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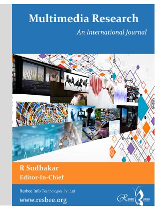

To Improve the Insect Pests Images- A Comparative Analysis of Image Denoising Methods

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Abstract: Pest, Plant disease, climate change, and disaster are the major factor to determine the yeild of the plant. Pest inthe plants are identified in different methods. To process the images with machine vision models' the quality of images isan important concern. Noise and unwanted artifacts integrated with the images at the time of acquisition and transmission. Noise is introduced in the images due to transmission, environment distortion, and sensor qualities. In this regard, some solutions related to the post-image-acquisition are required to enhance such issues. In this, image denoiser plays an important role to enhance the quality and minimize the noises in images. However, to preserve details of images a comparative analysis of related image denoising algorithms is conducted. In this study, the authors cover three types of filters to minimize the noise of insect pests' images to find better ones. The experiment of the comparative study revealed that the Total Variation (TV) algorithm gives better results as compared to another denoising algorithm at different noise levels.

Keywords: Denoising Filters;Gaussian filter; Image Processing;Mean filter;Total Variation;Weiner filter;

Nomenclature

Abbreviation	Expansion
PSNR	PeakSignalNoiseRatio
MSE	Mean Squared Error
TV	Total Variation
ISS	Improved Spectral Subtraction

1. Introduction

Image processing for daily routine life such as medical imaging, television, agricultural imaging as well as in research plays a vital role[1][2].In agricultural utilizations, Image-processing is used in farm scanning for the identification of pests and diseases in crops[3]. In this, the image acquisition phase is related to the collection of data from the different resources. At the time of data acquisition, interference, and imperfect imaging sensors can degrade the quality of images[4]. Other than these, the transmission and compression of images are also responsible for introducing noise in images. It affects the overall performance of image processing models[5].

Removing the noise in images is an important step and necessary for image analysis. It is a challenging task for the researcher, to remove the noise from the images without blurring and without loss of interesting information[6]. There are different denoising algorithms proposed by the researcher in recent times. In color images, the authors[7] proposed a total variation-based method for image denoising algorithm for image restoration. The algorithm shows an alternating minimization method for image restoration. The experimental results with the proposed method showed efficient results as compared to the other algorithms. In autonomous positioning, noise is a problem that leads to low precision in multi-source by the sensor. To deal with spectrum features a two-stage noise elimination model based on ISS with a Wiener filter was proposed by the authors[8]. The experimental outcome revealed that the proposed model was effective in the denoising process. The introduction of noises in the images is a big obstacle in image processing. The noise appearing in images during the transmission process or the image acquisition is due to low lighting conditions. In a study[9], the authors considered famous de-

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noising methods related to the spatial and transform domain for image reconstruction. They evaluated the mean, weiner, median, and adaptive filter from the spatial domain. And, ICA, wavelet transform, and spatial frequency from transform domain. However, each denoising algorithm hasits specifications to work on a specific kind of noise model. The effectiveness of the denoising algorithm in agricultural pests' images isunavailable and not covered by any researcher. It motivates the researchers to perform a comparative study on the different most relevant denoising algorithms to find the better one for insect pests' image denoising.

This paper aims to perform a systematic comparison between different denoising algorithms that gives important insights into choosing an appropriate algorithm used to find the most appropriate estimation from the degraded image[10]. The output of the denoising algorithms depends on the noise model. In this experiment, the authors used salt & pepper to evaluate the performance of selected algorithms. The study revealed results after the experimentation on different denoising algorithms. The scope of this study is related to the removal of noise from agricultural pest images.

The contribution of this study is:

- To describe different image denoising algorithms.
- To analyze different image-denoising algorithms with experimental purposes.
- To find the best algorithm after the experiment.

The organization of the study is as follows, Section 2describes the noise model, Section 3defines different image denoising algorithms used for the experiment, Section 4is related to the result and discussion, and the last section reflects the conclusion of this study.

