REVIEW PAPER ON IMAGE RESTORATION USING STATISTICAL MODELING

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Abstract

There are various applications of image restoration in today's world. Image restoration is an important process in the field of image processing. It is a process to recover original image from distorted image. Image restoration is a task to improve the quality of image via estimating the amount of noises and blur involved in the image. To restore image it's too important to know a prior knowledge about an image i.e. the knowledge about how an image was degraded or distorted. It is must to find out that which type of noise is added in an image and how image gets blurred. So the prior knowledge about an image is a one of the important part in image restoration. Image gets degraded due to different conditions such as atmospheric conditions and environmental conditions, so it is required to restore the original image by using different image restoration algorithms. There are varieties of reasons that are responsible for noise generation in an image and different blur models are responsible for generation of blur image. So it's necessary to remove such noise from an image and remove blur model by using different deblurring techniques to improve it's quality for visual appearance. The restoration of degraded images can be applied in many application areas that are needed to restore it for further processing. Application area varies from restoration of old images in museum, image coding and decoding, medical imaging, photography, and image acquisition and restoration. So this paper proposes image restoration method by using joint statistical modeling. This paper gives a review of different image restoration techniques used.

Keywords: *Image Blur, Image Restoration, Statistical Modeling.*

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1. INTRODUCTION

Concept of image restoration started in 1950's. Image restoration is based on the concept to improve the quality of an image through knowledge of the image formation process or physical process which led to its formation. The purpose of image restoration is to "undo" defects or damage which degrade an image. Degradation occurs due to different reasons such as motion blur, noise, and miss-focus of camera. There are various types of blur model. In cases of motion blur, it is possible to obtain a very good estimate of the actual blurring function and remove the blur to restore the original image.

Image restoration is different process from image enhancement [1]. In image enhancement the image features are extracted instead of restoration of degraded image. Image enhancement is the process in which the degraded image is handled and the appearance of the image by visual is improved [5]. It is the subjective process and increases contrast of image but image restoration is a more and more objective process than image enhancement.

Image restoration problems can be measured very precisely, where as enhancement process is difficult to represent in mathematical form. There are several application of image restoration like, legal investigations, scientific purpose, film making and archival, image and video coding and decoding and photography purpose [1]. The main application of image restoration i.e. image reconstruction is in radio astronomy, radar imaging and tomography in medical imaging. This paper explains reviews of different image restoration techniques available.

1.1 Degradation and Restoration Process

The main aim of restoration process is to remove the degradation from the image and obtain the image f^(x, y) which is close to the original image [6]. First of all see that how an image gets degraded and then how it can be restored by using different image restoration algorithms.

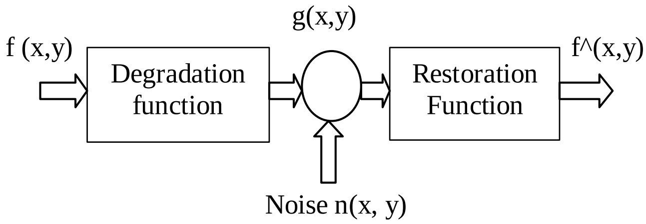

Fig-1: Degradation and Restoration Model

Consider the original image f(x, y) shown in fig.1. If noise n(x, y) operates on original input image then a degraded image g(x, y) is produced. The main objective of image restoration is that the output to be as same as possible to the original image. In mathematical format it can be represented as follows, [6]

$$g(x,y) = h(x,y) * f(x,y) + n(x,y) \quad (1)$$

The symbol * represents convolution of h(x, y) with f(x, y). From fig.1 it is clear that the original image gets convolved with the degraded image i.e. the original image f(x, y) gets convolved with the degradation function h(x, y). To convert the convolutions into multiplication take DFT of above equation in frequency domain.

$$G(u, v) = H(u, v). F(u, v) + N(u, v) \quad (2)$$

To calculate (x, y) take IDFT of equation (2),

$$G(u,v) = \frac{h(x,y)}{M.N.} + n(x,y) \quad (3)$$

The equation (3) is called as Degradative impulse response. To reduce the effect of noise from degraded image inverse filtering or pseudo inverse filtering can be used.

