Application of Different Filtering Techniques in Digital Image Processing

Sumant Sekhar Mohanty¹, Sushreeta Tripathy²*

¹Department of CSE, ²Department of CA, ITER, Siksha ‘O’ Anusandhan (DU), BBSR, India
*sushreetatripathy@soa.ac.in

Abstract. Noise in an image is a random variation of brightness or color information in the original image. Noise is consistently presented in digital images during picture obtaining, coding, transmission, and processing steps. Image noise is most apparent in image regions with a low signal level. There are various reasons for the creation of noise in an image, such as electronic noise in amplifiers or detectors, disturbances and overheating of the sensor, disturbances in the medium of traveling for a digital image, etc. Noise is exceptionally hard to eliminate from the digital pictures without the earlier information of the noise model. There are various types of noise that can be available in a noise model. Filters are used to remove these types of noises in a digital image in image processing. In this research, we have implemented different filtering techniques that have been used to remove the noises in an image.

1. Introduction

Digital image is the conversion of real image into a sequence of numbers that can be only understood by a computer. Digital images are very effective in the modern world for helping, recording and analyzing the documents, historic, scientific and personal evidence. Typically, the image is caught by the sensors and transmitted through the mediums. These sorts of pictures are useful and favourable for the very reasons of transmissions. Images and its data are widely applied in various fields like clinical, military observation, wrongdoing control and remote detection etc [1-3]. In this way, the genuine data of the source is fundamental for post activities. Noise in an image is an irregular change of splendour or shading data in the source image. It is the corruption of picture signals brought because of electronic and photometric sources. Recovery of corrupted images and getting the accurate result is very much in need for the success of activity. The digital image regularly includes picture enhancement and image restoration. Both are techniques of withdrawal of noises that are induced in the original source by using appropriate filtering and mathematical interpretation. The reason for this study was to know the sort of noise model present in a picture and to get the best-fitted separating techniques accessible for that noise [4].

The roadmap of this manuscript is well ordered: section 2 includes literature review and pre-study for this paper. Section 3 includes the definition of digital image and its various acquiring and transmission technology. Section 4 represents reasons for noise occurrences and its various effects. Various noise models and filtering techniques have been discussed in section 5. Discussion of various
filtering methods on noise models is mentioned in section 6. At last, the paper is being concluded in section 7.

2. Literature review

Addition of any error value during image acquisition and transmission process results in noisy data in digital image. The error value on the image fully depends on types of disturbances in the digitized image. It can be electronically generated, sensor disturbances, dispersion factor across the medium of transmission or physically created error values [5]. Different works have just been done previously on expulsion of noise from images. Utilizing various sorts of filters to expel noise and along these it helps in the picture improvement. At that point in picture pre-processing, the noise evacuation can build the effectiveness of the planned model. During the transmission, process pictures are corrupted by noise, a satisfactory noise decrease technique gives better determination by safeguarding indispensable attributes of an image.

In 1992, Rudin and Osher proposed the absolute variety minimization strategy which is another regularization filtering algorithm to channel through noise from homogenous locales however not its edges. For a given noisy picture \( v(x) \), creators proposed to recuperate unique picture \( u(x) \) as arrangement of an obliged minimization thought with the end goal that, all out variety of picture is limited, thus producing a consistent piecewise arrangement, but it is not widely applicable [6]. Different filters give divergent statistical values for dissimilar images. So, application of right denoising technique will be very much effective as well as conducive for the use of the informational values. In 2013 Sharavana Raju, Mohammad Shahawaz Nasir, T. Meera Devi have showed the statistical benefits of using right filtering technique in Synthetic Aperture Radar (SAR) images by comparing SNR, PSNR and RMSE values [7]. Various types of noise models and filtering techniques with their proper classification had been thoroughly mentioned by Abdalla Mohamed Hambal, Dr. Zhijun Pei, Faustini Libent Ishabalu in the year of 2017. In this paper they obtained a median filtering technique that ensures both noise free and less degradation of image quality as well [8].

In 2020, Mrs S.Tripathy and T.Swarnkar proposed median filter is a reasonable methodology while contrasted with different techniques, since picture quality of median filter is better. A near examination is complete by execution of filters dependent simulated output parameters PSNR and MSE. In 2020, S.Tripathy and T.Swarnkar proposed a mean filter inadequate to clear the excessive amount of impulse noise. It performs well overall anyway it fumbles when the likelihood of impulse noise and non-impulse noise occurrence turns out to be high. [9, 10].

