Image Restoration: Review, Application and Future scope

[1]Darshna Dalvadi

[1]Research Scholar
[1]Computer Science,
[1]C. U. Shah University , Wadhawan, India

Abstract : Image restoration has huge impact on getting back the original image which is damaged due to multiple reasons. There are several image processing techniques available for image restoration. This paper aims to review latest image restoration techniques. Various application areas of image restoration has been explored such as medical images, forensic science, social media, astronomical images, satellite images and the list may go on. This study has been undertaken to investigate the determinants of image restoration using various approaches. Through newly optimized procedures, there is hope to develop new methodology that raises the peak signal to noise ratio (PSNR) value of the recovered image, resulting in more accurate and efficient results.

***IndexTerms* – Image Restoration, filter, machine learning, deep learning, fuzzy**

I. INTRODUCTION

Digital images are electronic snapshots of a scene that are made up of image components in an extremely grid structure called pixels; each pixel has a price that is assigned to it. A quintal that represents the tone at a specific purpose are available with capacities ranging from ordinary shooting to Urology, remote sensing, microscopy, health imaging, and so on [1]. Image restoration is the process of restoring a deteriorated image. The contamination manifests itself in a variety of ways, including motion blur, low resolution, and noise. Image noise is defined as differences in color and brightness in an image when compared to an ideal image of the real scene. Image noise is caused by atmospheric disturbances. Visually, noise adds dirty grains of varying intensities to the photograph, which in some circumstances substantially reduces visual enjoyment and image details [2].

The method of image acquisition frequently results in inadvertent image degradation due to motion blur, insufficient lighting, mechanical difficulties, out of focus, and so on. In the actual world, image blur is most common while photographing moving objects. Image noise is caused by atmospheric conditions such as fog, rain, and snow. Image noise is nothing more than an unwanted signal generated in an image by the sensors of a capturing equipment. There are numerous approaches for removing blur or noise from digital photographs. Denoising and Deblurring are terms used to describe processes for removing blur or noise from digital images. Image restoration is concerned with removing or decreasing such undesirable artefacts from an image. A digital image is a visual element, also known as a pixel. The image's coordinates with the X and Y axes can be used to describe it. The picture degradation system shown below can be used to illustrate image degradation. A deteriorated function is nothing more than a low pass filter.