2. LITERATURE REVIEW

Image Restoration Technique

There are different image restoration algorithms studied by researchers such as Inverse filter, Wiener filter, Pseudo inverse filter, Blind image restoration algorithm, Recursive algorithm etc. Some of them are given as below,

2.1 Inverse Filtering

In this method divide the equation (2) by degraded frequency component H (u, v) and then solve for F (u, v) [6].

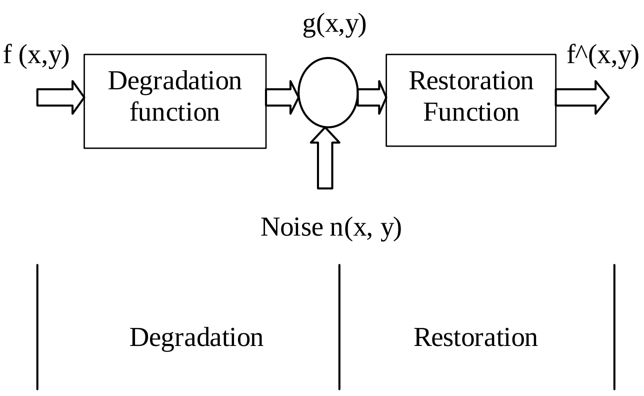

Fig-2: Degradation and Restoration Model using Inverse Filter

$$F(u,v) = \frac{G(u,v)}{H(u,v)} - \frac{N(u,v)}{H(u,v)} \quad (4)$$

The above equation is valid for two conditions i.e. if N (u, v) is known and H (u, v) does not to zero. Then F (u, v) for noise free image is,

$$F(u,v) = \frac{G(u,v)}{H(u,v)} \quad (5)$$

This equation is called as Inverse Filtering. There is no way to restore the image components if G (u, v) = H (u, v) = 0. So inverse filtering method gives poor result in case of noiseless and noisy blurred image. Sensor of image may be affected by environmental conditions or disturbance in atmosphere. During the digitization process noise may be added to original image. There are more chances to corrupt an image due to transmission process. Hence to avoid the noise equation (4) can be used as,

$$F(u,v) = G(u,v).M(u,v) - N(u,v).M(u,v) \quad (6)$$

Where, $M(u,v) = \frac{1}{H(u,v)}$ for $u^2 + v^2 \quad w_0$

$= 1$ for $u^2 + v^2 \quad w_0$

Steps in Inverse Filtering:
1. Take DFT of degraded image g(x, y) to obtain G (u, v)
2. Take DFT of degraded model H (u, v)
3. Compute F (u, v)
4. Take IDFT to obtain restored image f^(x, y).

Disadvantages of Inverse filter:
1. Properties of original image are not used
2. Inverse filter may be hard to built and that may not exist
3. Inverse filters are sensitive to noise

2.2 Pseudo Inverse Filtering

The drawbacks of the inverse filtering are given above. These drawbacks of inverse filtering can be overcome by using Pseudo inverse filtering. It is also called as modified inverse filtering. It can be defined as,

If $H(u, v) \rightarrow 0$, then

$F(u,v) = \frac{G(u,v)}{H(u,v)}$ ……… for H (u, v)   0,

$= 0$ ……… for H (u, v) = 0

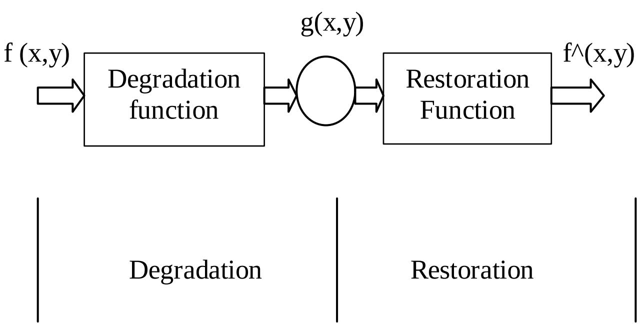

Fig-2: Degradation and Restoration Model using Pseudo Inverse Filter

Pseudo inverse filtering provides better result than inverse filtering. The inverse filtering and pseudo inverse filtering are sensitive to noise. This is limitation of these two filtering method of deconvolution.