2. Noise Model

Noise is the unwanted information attached to the images during the image acquisition and transmission. It is typically defined as the unwanted random variation in the original image pixel. These variations might be related to additive or multiplicative presence. In the additive noise model, extra information is added with the values of the original pixels to produce a noisy image. The mathematical form of the additive noise model is as follows in Equation 1.

$$y(a,b)= x(a,b) + n(a,b) \tag{1}$$

In Equation 1, x(a,b) is denoted the image intensity, n(a,b) is denoted the noise ratio, and y(a,b) is the noisy signal.

Salt and pepper noise[11] is the most popular noise type. It is generally caused by software failure, defects of camera sensors, or hardware failure during the image acquisition. In this model, the sparse occurrence of white and black pixels is seen on images. In this approach, only some pixels of the image arecorrupted. It sets the value of the pixel as either minimum (pepper) or maximum (salt). Generally, it set 0 for minimum and 255 for maximum. Furthermore, the other pixel values remain unchanged illustrated by Equation 2.

$$n(a,b) = \begin{cases} 0, pepper \\ 255, salt \end{cases} \tag{2}$$

3. Image Denoising Algorithms

There are many algorithms used for the minimization of noise. A good quality denoising algorithm can retrieve a good estimated image from a noisy image[12] are shown in Fig.1.

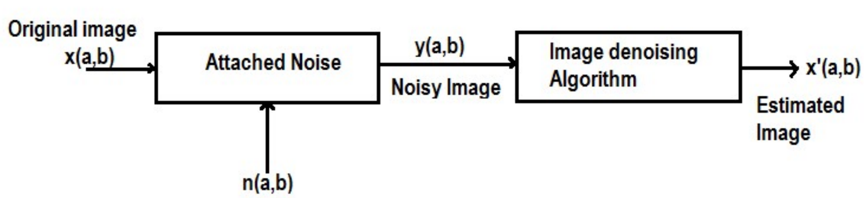

Fig. 1. *Denoising Procedure*

Here x(a,b) is the original input image, n(a,b) is the noise factor and y(a,b) is the noisy image. The denoising algorithms operate on a noisy image and give an estimated image x'(a,b) as output(denoised image).

3.1 Weiner Filter

It was invented by Norbert Weiner in 1940. It used both statistical characteristics of noise and degradation function in the denoising process. The target of the wiener filter is to minimize the error ratio. It is also possible to reconstruct an image with the help of inverse filtering, but this procedure is extremely responsive to additive noise. In this, the weiner filter helps to minimize the additive noise ratio and deals with blurring simultaneously[13]. The performance of the weiner filter is based on three factors they are (i) assumption (ii) requirement, and (iii) performance criteria. It used a linear equation to calculate pixel values that helped to reduce the noise ratio. The Wiener filter is a simple and fast approach. It uses linear equations to calculate the optimal weight values that help to minimize the noise ratio of a noisy image. It estimates covariance metrics and cross-correlation to calculate these optimal weights and helps to provide a good estimation of undistorted pixels. Furthermore, it requires only a few computational steps that make it faster [14]. Weiner filter for image denoising in Fourier domain demonstrated by Equation 3.

$$W(a,b) = \frac{h*(a,b)P_s(a,b)}{|h(a,b)|^2 P_s(a,b) + P_n(a,b)} \quad (3)$$

Where h(a,b) is the degradation function, h*(a,b) is a complex conjugate function, Pn(a,b) is the power spectrum of the noisy signal, and Ps(a,b) is the power spectrum of the original image.

It uses static estimation of local neighbor pixels to remove the noise ratio. The performance of the filter depends on noise variance. If the variance is big, it gives less smoothing and in the case of small variance, it gives high smoothing [15].

3.2 Mean Filter

It is used for image smoothing. It helps to reduce the variation of intensity between the neighborhood pixels. It is based on the idea of a spatial sliding window that changes the middle value of the filter window with a mean value of all neighbor pixels including itself[16][17]. With this technique, the unrepresentative pixel is replaced with the surrounding pixels' values. It is a common form of the linear filter also called the average mask. It works on the idea of shift multipliedbysum shown below in Equation 4.

$$x'(a,b) = \frac{1}{mn}\sum x(a,b) \quad (4)$$

In the above equation m and n(Dimension of the matrix), x(The input matrix), x' (Estimated matrix).