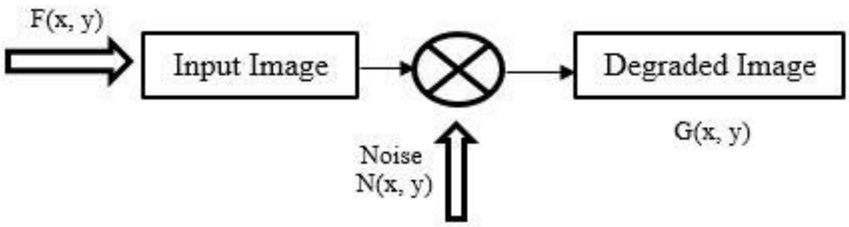


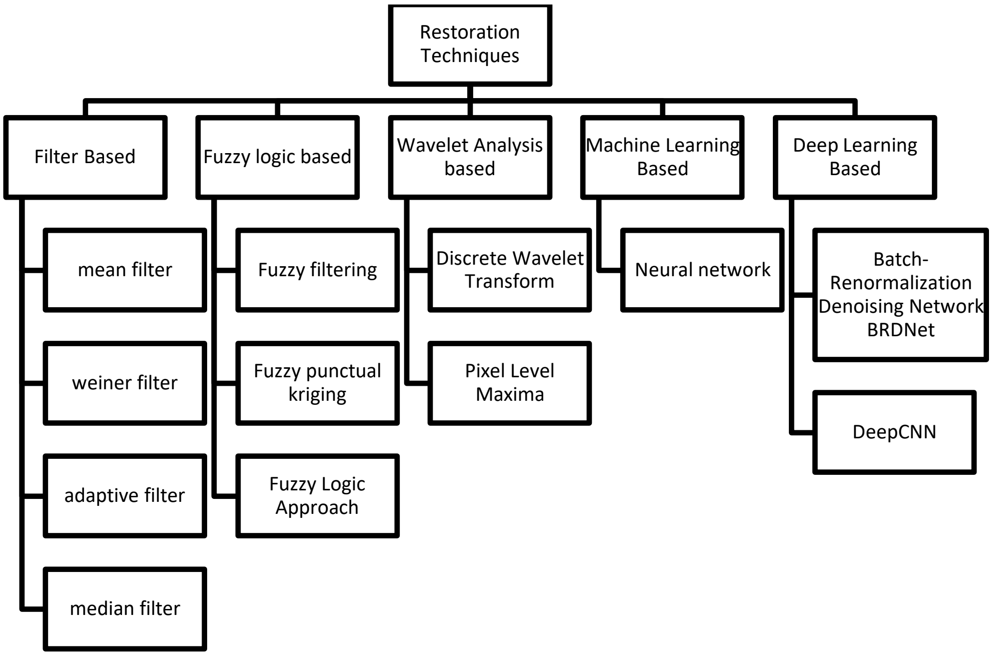
Fig.1 Image degradation model

The initial image could be two-dimensional (2D), as represented by image function f. (x, y). The picture input is treated as system h(x, y) by injecting noise n(x, y), allowing for the generation of the final image with degradation g(x, y). A digital image that has been restored can be expressed as a method for estimating an approximation to f. (x, y). The deteriorated image is represented by the equation below.

$$G(x,y)=H(x,y)*F(x,y)+N(x,y) \qquad (1)$$

II. Literature Review

This section represent various image restoration techniques. The main novelty of paper lies in this section as this paper categorize image restoration in various categories. Various categories are defined as per their restoration methods as shown in below chart.



2.1 Filter Based Restoration Techniques

Restoration Filters are the different types of filters that are used to operate on noisy images and estimate the clean and original image. It could include blurring methods or reverse blurring processes. The filter used in the restoration process differs from the filter used in the enhancing step.

2.1.1 Mean Filter

Filters based on arithmetic mean

This type of filter is also known as a linear filter since it aligns all of the image element morals across the window and aids in levelling the differences and blurring the contrasts in the image.

Geometric mean filters are similar to mean value filters in that they lose fewer visual features when processing the image.

Harmonic mean filter

This sort of filter is used in situations where the information values are high, but it cannot de-noise pepper noise and is superior to Gaussian noise and salt noise.

Filter with a contra harmonic mean

This type of filter is used in this case to remove salt and pepper noise, however it cannot remove both noises at the same time. If largely incorrect values are chosen, it behaves like a dragon. This filter eliminates pepper noise and, for a negative cost, salt noise [1].

2.1.2 Weiner Filter

For images damaged by additive noise and blurring, the Wiener filter is the MSE-optimal stationary linear filter. The Wiener filter must be calculated on the assumption that the signal and noise processes are second-order stationary in the random process sense. Wiener filters are most commonly used in the frequency domain. Given a degraded image x(n,m), the Discrete Fourier Transform (DFT) is used to calculate X. (u,v). The original picture spectrum is approximated by multiplying X(u,v) by the Wiener filter G(u,v):

$$S(u,v)=G(u,v)X(u,v)$$

2.1.3 Adaptive filter

An adaptive filter is a system that includes a linear filter with a transfer function that is controlled by variable parameters and the ability to alter those parameters using an optimization technique. Almost all adaptive filters are digital filters due to the complexity of the optimization techniques. Some applications necessitate the use of adaptive filters because some parameters of the desired processing operation (for example, the positions of reflective surfaces in a reverberant space) are unknown or changeable. The closed loop adaptive filter refines its transfer function using feedback in the form of an error signal.

In general, the closed loop adaptive process entails using a cost function, which is a criterion for optimum filter performance, to feed an algorithm, which calculates how to adjust the filter transfer function to minimize the cost on the following iteration. The mean square of the error signal is the most commonly used cost function.

Adaptive filters have grown considerably more prevalent as the capacity of digital signal processors has improved, and are now commonly employed in devices such as mobile phones and other communication devices, camcorders and digital cameras, and medical monitoring equipment.

2.1.4 Median Filter

The median filter is a type of non-linear digital filtering technique that is commonly used to reduce noise from a picture or signal. This type of noise reduction is a common pre-processing step used to improve the results of subsequent processing (for example, edge detection on an image). Median filtering is commonly employed in digital image processing because it preserves edges while reducing noise under specific conditions.

2.2 Fuzzy Logic based image restoration techniques

Fuzzy logic is a computing method based on "degrees of truth" rather than the traditional "true or false" (1 or 0) Boolean logic on which modern computers are based. Image restoration is the process where degraded image is improved. Fuzzy logic is used to check here the level of correctness in the image rather than checking degree of truth.