2.3 Wiener Filtering

The main drawback of inverse and pseudo inverse filtering is that they are sensitive to noise. But wiener filtering is not sensitive to noise so the drawbacks of above two filtering can be overcome in wiener filtering [4]. Wiener filtering gives better response in presence of noise. There are some assumptions in wiener filtering [6].

Assumptions:

1. Second order statistics of the noise
2. And un-degraded images are known

Let, $S_{f\,(n,m)}$ is power spectral density (PSD) of original image & $S_r(n,m)$ is PSD of noisy image. Then by using Wiener – Knintchine theorem,

$$S_f(n,m) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} R_f\,(x,y)^{-i2\Pi\left[\frac{nx}{M}+\frac{my}{N}\right]} \tag{7}$$

Where, $R_f\,(x,y)$ is the autocorrelation of original image.

$$S_r(n,m) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} R_r\,(x,y)^{-i2\Pi\left[\frac{nx}{M}+\frac{my}{N}\right]} \tag{8}$$

Where, $R_r\,(x,y)$ is the autocorrelation of original image.

Then autocorrelation functions are,

$$R_f(x,y) = \frac{1}{(N-x)(M-y)}\sum_{m=0}^{M-1-y}\sum_{n=0}^{N-1-x} f(n,m).f\,(x+n,y+m) \tag{9}$$

$$R_r(x,y) = \frac{1}{(N-x)(M-y)}\sum_{m=0}^{M-1-y}\sum_{n=0}^{N-1-x} r(n,m).r\,(x+n,y+m) \tag{10}$$

From equation (9) and (10) the Wiener filtering is defined as,

$$F(n,m) = \frac{H_c\,(n,m).G\,(n,m)}{H\,(n,m)^2+\left[\gamma\,\frac{S_r\,(n,m)}{S_f\,(n,m)}\right]} \tag{11}$$

Where, $H_c(n, m)$ is complex conjugate of parameter γ and H (n, m). For γ   1, the Weiner filter is parametric wiener filter. For changing blur impulse response the wiener filter gives better response. So in case of unfixed blurring impulse response the wiener filter is used. The parameter k is adjustable. It can be adjusted until the accurate restored image is obtained. For k = 0 wiener filter is used as inverse filter. If the value of the k is increases the wiener filter gives less restoration result and start to degrade the degraded image. When both noise and blur are present then Weiner filter is called as band pass filter. Only in presence of blur Weiner filter is used as high pass filter. If only noise is present in an image then the Weiner filter is used as low pass filter [6]. The main disadvantage of Weiner filter is that the power spectra of both undegraded image and power spectra of noise must be known.

Steps in Wiener Filtering:
1. Obtain FT of degraded image g(x, y) to obtain G (n, m)
2. Take FT of degraded model h(x, y) to obtain H (n, m)
3. Select the value for parameter ‘k’
4. Compute F (n, m) by using equation (7)
5. Obtain IFT of F (n, m) to obtain restored image f(x, y)
6. Until the best restoration result is obtained change the value of the parameter ‘k’ and continue the all steps from 1 to 5.

Advantages of Wiener filter:
1. Easy to design.
2. Begins to exploit signal.
3. They are not sensitive to noise.

Disadvantages of Wiener filter:
1. To estimate power spectrum density prior knowledge of noise and clean signal is required.
2. It gives fixed frequency response at all frequency.
3. Results are often too blurred.