Example: Mean values = $\begin{bmatrix} 70 & 20 & 50 \\ 67 & 240 & 52 \\ 68 & 62 & 60 \end{bmatrix}$ X $\begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix}$

Here the mean filter is applied to the noisy matrix it returns an average matrix.

3.3 Total Variation Regularization

To solve the issue of over-smoothness in image denoising algorithms and preserve the texture information TV regularization is proposed by the researchers[18][19]. In any natural image, the intensity of pixels varies region-wise and is locally smooth. For this, TV used statistical facts of images to perform denoising. The mathematical formation of TV is as follows in Equation 5.

$$TV(x) = ||\nabla x||_1' \quad (5)$$

Here ∇x denoted the gradient of x.

It is the best algorithm that effectively preserves the edges but also gives optimal results. But the algorithm has some drawbacks such as the stair casing effect, over-smoothed textures, etc., [21]

3.4 Gaussian Filter

Gaussian filter for image denoising is a smoothening filter that performs convolution operation on 2D images and produces blur effects to remove the noises[20][21]. It is more likely as a mean filter, but it uses different kernel values depending on the point spreading function. The equation of the Gaussian filter is shown in Equation 6.

$$G(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}} \quad (6)$$

The formation of the Gaussian kernel depends on σ.

4. Experiment Setup

Experiments on selected algorithms are evaluated on pest images. The authors used Python programming in the Google Colab platform to access the filter's output. To perform denoising, the authors used images, OpenCV, NumPy, and Matplotlib Python libraries. In recent studies, there is no common dataset used to evaluate image-denoising algorithms. Most of the studies used Lena, camera, etc, images. In this direction,[23] used 68 images to measure the performance of different denoising algorithms. To evaluate the performance of selected denoising models, we experiment on 3 different insect pests' images of size 512 x 512 such as tobacco caterpillars, thrips, and whiteflies. In our experiment, we use the parameters as follows: 5x5 patch for denoising filters, noise ratio is in the range of [0.10,0.20,0.30,0.50].

The target of the denoising algorithm is to handle all images degraded by salt and pepper noise. The noise ratio affects the performance of the algorithm. For this, to perform a fair comparison, different noise ratios were used by the authors. After experimenting, the PSNR method is used to assess the performance of selected denoising algorithms as follows in Equation 7[24].

$$\mathrm{PSNR} = 10\log_{10}\left(\frac{R^2}{\mathrm{MSE}}\right) \quad (7)$$

In this, x(a,b) original image and x'(a,b) is the estimated image, R is the fluctuations of the original image data types. M x N is the dimension of the image. With the help of all these parameters,MSEis calculated as follows in Equation8.

$$\mathrm{MSE} = \frac{\sum_{M\times N}[x.(a,b)-x'(a,b)]^2}{MXN} \quad (8)$$

5. Result&Discussion

Generally, an image has 0 to 255 grey-level values. Here 0 is related to the black and 255 is related to the white colour. We use PSNR which provides quantitative results of selected methods. The visual comparison of different reconstructed images with a noise ratio of 0.50 is shown in Figures [2-4]. In this experiment, Table 1 shows the results of different selected algorithms. We observe that the average filter gives satisfactory results for all noise ratios. It results in a superior low noise level. For a higher noise ratio, TV gives better results than other algorithms. This method gives the highest PSNR for Thrips and Whitefly.

Table 1. *PSNR comparison of different algorithm*

Image	Noise Ratio	Noisy Image(dB)	Mean (dB)	Weiner(dB)	TV(dB)
Tobacco Caterpillar	0.10	15.26	**24.71**	22.06	23.32
	0.20	12.24	**22.19**	20.20	22.01
	0.30	10.48	20.21	18.82	20.58
	0.50	08.24	17.11	16.48	17.80
Thrips	0.10	14.94	**26.98**	21.85	25.95
	0.20	11.93	22.44	20.06	23.20
	0.30	10.64	19.69	18.43	20.67
	0.50	07.94	16.20	15.76	16.96
Whitefly	0.10	14.84	**25.89**	21.60	25.29
	0.20	11.84	22.06	19.68	22.56
	0.30	10.06	19.44	18.13	20.13
	0.50	07.84	15.85	15.43	16.49

