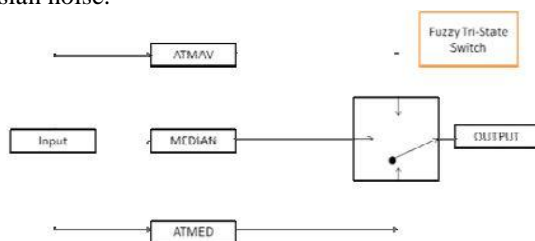

Fig 9: Block Diagram of FTS filter

Gaussian Noise Removal using Enhanced Fuzzy Classifier (GNREFC): Gaussian Noise Removal using Enhanced Fuzzy Classifier [6]is a new De-noising techniques in which a new filter is developed to remove Gaussian noise in gray and color image. It is based on Trapezoid membership function. The trapezoid membership function and a simple derivative model are introduced to minimize the PSNR, noise level and finally to maximize the accuracy.

In the initial process, gray tone image f is denoted as f = $\{(i_{x,y}, \beta_{x,y}(i,j)\}$ where (x,y) are dimensions, $i_{x,y}$ is the intensity value of gray scale image and $\beta_{x,y}$ is the membership function of color image which is calculated by an equation

$$\beta(x,y) = e^{[\mu(x+i,\ y+j)\ -\ \mu(x,y)]}$$

where i,j denotes the edge value and $\mu(x,y)$ denotes membership function at point (x,y).

The Gaussian noise removal using fuzzy derivative is denoted as

$$\Delta(x,y) = f(x,y+1) - f(x,y)$$

For positive value, this is classified as 'presence of noise' and for negative value as 'absence of noise'.

This function results as higher PSNR and less error ration as compared to other techniques. This filter outperforms the entropy filter, range filter and standard filter in terms of PSNR and MSE.

Simple and Fast Non-Linear Technique: This is a simple and fast non-linear technique to remove Gaussian noise in digital image. It operates in two stages: first stage estimate amount of noise corruption from the corrupted image and second stage removes the identified noisy pixels. In this techniques [7], the absolute difference between center pixel and surrounding pixels is computed. The difference is directly proportion to the level of noise in image and compared with threshold. The threshold can be defined as the product of smoothing factor and noise standard deviation. The smoothing factor is chosen as two for optimal performance and noise standard deviation is estimated using Immerkaer's fast method [9]. The pixels having absolute differences value within threshold are considered and the value of center pixel is replaced with mean value of those pixels. The above method is repeated for the whole image.

De-noising Performance: This filter shows good performance, less blurring and edge preservation for low as well as high noise variance as compared to standard mean filter, k mean filter and other filters.

Computation Time: It takes less computation time as compared to standard filters and recently proposed trilateral filter to restore the original image.

Color image De-noising: This filter is also applied on color image (RGB color space). It is simply applied to R-, G- and B- plane individually and then combined to form the

restored color image. The resultant restored image shows this filter smoothen the noise with better edge preservation. Due to less complexity and computational time, it can also be implement in hardware.

Standard Deviation based Filter: This technique [12] is based on Standard Deviationfiltering method. Here a 5x5 window is considered for detection scheme. This 5x5 window is divided into nine 3x3 sub-windows in which the test pixel appears.The standard deviations of all sub-windows are calculated in which the test pixel appears and is providing relative information about the amount of the noise, if present, of the test pixel. The maximum standard deviation and minimum standard deviation are calculated using constants k_1 and k_2. The reasonable values are obtained as 0.5 and 2 respectively. It is concluded that the pixel is corrupted if the difference magnitude, $|\mu-x|$ lies in the range [a, b] where μ is mean of 3x3 neighborhood of the test pixel in which test pixel lies at the center of the window and x is test pixel intensity.

Its performance is excellent and far superior to standard mean filter. There is improvement in PSNR for different variances and means.

CONCLUSION:

In this paper, some recent developed Image De-noising filtering techniques are discussed based on Impulse (Salt and Pepper) noise and Gaussian noise. The decision to apply which particular filter is based on the type of noise and noise level.In Gaussian noise, Tri-State Filter can be used as a pre-processing step for detecting edges of a Gaussian corrupted images as it preserves edges well.Simple and Fast Non-Linear Technique can also be implement in hardware. In Impulse noise, Kriging Interpolation Filter and Robust Filter can handle high density noise efficiently without loss of edges and detailed information whereas Robust Statistics Based Filter doesn't handle high density noise. Kriging Interpolation Filter suppresses noise (up to 90%) efficiently without loss of edges and detailed information.

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