Improved Image Restoration Methods: A Review

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Abstract – Image processing applications are widely used in various commercial and non-commercial processes. They are used in different fields of science like medical field, space research, forensics and the list goes on. But there are certain problems with current image restoration methods. They include blurring and unwanted noise. Present methods have well restoration ability but the implementation is hard. This paper presents an analysis and results of Image Restoration done gradually, Dual Domain Image Restoration and restoration of the corrupted image in PCA domain.

Key Words – Image Restoration, PCA, Review, Dual Domain Image Restoration.

1. INTRODUCTION

In Image Restoration goal is to obtain and approximate original image data by removing unwanted noise from a corrupted noise. Corruption is caused by various internal and external factors such as sensors and environmental factors. Thus, image restoration is very important to get original image. Several algorithms have been proposed but most of them to fail to give promising results because the image contains noise level that are very high and are difficult to obtain. Here we investigate and review few methods to solve problems associated with image restoration and adapt these methods in a flexible manner to get high quality original image while using low computational power and complexity.

2. METHODS

A. Image Restoration done gradually.

Noisy image is a combination of white noise and original clean image. In this method, noise is reduced from the noisy image gradually in small steps. The value of these steps (noise estimation) is estimated[1], [2]. If the value obtained is overestimated, image loses its data and if it is underestimated, the image maintains residual noise and data. This is done by masking the noisy signal and then taking the Fourier transform of the signal in frequency domain. Finally, SNR is calculated. It is done in 2 main steps.

1) Gradient Descent: Restoring the image by using Gradient Descent which ultimately means reducing the image in small steps gradually. Noisy image is a mixture of white noise(w) and the original image(O). Hence making it a noisy image(N). The equation is as follows:

\[ N = w + O \]

The goal of this method is to separate original image with most of its data from noise. Gradient Descent is defined as:

\[ O_{t+1} = O_t - L \nabla W(O_t) \]

where L is the direction of step size. The value of L determines whether the image will be overestimated or underestimated[3], [4]. If overestimated, the image will lose its detail and if underestimated, the noise will contain the remaining noise. Finally, by putting the gradient of energy we will get the noise estimate.
2) Masking and Convolving: In this process, the noisy image’s gradient is taken by subtracting the center most pixel from the nearby pixels. The gradient is given by

\[ d_{i,p,q} = O_{i,q} - O_{i,p} \]

where \( O_{i,p} \) is the center pixel value and \( O_{i,q} \) is the neighboring pixels values.

This gradient and annealing forms two parts, range part and spatial part. When combined together forms a bilateral mask(k), which when convolved with the noisy image removes large amplitude signals. This masked gradient is given as \( kd_{i,p,q} \). To convert into frequency domain, Discrete Fourier Transform(DFT) is taken of masked gradient giving Fourier Coefficients \( D_{i,p,f} \) for frequency \( f \) which is given as,

\[ D_{i,p,f} = \sum_{q \in N_p} \text{ } d_{i,p,q} \left[ \left( \frac{d_{i,p,q}^2}{T_1} \right) K_r \left( \frac{q-p^2}{S_t} \right) e^{-\frac{j}{2r+1} \pi f} \right] \]

where \( K_r \) is range part and \( K_s \) is spatial part \( T_i \) is first scale parameter that determines temperature reducing over time and \( S_i \) is the second scale parameter for increasing. To get small amplitude signals, another mask(K) is used to remove medium amplitude signals by forming a masked spectrum. Finally, estimate noise \( n_{i} \) is calculated by taking Inverse Discrete Fourier Transform(IDFT) of masked spectrum \( KD_{i,p,f} \). It is given by

\[ n_{i,p} = \frac{1}{(2r+1)^2} \sum_{f \in F_p} D_{i,p,f} K \left( \frac{D_{i,p,f}^2}{V_i} \right) \]

where \( V_i \) is the variance of the Fourier Coefficients given by

\[ V_i = \sigma^2 \sum_{q \in N_p} k_r \left( \frac{d_{i,p,q}^2}{T_1} \right)^2 k_s \left( \frac{q-p^2}{S_t} \right)^2 \]

B. Dual Domain Image Restoration

To further improve the SNR of the restored image, this method is used[5], [6]. The image containing noise is passed through a non-linear filter and wavelet shrinkage to filter out high and low variance of the image respectively. To get the final, restored image, these two values are combined together. This is done by non-linearly filtering the
FIG 1. IMAGE RESTORATION DONE GRADUALLY

image containing noise to obtain high variance values in spatial domain. These high variance values are then subtracted from the noisy image to obtain low variance values. Further, Fourier transform is carried out on these values. By using wavelet shrinkage in frequency domain, image is considerably reduced. Finally, the image is reconstructed. First, we take a guide image and the noisy image in spatial domain. Guide image is the 30th iteration of the image restored in the previous method called Image Restoration done gradually. They are non-linearly filtered to get high variance values. Then, in domain transform, high variance values are subtracted from guide image and noisy image to get low variance values. Further, Fourier Transform is carried out. By using wavelet shrinkage in frequency domain, noise is reduced. Finally, the image is reconstructed by adding these two layers.

FIG 2. DUAL DOMAIN IMAGE RESTORATION

C. Restoring Corrupted Image in PCA Domain

This method involves image restoration in PCA domain. The PCA method divides a corrupted image which is temporally filtered into two parts each having distinct characteristics. The first part obtained contains less noise and great contrast while the second part obtained contains less contrast and high level of noise[7]. The first part is filtered by KPCA method. The second part is filtered using anisotropic filter. Then these two are
passed through the inverse PCA domain which reconstructs the image having the original data efficiently. In restoration process, the main goal is to reconstruct the image from the corrupted image by non-linear filter, anisotropic diffusion filter in PCA domain. The Viola & Jones algorithm is used to detect the image and create a training set. The training set is transformed in PCA domain to Eigen vector that holds intensity variance among the image. Threshold value can be calculated from the variance and intensity of Eigen vectors. After this process, the image is non-linearly filtered, it is combined with weighted average filter. White noise is reduced considerably which makes it easier to separate the image features. Then, by using the spatial filter, the resulting image is projected into the eigenspace in the PCA domain. This divides the image into two sub-images, the first sub-image obtained contains less noise and great contrast which represents the small features, and the second sub-image contains high levels of noise and less contrast which represents large features. These two features are denoised separately. Small features should be denoised with KPCA method. On the other hand, large features are denoised using anisotropic filter without destructing the details of the image. These are combined together using inverse PCA transform to obtain the restored image.

![FIG 3. CORRUPTED IMAGE RESTORATION IN PCA DOMAIN](image)

**CONCLUSION**

Image Denoising is the most interesting and significant in the field of Image Processing. It is basically the removal of noise and reserving the important features of the image. Several methods and techniques has been introduced to solve this problem. Many advancements are made to the existing techniques. In this paper we review few of the methods and compare them with each other. First method is Image Restoring done gradually. This improves SNR. But to further improve the SNR, second method comes into play. Here image is restored in Dual Domains, namely, spatial domain and frequency domain. The third method involves image restoration in PCA Domain. This method is bit expensive and complex in compare to previous two methods, but it has better results in case of preserving great features of the image.

**Reference**