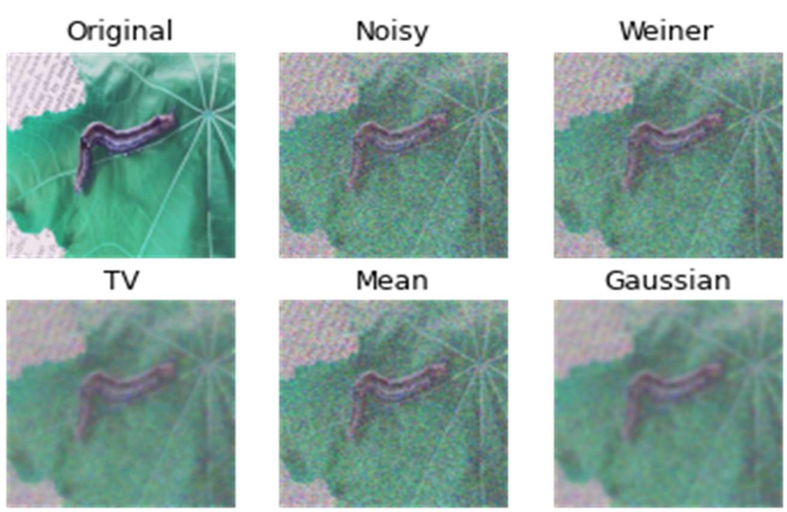

Fig. 2. *Reconstructed Image of Tobacco Caterpillar for noise ratio=0.50*

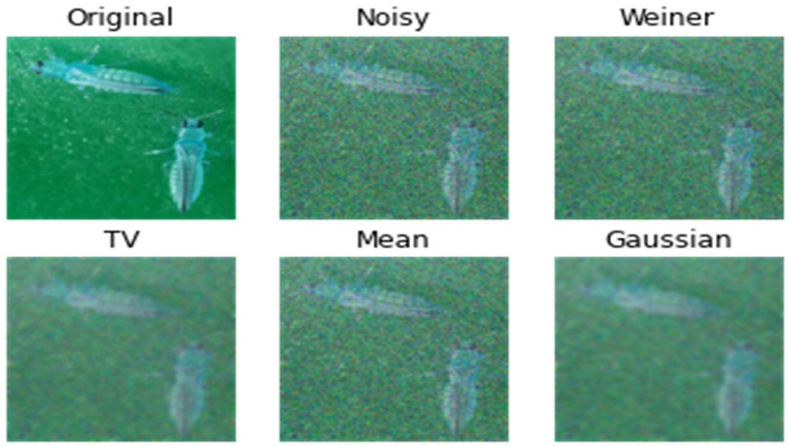

Fig. 3.*Reconstructed Image of Thrips for Noise ratio=0.50*

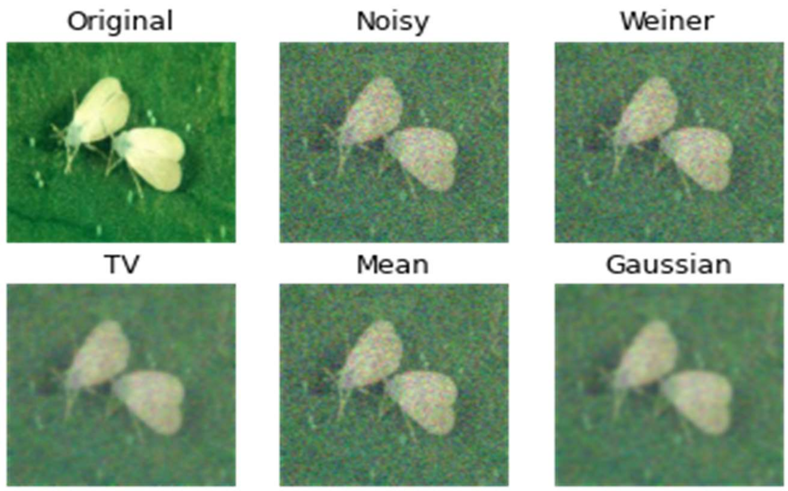

Fig. 4.*Reconstructed Image of Whitefly for noise ratio=0.50.*

The visual inspection demonstrated that the denoising process was achieved by different algorithms. The visual inspection revealed that the image produced by the Weiner filter is pretty similar toa noisy image and the image produced by the Gaussian filter showed over-smoothening. Fig. 3 of the thrips image showed that the region of interest or pest object after the noise introduction was very hard to locate. The sub-image produced by TV and the Gaussian filter in Fig. 3 showed that the Gaussian filter completely blurs the image and also destroys edges or useful features, on the other hand TV method produced slightly better images with less blur effect and also managed edge information.

In Table 1, the experiment was conducted on different insect pests images such as tobacco caterpillars, Thrips, and whitefliesat different noise levels. The results in Table 1 on the image Tabacco caterpillar showed that at noise ratios of 0.10, 0.20, and 0.50 the results produced by the mean filter are better than the other algorithms. The denoising algorithm on the thrips image showed that TV achieved the highest performance when the noise ratio was 0.20,0.30, and 0.50. The same results achieved by TV for whitefly images demonstrated the highest PSNR at a noise ratio of 0.20 and 0.30.

6. Conclusion

In the field environment, Noises are random and deterministic in agricultural imaging. It is very difficult to remove noise properly in the images. The selection of the best algorithm for agricultural image denoising is also a hectic task. This study presented a survey on image-denoising approaches. It is an important pre-processing step for digital image processing. This survey demonstrated different types of denoising models to reconstruct the insect pest images that are corrupted with salt and pepper noise. The experimental opinion under the PSNR scheme shows the efficient denoising