3. Digital imaging and its transmission technology

The digital picture represents the 2-D function \( f(r, c) \), where \( (r, c) \) coordinates in two-dimensional space and \( f \) is the intensity of that coordinate. Acquisition alludes to the modes of digital image generation, which are overall and conventionally known as “modalities”. Generally utilized modalities for clinical imaging are radiography, mammography, ultrasound, and MRI. Commonly used modalities for military imaging are Parallel Simulated Annealing (PSA), photogrammetric and other advanced technologies [11]. Likewise, different acquiring methods are used for different problematic surroundings. There are different methods for transmission accessible for a picture. These are carefully followed how a piece of image information will respond in a specific medium. Picture transmission is a methodology for encoding, sending, and unravelling digitized information in such a way the main features of the image, for instance, outlines, might be shown first at low goals and hence refined to higher and higher resolution. Progressive image transmission permits an estimated picture to be developed rapidly and the details to be transmitted progressively through several passes over the image. This strategy shows up helpful for picture communication over slow channels. Raster transmission procedures, an advanced picture are communicated as a gathering of lines, or lines, of the picture lattice, line by line start to finish [12]. In like manner, various procedures are accessible according to its medium, source and receiver type and speed of the transmission.
4. **Reasons for image noise and its effects**

In a digital image, noise is the distortion of the original image by the interfaces of unwanted signals. It is utilized to demolish most of the piece of the image information. Image distortion is generally pleasant in image processing. These noises might be originating from noises sources present in the region of picture catching gadgets, faulty memory location or might be acquainted due with defect/incorrectness in the picture catching gadgets like cameras, skewed focal points, weak focal length, dispersing and other unfriendly conditions might be available in the environment. Digital noise may emerge from different sorts of sources, for example, charge coupled device (CCD) and complementary metal oxide semiconductor (CMOS) sensors which are present in picture acquisition devices. Noise in an image degrades the quality of the image and its details. Lesser details mean lesser information from the data [13]. This means we couldn’t use this data for our study and specific work doesn’t fulfil our very reason for acquisition and transmission of the image. From a reference CTP study performed at 80 keV and 190 mAs by K. Juluru, J.C. Shih and their team, this re-enactment study shows the capability of a 33% decrease in tube current and dose while keeping up picture standard and quantitative interpretations. So, maintaining image noise free could be beneficial for data interpretation as well as fewer resource uses [14].

5. **Noise Model and Filtering Technique**

Noise produces undesirable impacts, for instance, artifacts, unrealistic edges, inconspicuous lines, corners, obscured objects and disturbs background scenes. To decrease these undesirable effects, prior learning of noise models is fundamental for further preparation of image data [15-18].

5.1. **Gaussian noise (GN)**

Gaussian noise is a statistical noise having Gaussian distribution. It commonly arises in amplifiers or detectors as electronic noise. White gaussian noise(WGN) is an exceptional instance of GN. WGN is spatially correlated, that noise of each pixel is independent and identically distributed. The standard model of GN is additive, subordinate at each pixel and subject to the signal intensity, caused fundamentally by Johnson–Nyquist noise (which is otherwise called thermal noise, including what begins from the reset noise of capacitors ("kTC commotion")). [6, 7] So it’s basically coming from the electronic sensors.

5.2. **Noise of salt and pepper**

It is otherwise called “spike and incautious noise”. This noise is often caused by a sharp and sudden disturbance within the image signal. Scattered light and dark disturbances have occurred within the image. Pixels within the image area unit totally different to their encompassing pixels in color and intensity.

5.3. **Speckle noise**

Pulse generator picture standard is mostly reduced due to speckle noise. Speckle noise is a typical marvel in all intelligent imaging frameworks like a laser, acoustic and SAR symbolism. The source of this sort of commotion is caused because of arbitrary obstruction between the coherent returns given from such huge numbers of disperses present on an earth surface, on the size of a wavelength of the incident radar wave [6, 7].

5.4. **Poisson noise**

Poisson noise also called photon noise. It is happening due to some statistical variation in the assessment. The uncertainty associated with this type of noise is the measurement of light and independent of photons [8]. The expected magnitude of the signal is signal dependent and independent of low light conditions.
Reducing noise from the digital image is a test for the specialists in the preprocessing phase. There are different filtering methods that are accessible for various sorts of noise reductions. Broadly these filters are classified into three types of Linear, Adaptive & Non-linear.

