Image Restoration Technique with Non Linear Filter

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Abstract

In this paper, we present a novel approach to process the image using different filtering methods by Image Restoration. The aim is to enhance the digital image, reconstruct it into the original form from the noisy image. This paper is an overview of effective algorithms that can be used for image restoration. For which, techniques are used on the basis of non linear filters to restore the image. The performance of Histogram Adaptive Fuzzy (HAF) filter is carefully examined and compared with other filters like, Weighted Fuzzy Mean (WFM) filter, Minimum-maximum Detector Based (MDB) filter, Adaptive Fuzzy Mean (AFMF) filter, Centre Weighted Mean (CWM) filter, and Min-max Exclusive Mean(MMEM) filter on the basis of (Peak Signal to Noise Ration) PSNR. Experimental results on images will illustrate the capabilities of all the studied approaches.

Keywords: *Image processing, Image Restoration, Fuzzy, Impulse Noise, Filters, Histogram Adaptive Fuzzy Filter, Neural Network.*

1. Introduction

Image Processing is a form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or, a set of characteristics or parameters related to the image. Where, an image is defined as an array, or a matrix, square pixel arranged in rows and columns. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal processing techniques to it. Image processing usually refers to digital image processing. The field of digital image processing refers to processing digital images by means of a digital computer. It includes many techniques they are Image segmentation, Image Recognition, Image Differencing and Morphing, Digital Compositing, Color Corrections, Image Restoration, etc.

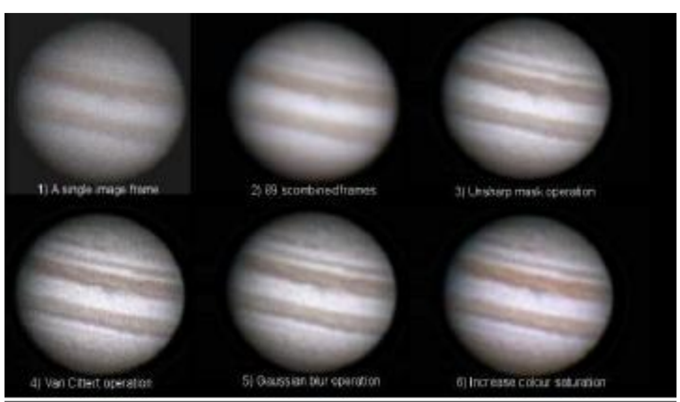


Figure 1. Image Processing Technique

2. Techniques and Methods

A. Image Restoration

Image Restoration is the process of obtaining the original image from the degraded image given the knowledge of the degrading factors. Digital image restoration is a field of engineering that studies methods used to recover original scene from the degraded images and observations. Techniques used for image restoration are oriented towards modeling the degradations, usually blur and noise and applying various filters to obtain an approximation of the original scene [16]**.** There are a variety of reasons that could cause degradation of an image and image restoration is one of the key fields in today's Digital Image Processing due to its wide area of applications. Commonly occurring degradations include blurring, motion and noise [3][14]. Blurring can be caused when object in the image is outside the camera's depth of field sometime during the exposure, whereas motion blur can be caused when an object moves relative to the camera during an exposure.

Figure 2. Restoration of Image into Original Form

The purpose of image restoration is to "compensate for" or "undo" defects which degrade an image. Degradation comes in many forms such as motion blur, noise, and camera misfocus. In cases like motion blur, it is possible to come up with a very good estimate of the actual blurring function and "undo" the blur to restore the original image. In cases where the image is corrupted by noise, the best we may hope to do is to compensate for the degradation it caused. In this project, we will introduce and implement several of the methods used in the image processing world to restore images [25].

The field of image restoration (sometimes referred to as image de-blurring or image de-convolution) is concerned with the reconstruction or estimation of the uncorrupted image from a blurred and noisy one. Essentially, it tries to perform an operation on the image that is the inverse of the imperfections in the image formation system. In the use of image restoration methods, the characteristics of the degrading system and the noise are assumed to be known a priori. In practical situations, however, one may not be able to obtain this information directly from the image formation process. The goal of blur identification is to estimate the attributes of the imperfect imaging system from the observed degraded image itself prior to the restoration process. The combination of image restoration and blur identification is often referred to as blind image de-convolution. Image restoration algorithms distinguish themselves from image enhancement methods in that they are based on models for the degrading process and for the ideal image. For those cases where a fairly accurate blur model is available, powerful restoration algorithms can be arrived at. Unfortunately, in numerous practical cases of interest, the modeling of the blur is unfeasible, rendering restoration impossible. The limited validity of blur models is often a factor of disappointment, but one should realize that if none of the blur models described in this chapter are applicable, the corrupted image may well be beyond restoration. Therefore, no matter how powerful blur identification and restoration algorithms are, the objective when capturing an image undeniably is to avoid the need for restoring the image.