filter. The experiment on different discussed algorithms revealed that total variation is one of the better denoising approaches after the comparison of other selected algorithms. The experiment also revealed that the Mean filter for the noise reduction approach also achieved comparatively better performance as compared to the

Gaussian and average filter.Froma future perspective, our target is to enhance the current version of Total variation algorithms.To develop a better classification accuracy device with less computational time with better insect recognition.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

References

[1] K. Andrey, P. Maxim, M. Nikolay, and A. Khvostikov, "How to choose adaptively parameters of image denoising methods?," 2019 Ninth International Conference on Image Processing Theory, Tools and Applications (IPTA), Istanbul, Turkey, 2019, pp. 1-6.

[2] Ismail, D. Budiman, E. Asri, and Z. R. Aidha, "The Smart Agriculture based on Reconstructed Thermal Image," 2022 2nd International Conference on Intelligent Technologies (CONIT), Hubli, India, 2022, pp. 1-6.

[3] X. Liu, Q. Zhang, R. Luan, and F. Yu, "Applications of perceptual hash algorithm in agriculture images", 2013 6th International Congress on Image and Signal Processing (CISP), Hangzhou, China, 2013, pp. 698-702.

[4] Nitin, Gupta SB.,"A Hybrid Image Denoising Method Based on Discrete Wavelet Transformation with Pre-Gaussian Filtering", Indian Journal of Science and Technology, Vol.15, no. 43, pp. 2317-2324, 2022.

[5] Nitin, Gupta SB, Yadav R, Bovand F, and Tyagi PK.,"Developing precision agriculture using data augmentation framework for automatic identification of castor insect pests", Front, Plant Sci. vol. 14 pp. 1101943, 2023.

[6] G. Pattnaik and K. Parvathi, "Performance Evaluation of Pest Detection Techniques via Image Processing in Agriculture", 2018 International Conference on Applied Electromagnetics, Signal Processing and Communication (AESPC), Bhubaneswar, India, 2018, pp. 1-5.

[7] Y. W. Wen, M. K. Ng, and Y. M. Huang, "Efficient Total Variation Minimization Methods for Color Image Restoration", in IEEE Transactions on Image Processing, vol. 17, no. 11, pp. 2081-2088, Nov. 2008.