2.2.1 Fuzzy Filtering based approach

Paper [5] provides a modified way to filtering Salt & Pepper Noise for grayscale photos using Fuzzy logic with an auxiliary BDND algorithm and FSM filtering. The primary goal of this technique is to provide an effective approach for distinguishing undesired noise pixels from picture edge pixels in order to restore details and textures in grayscale images. The method is divided into two phases: one detects corrupted pixels in the image using a modified boundary discriminative noise detection approach along with IF-Then rules to locate salt and pepper noise with higher precession, and the other is a noise cancellation step that uses a fuzzy switching median filter to remove noisy pixels discovered during the noise detection phase. Extensive simulation on grayscale pictures demonstrates that the proposed filter beats numerous current filters.

2.2.2 Fuzzy Punctual Kriging based approach

The paper [6] describes an intelligent picture restoration approach that combines the geo-statistical interpolation technique of punctual kriging, fuzzy logic, and type-II and fuzzy smoothing-based approaches. Images degraded by Gaussian white noise are recovered by first using fuzzy logic to identify which pixels require kriging. A fuzzy type II inference system is used. A type II fuzzy set was utilized to create a fuzzy map for detecting noisy pixels. This fuzzy map of noisy pixels improves the suggested technique's performance in terms of image restoration as well as computing cost. To estimate the noisy data, local neighborhood information is used to assure noise-free pixels in a 3 3 window. The punctual kriging approach is then applied to estimate the intensity of a noisy pixel. A performance-based evaluation of image restoration approaches was performed against the adaptive Weiner filter and existing fuzzy kriging approaches. Experiment results with 450 photos and various image quality measures show that the suggested approach with fuzzy type II is successful for detecting noisy pixels and utilizing local information in conjunction with kriging-based estimate.

2.2.3 Fuzzy logic approach

Paper [7] demonstrates that while fuzzy logic is a simple method for noise removal, it contains a fatal flaw. It cannot display the provided image using any mathematical model. It is convincing to define a membership function to match the need, but it is accompanied by the uncertainty of whether it will be useful or not when the input image changes. It is not a good method if we have to alter the membership function repeatedly. By trial and error, it takes time to set the membership function for each image. In every publication, the fusion approach outperforms the others. (Every approach has a PSNR of at least 33.) It mixes many images to pick the best one.

However, a crucial and inescapable question is that it takes far too long than other approaches. It imposed a constraint on implementing it on a real-time system. To speed up, it may need to employ greater hardware. "Selective Multi-Source Total Variation Image Restoration" emoted in the same way. As experiment equipment, it employs a 3.4GHz I7 CPU and 32 GB RAM. It cannot match our requirement for a real-time system, such as a mobile robot. On the other hand, we can see that non-local methods have the same issue. Non-Local approaches are also effective. Despite not having the same performance, its PSNR is close to 30. However, it will take some time to complete all processes. As a result, some methods attempt to accelerate it.

2.3 Wavelet Analysis based image restoration techniques

Although Wiener filtering is the best compromise between inverse filtering and noise smoothing, it actually amplifies the noise when the blurring filter is solitary. This implies that removing the amplified noise will necessitate a denoising step. A natural technique for this purpose is Donoho's wavelet-based denoising scheme, a successful approach introduced lately. As a result, the image restoration process is divided into two steps: Image denoising using Fourier-domain inverse filtering and wavelet-domain denoising.

2.3.1 Discrete Wavelet Transform

The paper[8] covers selected mathematical approaches for digital signal and image processing based on wavelet transform and signal decomposition, with applications in system identification, analysis, and modelling. The majority of the work is devoted to signal de-noising using hard and soft thresholding, as well as the recovery of degraded signals and images. As an alternative to probabilistic models, the wavelet transform approach was utilized here to restore distorted image portions. The proposed approaches give the outcomes of iterated wavelet transform interpolation of missing signal and picture components for simulated signals as well as biomedical magnetic resonance images. The resulting methods are strongly related to signal segmentation, change point detection, and prediction, with applications in process control, computer vision, signal or image processing, and artificial intelligence.

2.3.2 Pixel Level Maxima

With the growing need for higher image quality, a plethora of image processing algorithms are being developed. Paper [9] revealed a method for removing motion blur from images captured by any camera. Motion blur is caused by the relative motion of the camera and the scene during the exposure time of the image, which includes both camera and scene object motion. Image restoration attempts to reconstruct or estimate an uncorrupted image from a degraded version of the same image. Blind deconvolution and Wiener filter approaches, which use regularized iteration to repair the deteriorated image, are the most closely related study. This paper proposes combining the Wiener filter with picture fusion to reduce computational complexity while producing more acceptable image restoration outcomes. The performance of each stage is tabulated for characteristics such as SNR and RMSE of restored images.