In restoration process, degradation is taken to be a linear spatially invariant operator –

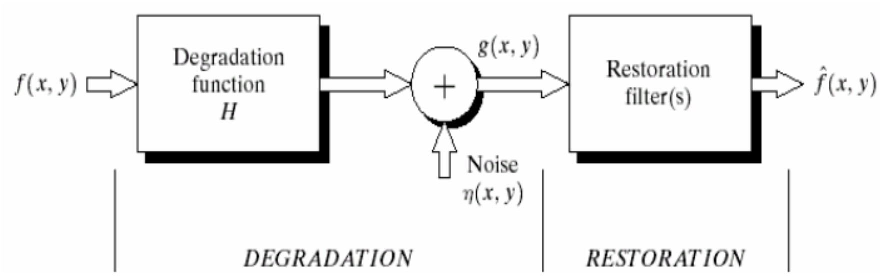


Figure 3. Processing of Image Restoration

$$g(x, y)= h(x, y) * f(x, y) + \eta(x, y) \qquad (1)$$

where, if g(x, y) is noise free, restoration can be done by using the inverse transfer function of h(u, v) as the restoration filter and η(x, y) is the noise.

The restoration techniques use various types of filters for achieving best performance, like inverse filter, wiener filter, constrained least square filter, Histogram Adaptive Fuzzy filter, Min-max Detector Based filter and Centre Weighted Mean filter etc.

B. Image Noise Model

When it has been discussed on noise it can be introduced in the image, either at the time of image generation (e.g. when we use camera and photographic films to capture an image) or at the time of image transmission. According to this different categories of noise having certain characteristics. In photographic films; the recording noise is mainly due to the silver grains that precipitate during the film exposure. They behave randomly during both film exposure and development. They are also randomly located on the films. This kind of noise, which is due to silver grains, is called film grain noise. This is a Poisson process and becomes a Gaussian process in its limit. The film grain noise does not any statistical correlation for distance between samples greater than the grain size. Therefore film grain noise is a white noise two dimensional random process. In photo electronic detectors, two kind of noise appears: (a) Thermal Noise: Its source is the various electronic circuits. It's a two-dimensional additive white zero-mean Gaussian noise, and (b) Photoelectron Noise: it is produced by random fluctuation of the number of photons on the light sensitive surface of the detector [20]. If its level is low it can be treated as a poison distributed noise otherwise it can be treated as a Gaussian distributed noise. Thus it can be said as signal dependent noise. Another kind of noise that is present during the image transmission is Salt-Pepper noise [7]. It appears as black and/or white impulse of the image. Its source is usually man-made or atmospheric noise, which appears as impulsive noise. It has following form: where z(k,j) denotes the impulse and i(k,j) denotes the original image intensity at the pixel (k, j). In case of the-CCD cameras, the main form of noise is the transfer loss noise.

C. Filters

Elimination of noise is one of the major works to be done in computer vision and image processing, as noise leads to the error in the image. Presence of noise is manifested by undesirable information, which is not at all related to the image under study, but in turn disturbs the information present in the image. It is translated into values, which are getting added or subtracted to the true gray level values on a gray level pixel. These unwanted noise information can be introduced because of so many reasons like: acquisition process due to cameras quality and restoration, acquisition condition, such as illumination level, calibration and positioning or it can be a function of the scene environment. Noise elimination is a main concern in computer vision and image processing. A digital filter [1][7] is used to remove noise from the degraded image. As any noise in the image can be result in serious errors. Noise is an unwanted signal, which is manifested by undesirable information. Thus the image, which gets contaminated by the noise, is the degraded image and using different filters can filter this noise. Thus filter is an important subsystem of any signal processing system. Thus filters are used for image enhancement, as it removes undesirable signal components from the signal of interest. Filters are of different type i.e. linear filters or nonlinear filters [4]. In early times, as the signals handled were analog, filters used are of analog. Gradually digital filters were took over the analog systems because of their flexibility, low cost, programmability, reliability, etc. for these reasons digital filters are designed which works with digital signals. The design-of digital filters involves three basic steps: (i) the specification of the desired properties of the system, (ii) the approximation of these specifications using a causal discrete time system, and (iii) the realization of the system using finite precision arithmetic.