[8] Mingduo Li, Jinhua Wang, Liwen Guo, Qinggang Meng, Mengqian Li, Jinliang Hou, "A novel fusion denoising algorithm of spectral subtraction and Wiener filtering for MEMS magnetic signal in PDR positioning", Alexandria Engineering Journal, Volume 75, 2023, Pages 139-150.

[9] Hussein, Taha & Omar, Hoger & Jihad, Kamal.,"A study on image noise and various image denoising techniques",Vol. 11. pp. 27-42, 2021.

[10] Kostadin Dabov, Alessandro Foi, Vladimir Katkovnik, and Karen Egiazarian, "Image denoising with block-matching and 3D filtering", Image Processing: Algorithms and Systems, SPIE,Electronic Imaging,Vol.6064,2006.

[11] P. Luo, X. Zhang, Z. Chang, and W. Liu, "Research on Salt and Pepper Noise Removal Method Based on Adaptive Fuzzy Median Filter", 2021 IEEE 5th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), 2021, pp. 387-392.

[12] Govindaraj V., Sengottaiyan G.," Survey of Image Denoising using Different Filters", International Journal of Science, Engineering and Technology Research (IJSETR)Volume 2, Issue 2, 2013.

[13] Jaspreet K., Rajneet K., "Biomedical Images denoising using Symlet Wavelet with Wiener filter", International Journal of Engineering Research and Applications,Vol.3,Issue 3, 2013.

[14] Anilet B., Chiranjeeb H. and Punith C.,"Image Denoising Method Using curvelet Transform and Wiener Filter", International Journal of Advanced Research in Electrical Electronics and Instrumentation Engineering ,Vol. 3, Issue 1, 2014.

[15] Sarungbam B. and Yambem J., "Denoising of Image by Wiener Filtering in Wavelet Domain", Advanced Research in Electrical and Electronic Engineering, Volume 2, Issue 11, 2015.

[16] Windyga, S. P.,"Fast Impulsive Noise Removal, IEEE transactions on image processing", Vol. 10, No. 1, pp.173-178, 2001.

[17] S. S. Vallepalli and M. M. Rajendran, "Image De-noising using mean pixel algorithms corrupted with photocopier noise," 2012 19th International Conference on Systems, Signals and Image Processing (IWSSIP), Vienna, Austria, 2012, pp. 530-535.

[18] Rudin LI, Osher S, Fatemi E.,"Nonlinear total variation based noise removal algorithms", In: Paper presented at the eleventh annual international conference of the center for nonlinear studies on experimental mathematics: computational issues in nonlinear science, Elsevier North-Holland, Inc, New York, pp. 259–268, 1992.

[19] L. Deng, Q. Fang, H. Zhu, and G. Zhou, "Image denoising based on spatially adaptive high order total variation model", 2016 9th International Congress on Image and Signal Processing, BioMedical Engineering and Informatics (CISP-BMEI), Datong, China, 2016, pp. 212-216. doi: 10.1109/CISP-BMEI.2016.7852710.

[20] Shreyamsha Kumar, B.K.,"Image denoising based on Gaussian/bilateral filter and its method noise thresholding", SIViP 7, pp. 1159–1172, 2013.

[21] M. Wang, S. Zheng, X. Li, and X. Qin, "A new image denoising method based on Gaussian filter", 2014 International Conference on Information Science, Electronics and Electrical Engineering, Sapporo, Japan, 2014, pp. 163-167.

[22] Chambolle A, Pock T.,"A first-order primal-dual algorithm for convex problems with applications to imaging", J Math Imaging Vis, vol. 40 no. 1, pp. 120–145, 2011.

[23] S. Roth and M. J. Black.,"Fields of experts: A framework for learning image priors", In IEEE Conference on Computer Vision and Pattern Recognition, 2005.

[24] K. Lakshmi and R. Nanamran, "Development of Wavelet Packet Transform based Image Fusion Technique with Improved PSNR on Medical Images for Simultaneous Evaluation in Comparison with Wavelet Transform based Image Fusion Technique", 2022 14th International Conference on Mathematics, Actuarial Science, Computer Science and Statistics (MACS), Karachi, Pakistan, 2022, pp. 1-5.