2.4 Geometric Mean Filtering

Inverse filter achieves different results at two different frequencies. The inverse filter achieves good resolution at the spatial frequencies i.e. at the lower frequencies, but it gives poor performance at the higher frequencies. The Wiener filter gives best noise performance than inverse filtering and pseudo inverse filter but it achieves this by smoothing the image at the expense and then it performs image restoration by modifying filter, *M*,. Mathematically it can be written as,

$$F^{\wedge}(u,v) = \left[\frac{H^*(u,v)}{/H(u,v)/^2}\right]^{\alpha}\left[\frac{H^*(u,v)}{/H(u,v)/^2+\beta\left[\frac{S_n\,(u,v)}{S_f\,(u,v)}\right]}\right]^{1-\alpha} G\,(u,v) \tag{12}$$

2.5 Blind Image Restoration

Kundur [2] proposed ‘Blind image deconvolution’ algorithm. When point spread function (PSF) is unknown then blind image deconvolution or blind image restoration method is used to recover the original image from its set of blurred images [2]. If blur kernel is unknown then blind deconvolution is useful to recover the sharpness of blurred image. PSF is inverse of Fourier transform. In case of unknown additive noise, image spectral density, degradation filter by using blind deconvolution it is possible to restore image. Mathematically it can be written as,

$$y = k \quad x \tag{13}$$

Where x is a visually sharp image and k is a non negative blur kernel. There are two types of measurement in blind image restoration i.e. direct measurement and indirect measurement. The indirect estimation uses spatial or temporal averaging to achieve image restoration. The direct method first estimate noise level and impulse response of blur then achieve image restoration. Iterative and Non iterative methods are used in blind deconvolution algorithm. Maximum estimation takes place in iterative method and in non iterative method APEX method is used [2]. In APEX, it is assumed that the PSF estimates shape width and it is having a particular shape [3].Some important blind image deconvolution algorithms are Decision-direct estimation, Godard algorithm and Bussgang blind deconvolution.

2.2 Proposed Method

This paper proposes image restoration by using joint statistical modeling in space and transform domain which achieves both local smoothness and nonlocal self-similarity of natural images. A new Split Bregman-based algorithm is used to solve inverse problems. Due to the image inverse problem there can be always abnormal behavior of images occurs in digital image processing. So to resolve the issue related to quality of image the knowledge about properties of image must be known. There are so many image properties like contrast, brightness, resolution etc. But to solve the image inverse problem in proposed algorithm the two main image properties such as local smoothness and non local self similarity are used. In this paper two models are used at the same time so named as joint statistical modeling.

1. Local smoothness
2. Non local smoothness

1. Local smoothness:

Local smoothness is property of image in which the values of neighboring pixels are nearly similar. In mathematical format local smoothness is written as,

$$\Psi_{LSM}(u) = ||D_v u||_1 + ||D_h u||_1 \qquad (14)$$

Local smoothness is achieved in space domain at pixel levels. The above equation of local smoothness provides unique solution than other algorithms.

2. Non local smoothness:

Only local smoothness property cannot obtain best solution to image restoration. So another image property is also used at the same time to achieve best solution to image restoration. It is used to recover the sharpness and edges of the image. In mathematical format the non local self similarity in 3D transform domain can be written as,

$$\Psi_{NLSM}(u) = \sum_{i=1}^{n} || T^{3D} (Zu^i)||_1 \qquad (15)$$

3. CONCLUSIONS

In this paper various types of image restoration algorithms are discussed and explained with their advantages and disadvantages. Various researchers worked to improve the efficiency of the different algorithms. Basically image restoration is done mostly using, inverse and pseudo-inverse filter, Weiner filter, and Blind Deconvolution algorithm. This paper proposed image restoration using joint statistical modeling to achieve the two image properties which are essential in restoration process. This concept will be used in application of image inpainting, mixed and Gaussian noise removal.

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BIOGRAPHIES

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