2.4 Machine Learning Based image restoration techniques

Image Processing algorithms are used in many Computer Vision systems. A face enhancement software, for example, may utilize computer vision algorithms to detect faces in a photograph and then apply Image Processing techniques such as smoothing or grayscale filters on it. Many modern image processing approaches use Machine Learning Models, such as Deep Neural Networks, to modify images for a range of objectives, such as applying creative filters, tweaking an image for optimal quality, or improving certain image details to maximize quality for computer vision tasks.

2.4.1 Neural network based approach

Paper [10] offers a multi-scale picture restoration strategy based on neural networks. Multilayer perceptrons are trained with simulated images of degraded grey level circles in order to teach the neural network about the intrinsic space relations of the damaged pixels. The current method simulates degradation by blurring the pixels with a low pass Gaussian filter and adding noise at predetermined rates. For the supervised learning process, the training procedure uses the deteriorated picture as input and the non-degraded image as output. As a result, the neural network conducts an inverse operation, retrieving a nearly non-degraded image in terms of least squared. The primary difference between this strategy and others is that the space relations are taken from multiple scales, supplying relational space data to the neural network. The approach is an attempt to devise a simple procedure that leads to the best possible solution to the problem. The multi-scale operation is simulated by considering several window sizes surrounding a pixel. During the generalization phase, the neural network is exposed to indoor, outdoor, and satellite degraded photos using the identical techniques that were used for the artificial circle image.

2.5 Deep Learning based image restoration techniques

Image restoration and recognition are critical computer vision problems that are inherent in autonomous systems. These two processes are frequently carried out in a sequential order, with the restoration procedure being followed by the recognition. This research, on the other hand, provides a collaborative framework that executes both tasks concurrently within a shared deep neural network architecture. This collaborative framework incorporates (i) common layers, (ii) restoration layers, and (iii) classification layers to merge the restoration and recognition activities. The restoration and classification losses are combined in the total loss function. The suggested joint architecture, which is built on capsules, provides an efficient solution that can deal with noise, image rotations, and occlusions.

2.5.1 Batch-Renormalization Denoising Network BRDNet

In the realm of picture denoising, deep convolutional neural networks (CNNs) have received a lot of interest. However, there are two drawbacks: (1) training a deeper CNN for denoising tasks is extremely difficult, and (2) most deeper CNNs suffer from performance saturation. We present the construction of a novel network dubbed a batch-renormalization denoising network in this paper (BRDNet). In particular, we join two networks to enhance the network's width and so collect additional characteristics. We can address the internal covariate shift and small mini-batch concerns because batch renormalization is integrated into BRDNet. Residual learning is also used holistically to help with network training. To extract more information for denoising operations, dilated convolutions are used. Extensive experimental findings reveal that BRDNet outperforms current image-denoising approaches [12].

2.5.2 DeepCNN

Image restoration has long been a source of contention in image processing and low-level computer vision. Due to their improved performance, discriminative convolutional neural network (CNN)-based techniques have recently received a lot of attention. However, because most of these frameworks are built for a single image restoration task, they rarely perform well on additional image restoration tasks. To overcome this issue, we present a modular deep CNN framework that takes advantage of the frequency characteristics of various types of artefacts. As a result, by altering the architecture, the same approach may be used for a range of image restoration jobs [13].

A quality enhancement network based on residual and recursive learning is presented for eliminating artefacts with comparable frequency characteristics. Residual learning is used to accelerate the training process and improve performance; recursive learning is used to dramatically reduce the number of training parameters while improving performance. Furthermore, lateral connections route the collected features through numerous pathways between different frequency streams. One aggregation network aggregates the results of these streams to improve the restored images even further. Three example applications are used to highlight the capabilities of the proposed framework: image compression artefacts reduction (CAR), image denoising, and single image super-resolution (SISR). Extensive studies show that the proposed framework outperforms state-of-the-art techniques for these applications on benchmark datasets [13].

III. Application

Image restoration has various application areas ranging from medical image to satellite images. Any kind of image which is degraded with various reason can be made more sharp or readable with the help of image restoration techniques. Paper [3] states image restoration use in any kind of image processing task. If captured image is blurred due to noise ten its task of image restoration techniques to make it good. Paper [14] describes various past, present and future advancements and application areas of image restoration techniques. Now a days as people are using more and more CCTV cameras, which has led to automatic object detection or activity detection an important part of analysis. So, Image restoration techniques can be used in agriculture, medical, health care, crime analysis, satellite images, video surveillance, and driver’s drowsiness detection as given in [15]. With help of image restoration complete detection is not possible but it is used as preprocessing step for any image processing application.