5.5. **Linear filters**

This filtering method brings the estimation of every pixel into closer concordance with the estimations of its neighbors. Linear filters are not beneficial because in general they have sharp edges, obliterate lines and other fine picture characteristics, and perform ineffectively within the sight of signal dependent noise. It is regularly utilized as the reason for nonlinear noise reduction filters [19, 20]. Mean and Gaussian filters are some of its examples.

5.6. **Adaptive filters**

It is more explicit than a linear filter, saving edges and other high-frequencies, normally different in brightness, parts of an image. If the fluctuation is huge, this performs small smoothing. If it is small, this performs more smoothing. This methodology consistently delivers better outcomes over linear filtering [21, 22]. Wiener filter is an example of this type of filtering methodology.

5.7. **Non-linear filters**

Non-linear is easy to utilize the methodology for smoothing images. This filter is utilized for diminishing the measure of intensity variety between two pixels. Median Filter is one of its examples. It is determined by first arranging all pixel values into increasing order and afterwards supplant the pixel being determined with the centre pixel values. If the neighbouring pixel of the picture which is to be considered contains n even number of pixels, then the mean of the two centre pixel values is utilized to restore [23].

6. **Result and discussion**

PSNR is utilized to measure the nature of recreation of lossy and lossless compression and addition of different kind unwanted noise values. When looking at compression codecs, PSNR is an estimate of human impression of reconstruction quality. A higher PSNR for the most part shows that the reformation is of higher standard, now and again it may not [22- 24]. For concealing pictures with three RGB esteems for every pixel, the importance of PSNR is the comparable beside the MSE is the absolute over totally squared worth differentiations isolated by picture size and by three. Here we have mainly focused on four filtering techniques (Mean filter, Gaussian filter, Wiener filter, Median filter) of four noise models i.e., salt & pepper, gaussian, speckle and poisson. The PSNR described below:

\[
PSNR = 10 \log_{10} \left( \frac{1}{MSE} \right) \text{dB}.
\]  

(1)

| Noise models            | Filters                                |
|-------------------------|----------------------------------------|
| Noise of salt and pepper| Mean, median, gaussian and morphological filters |
| Gaussian Noise          | Mean(append), median and gaussian filters |
| Speckle Noise           | Mean(append), median filter            |
| Poisson Noise           | Spatial domain and transform domain filters |

Table 1. Noise models and best suited filters
Table 2. MSE values of denoised images

| Noise types     | Mean filters | Gaussian filter | Wiener filter | Median filter |
|-----------------|--------------|-----------------|---------------|--------------|
| Gaussian        | 333.770      | 117.419         | 64.705        | 73.064       |
| Salt and pepper | 365.441      | 157.503         | 174.739       | 97.342       |
| Speckle         | 388.518      | 202.369         | 389.855       | 203.655      |
| Poisson         | 332.717      | 123.799         | 75.137        | 80.655       |

Graphical representation of Table 2 data has been shown on Figure 1.

In Table 2 the row sections define four noise models (Gaussian, Salt & Pepper, Speckle and Poisson) where columns define filtering techniques (Mean, Gaussian, Wiener and Median). MSE values are defined by comparing the original source image with the denoised image (after removing the noise by applying filtering techniques). It is concluded from the above table that MSE values of Gaussian, Salt & Pepper, Speckle and poisson noise models are lowest in Wiener, Median, Gaussian and Wiener filters respectively.

Figure 1. Shows MSE values of denoised image in a graph.

Table 3. PSNR values of denoised images

| Noise types     | Mean filters | Gaussian filter | Wiener filter | Median filter |
|-----------------|--------------|-----------------|---------------|--------------|
| Gaussian        | 22.896       | 27.433          | 30.021        | 29.493       |
| Salt and pepper | 22.502       | 26.157          | 25.706        | 28.247       |
| Speckle         | 22.236       | 25.069          | 22.221        | 25.041       |
| Poisson         | 22.910       | 27.203          | 29.372        | 29.064       |

Graphical representation of Table 3 data has been shown on Figure 2.