3. Proposed Methodology and Solution

A. Method Used

Filtering is a technique for enhancing the image. Linear filter is the filtering in which the value of an output pixel is a linear combination of neighborhood values, which can produce blur in the image. Thus a variety of smoothing techniques have been developed that are non linear. Median filter (MF) is the one of the most popular non-linear filter. When considering a small neighborhood it is highly efficient but for large window and in case of high noise it gives rise to more blurring to image. In image processing applications two-dimensional median filters have been used with some success, and various methods [10][2][23] have been proposed to extend the median operation to two dimensions. By using MF, too much signal distortion is introduced, and features such as sharp corners as well as thin lines are lost. To overcome these problems, several variations of median filters have been developed, specifically, the multistage filter [11], the improved recursive median filtering (RMF) scheme [13], minimum-maximum exclusive mean (MMEM) filter [24], and the detection-estimation based filter [9], which incorporated a statistical noise-detection algorithm and the median filter for removal of impulsive noise. By using these approaches, still, the performance is achieved only when the noise ratio is small. Due to their lack of adaptability, these variations of median filters cannot perform well when noise ratio NP>=20% where, NP= Impulse Noise.

The weighted median (WM) filter [18] is an extension of the median filter, which gives more weight to some values within the window. This WM filter allows a degree of control of the smoothing behavior through the weights that can be set, and therefore, it is a promising image enhancement technique. A special case of WM filter called center weighted median (CWM) filter [12]. The Centre Weighted Mean (CWM) filter has got a better average performance over the median filter. However the original pixel corrupted and noise reduction is substantial under high noise condition. Hence this technique has also blurring affect on the image. A new technique based on nonlinear Min-max Detector Based (MDB) filter for image restoration. The aim of image enhancement is to reconstruct the true image from the corrupted image. The proposed schemes MDB [19] filter is found to be superior, i.e. better restored results and other parameter for restoration compared to the existing schemes when Salt and Pepper impulse noise is considered.

After this, much better results are obtained by using Histogram Adaptive Fuzzy filter, based on Neural Network [17] or Fuzzy theory [22]. Neural networks exploit their frameworks with many theorems and efficient training algorithms. They embed several input-output mappings on a black-box web of connection weights. However, we cannot directly encode the simple rule of a spatial windowing operation, such as: “If most of the pixels in an input window are BRIGHT, then assign the output pixel intensity as BRIGHT.” On the other hand, fuzzy systems can directly encode structured knowledge. Fuzzy systems may invariably store banks of common-sense rules linguistically articulated by an expert or may adaptively infer and modify their fuzzy rules using representative symbols (e.g., DARK, BRIGHT) as well as numerical samples. In the latter case, fuzzy systems and neural networks naturally combine. This combination produces an adaptive system in that the neural networks are embedded in an overall fuzzy architecture, where fuzzy rules from training data are generated and refined. Currently, the hybrid neuro-fuzzy networks do not represent general means in restoring images, which is particularly effective for removing highly impulsive noise while preserving edge sharpness. Initially, Yu and Lee in 1993 used the adaptive fuzzy median filter (AFMF) with the back-propagation algorithm [15] to tune a set of *randomly* given initial membership functions. Their simulation results have shown that AFMF performs better than MF when *NP*>30%. The strategy shows that the initial membership function requires lengthy computation time to complete the training process.

To overcome the problem, in order to make neuro-fuzzy [21] approach feasible in image restoration applications, this "retraining problem" must be removed, an algorithm is developed to utilize (corrupted) input histogram to determine parameters for the near-optimal fuzzy membership functions which uses the Histogram Adaptive Fuzzy (HAF) filter. Construction of the HAF filter involves three steps: (1) define fuzzy sets in the input space, (2) construct a set of IF-THEN rules by incorporating in put histogram statistics to form the fuzzy membership functions, and (3) construct the filter based on the set of rules. A systematic algorithm based on conservation in the histogram potential to obtain a set of well conditioned membership functions, along with system architecture of HAF [8].