IV. Future Research Trends

Filters are used as the most traditional approach for image restoration. Recent research reveals that there is huge research scope for developing more accurate image restoration technique using machine learning or image processing approach. Researchers are doing advancement in CNN architecture and adding the layer for image restoration in it. Thus, there is huge research scope in developing robust and accurate image restoration technique using deep learning approach.

V. Conclusion

Image restoration is important process as many times while capturing the image some noise is added to the image which degrades the quality of the image. There are various kind of noise removal techniques known as image restoration techniques. This is the only paper in the area of image restoration technique which classifies image restoration techniques based on the approach it use. This paper classifies image restoration technique in mainly five categories: filter based, fuzzy logic based, wavelet analysis, machine learning based and deep learning based approach. This paper also describes various application areas of image restoration.It explains the future research tends in the area of image restoration.

References

1. Borker, Samarth and Sanjiv Vedu Bonde. “Contrast Enhancement and Visibility Restoration of Underwater Optical Images Using Fusion.” *International Journal of Intelligent Engineering and Systems* 10 (2017): 217-225.
2. Jaakko Lehtinen, Jacob Munkberg, Jon Hasselgren, Samuli Laine, Tero Karras, Miika Aittala, Timo Aila, Noise2Noise: Learning Image Restoration without clean Data arXiv:1803.04189
3. Bhatt, Dulari, Chirag Patel, and Priyanka Sharma. "Intelligent Farm Surveillance System for Bird Detection." (2011) in GRDET.
4. Ding Liu, Bihan Wen, Yuchen Fan, Chen Change Loy, Thomas S. Huang, Non Local Recurrent Network for Image restoration, arXiv:1806.02919
5. Jaya Gupta, Om Prakash , Image restoration using fuzzy logic with auxiliary BDND filter: A modified approach, IEEE,2015
6. AsmatUllah Chaudhary, Jin Young Kim, Tran Anh Tuan, Improved adaptive fuzzy punctual kriging filter for image restoration IJICIC, February 2013.
7. Kun-yu, Tien, Hooman Samani, JUI HUA, LUI, A Survey on Image Processing in Noisy Environment by Fuzzy Logic, Image Fusion, Neural Network, and Non-Local Means, 2017
8. A. Prochazka, J. Ptacek , and I. Sindelarov , Wavelet transform in signal and image restoration, 2014
9. Arun Kumar Patel, Nitin Muchhal, R.N. Yadav, Method for Image Restoration using Wavelet based Image Fusion in International Journal of Computer Applications (0975 – 8887) Volume 39– No.13, February 2012
10. Ana Paula A. de Castro and José D. S. da Silva "Neural network based multiscale image restoration approach", Proc. SPIE 6497, Image Processing: Algorithms and Systems V, 64970Q (27 February 2007); https://doi.org/10.1117/12.703468
11. Satyadhyan Chickerur and Aswatha Kumar M., “ Image Restoration: Past, Present and Future”, Recent Patents on Computer Science 2010; 3(2) . https://doi.org/10.2174/2213275911003020108
12. J. D. Fuletra and D. Bosamiya, “A survey on drivers drowsiness detection techniques,” International Journal on Recent and Innovation Trends in Computing and Communication, vol. 1, no. 11, pp. 816–819, 2013.
13. A. K. Katsaggelos, "Recent trends in image restoration and enhancement techniques," Proceedings of APCCAS'96 - Asia Pacific Conference on Circuits and Systems, 1996, pp. 458-459, doi: 10.1109/APCAS.1996.569312.
14. Dulari Bosamiya Mr. Akash K. Mehta, A Survey of the Farm Surveillance System for Animal Detection in Image Processing, International Journal Of Engineering Development And Research, 2014
15. Patel Milan, Dulari Bosamiya , Review Of Different Techniques For Ripe Fruit Detection, International Journal Of Engineering Development And Research, 2016
16. RACHANA PATEL, REEVA SONI, DULARI BHATT, Tumor Detection using Normalized Cross Co-Relation, IJRMEET, 2013
17. Bhagchandani, Ashish., Dulari Bhatt and Madhuri Chopade (14/03/2018). Various Big Data Techniques to Process and Analyze Neuroscience Data. https://www.researchgate.net/publication/328529465_Various_Big_Data_Techniques_to_Process_and_Analyze_Neuroscience