In Table 3 the row sections define four noise models (Gaussian, Salt and Pepper, Speckle and Poisson) where columns define filtering techniques (Mean, Gaussian, Wiener and Median). PSNR values are defined by comparing the original source image with the denoised image (after removing 


the noise by applying filtering techniques). It is concluded from the above table that PSNR values of Gaussian, Salt & Pepper, Speckle and poisson noise models are highest in Wiener, Median, Gaussian and Wiener filters, respectively.

![Figure 2. Shows PSNR values of denoised image in a graph.](image)

From the above two tables and comparing MSE and PSNR values it is concluded that Wiener, Median, Gaussian and Wiener filters are best suited for Gaussian, Salt & Pepper, Speckle and Poisson noise models, respectively.

7. **Conclusion**

Delusion and noises influence digital images collection, it influences the entire picture taking care of and very purpose for the accumulation. Disposal of noises on the preprocessing stage is another requesting position. Removing noises from the given type of noisy image is particularly challenging. So, every type of noise model is denoised by a certain type of filter. As discussed here we have focused on the common four types of noise models i.e., salt & pepper, Gaussian, speckle and poisson. Also applying four types of filters i.e., mean, gaussian, weiner and median filter on each type of noise model. By calculating MSE and PSNR we have found out which type or types of filter are best suited for the certain noise model. The Gaussian noise model is best suited with a Wiener filter for denoising. Likewise, median filter is for salt & pepper, gaussian and median filters for speckle noise model, wiener filter for poisson model.

**References**

[1] Tripathy S and Swarnkar T 2021 *Intelligent and Cloud Computing* Springer, Singapore p 819.
[2] Tripathy S, Hota, S and Satapathy P 2013 *Int. Conf. on Emerging Research in Computing, Information, Communication and Application*, 1-6.
[3] Tripathy S and Hota S 2012 *Int. Conf. on Computing and Control Engineering* 40
[4] Tripathy S and Singh R 2021 3rd *Int. Conf. On Sustainable computing (SUSCOM-2021)*
[5] Ahmad K, Khan J and Iqbal U D 2019 8th *Int. Conf. on Modeling Simulation and Applied Optimization (ICMSAO)* IEEE pp 1-6
[6] Rudin L I, Osher S and Fatemi E 1992 *Physica D: nonlinear phenomena* 60 259
[7] Raju K S, Nasir M S and Devi T M 2013 *IOSR Journal of Computer Engineering (IOSR-JCE)* 15 10.
[8] Hambal A M, Pei Z and Ishabailu F L 2017 *Int. Journal of Science and Research (IJSR)* 6 2033
[9] Tripathy S and Swarnkar T 2020 *In Advanced Computing and Intelligent Engineering* Springer, Singapore p 455
[10] Tripathy S and Swarnkar T 2019 *Int. Journal of Recent technology and Engineering* 8 7376
[11] Alsafi E and Zaghloul S S 2017 *Int. Journal of New Computer Architectures and Their Applications* 7 77-89
[12] Tripathy S 2014 *Int. Journal of Emerging Technologies in Computational and Applied Sciences* 146
[13] Kumar V and Gupta P 2012 *International Journal of Emerging Technology and Advanced Engineering* 2 56
[14] Tripathy S and Swarnkar T 2020 *Int. Journal of Advance science and Technology* 29 p 4214
[15] Shinde B, Mhaske D, Patare M, Dani A R and Dani A R 2012 *Int. Journal of Engineering Research and Applications* 2 1071
[16] Tripathy S 2019 *Int. Journal of Innovative Technology and Exploring Engineering* 8 2278.
[17] Dutta S, Pal S K, Mukhopadhyay S and Sen R 2013 *Journal of Manufacturing Science and Technolo*, 6 212
[18] Baldoni J, Lionello G, Zama F and Cristofolini L 2016 *Journal of Strain Analysis for Engineering Design* 51 416
[19] Frost V S, Stiles J A, Shanmugan K S and Holtzman J C 1982 *IEEE Transactions on pattern analysis and machine intelligence* 2 157.
[20] Garcia J, Ramírez A H and Prieto D V 2005 *Int. Journal for Light and Electron Optics* 116 44
[21] Makandar A and Halalli B 2015 *Int. Journal of Computer Applications* 109 12
[22] Tripathy S and Swarnkar T 2020 *Procedia Computer Science* 167 285
[23] Tripathy S and Swarnkar T 2020 *Journal of Discrete Mathematical Sciences and Cryptography* 23(1) 167
[24] Kong L, Chen L and Wang M 2021 *In Journal of Physics: Conference Series* 1813 012034