B. Solution

In any noise removal schemes, attention is given to remove noise from images in addition to keeping as much original properties as possible. However, since both the objectives are contradicting in nature, it is not possible for any nonlinear scheme to fulfill both the objectives. It has been observed through the simulation of the existing schemes [5][6][12]that they also fail in providing satisfactory results under high noise conditions. Since impulse noise is not uniformly distributed across the image, it is desirable to replace the corrupted ones through a suitable filter. For this purpose, a preprocessing is required to detect the corrupted location prior to filtering.

C. Mathematical Analysis

To assess the performance of the proposed filters for removal of impulse noise and to evaluate their comparative performance, different standard performance indices have been used here. These are defined as follows:

Peak Signal to Noise Ratio (PSNR): It is measured in decibel (dB) and for gray scale image it is defined as:

$$\text{PSNR (dB)} = 10\log_{10}\left[\frac{\sum_i \sum_j 255^2}{\sum_i \sum_j (s_{ij} - \hat{s}_{ij})^2}\right] \qquad (2)$$

Where S_{ij} *and* $\hat{S}_{ij}$ are the original and restored image pixels respectively. The higher the PSNR in the restored image, the better is its quality.

Signal to Noise Ratio Improvement (SNRI): SNRI in dB is defined as the difference between the Signal to Noise Ratio (SNR) of the restored image in dB and SNR of restored image in dB i.e.

$$\text{SNRI (dB)} = \text{SNR of restored image in dB} - \text{SNR of noisy image in dB} \qquad (3)$$

Where,

$$\text{SNR of restored image dB} = 10\log_{10}\left[\frac{\sum_i \sum_j {s_{ij}}^2}{\sum_i \sum_j (s_{ij} - \hat{s}_{ij})^2}\right] \qquad (4)$$

And,

$$\text{SNR of Noisy image in dB} = 10\log_{10}\left[\frac{\sum_i \sum_j {s_{ij}}^2}{\sum_i \sum_j \left(s_{ij} - X_{ij}\right)^2}\right] \qquad (5)$$

Where, X_{ij} is Noisy image pixel. The higher value of SNRI reflects the better visual and restoration performance.

4. Simulation Result

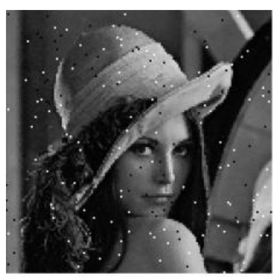
In this section, experimental results are presented which explored the characteristics of the various filters used and tested. The comparative analysis has been presented on the basis of different percentage of noise for the standard LENA image which is shown in the Table (1). The result is taken by comparing the performance of HAF with MDB, WMF, AMFM, MMFM, and CWM on the basis of PSNR.

Comparatively, HAF gives the best result in terms of PSNR criterion for the full range of the impulsive noise rate. The above conclusion is on the basis of image of LENA, the result of which is shown in Figure 4.

Table 1. Peak Signal to Noise Ratio (PSNR)

NP%	**Filtering Techniques**					
	CWM	***MMEM***	***AFMF***	***MBD***	***WFM***	***HAF***
10	26.58	27.08	28.38	27.72	26.97	37.30
20	24.03	25.63	27.38	26.24	23.87	36.06
30	21.38	24.80	26.00	24.37	21.80	34.98
40	19.56	23.66	24.12	23.72	20.17	33.60
50	16.90	22.54	24.05	21.64	18.70	31.54


(a)


(b)


(c)


(d)


(e)


(f)

(g)

Figure 4. Experimental Result with Image at 30% Impulse Noise, where (a) noisy Image (b) on applying CWM filter (d) on applying MMEM filter(e) on applying AFMF filter(f) on applying WFM filter (g) on applying MDB filter (h) on applying HAF.

5. Conclusion

This paper focus on the effective algorithms which has been used for Image Restoration by using different filtering techniques which tells that HAF filtering gives far better performance on the basis of PSNR, than any other non linear technique. We aim to develop a technique to recover image, video (signals) with high percentage of noise and defects.

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