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# Image Processing Algorithms for Image Restoration

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**ABSTRACT:** Image restoration is necessary for restoring deteriorated photographs that have suffered from noise, blur, or other distortions, among other things. Important information and features in the image may be lost as a result of these degradations, which may be introduced during the process of acquiring, transmitting, or storing the image. These details and features are recovered using image restoration techniques, which increases the image's usefulness for tasks like analysis, diagnostics, and decision-making. Degraded images, for instance, can impact the precision of diagnosis and treatment planning in medical imaging. The quality and dependability of medical imaging can be increased through image restoration, improving patient outcomes. Degraded images can also affect a system's ability to detect and recognise important objects in satellite imaging and security systems. The images can be improved with image restoration, making them better suited for these uses. In conclusion, image restoration is required to enhance the quality and usefulness of damaged images for a variety of applications.

**KEYWORDS:** Inverse Filtering, Constraint Least Squared Filtering, Wiener Filtering, Image Noise.

## I. INTRODUCTION

Improving the quality of images that have been negatively affected by elements like noise or blur is a crucial task in image processing. Many industries, including security systems, medical imaging, and satellite imaging, use image restoration techniques based on image processing algorithms like inverse filtering, constrained least squares filtering, Wiener filtering, and Lucy-Richardson filtering. Depending on the type of degradation, the degree of restoration needed, and the computational resources available, the right algorithm should be chosen. An overview of image restoration methods and use cases is given in this abstract.

## II. IMAGE RESTORATION TECHNIQUES

The quality of degraded images can be improved using a variety of image restoration techniques. Several of the frequently employed methods include:

- 1) **Spatial Domain Techniques:** These methods can be used to eliminate noise, blur, or other distortions because they work directly on the image pixels. Median filtering, mean filtering, and adaptive filtering are a few examples of spatial domain techniques.
- 2) **Frequency Domain Techniques:** These methods can be used to get rid of periodic noise or distortions because they work with the image's Fourier transform. Fourier filtering, notch filtering, and Wiener filtering are a few examples of frequency domain techniques.
- 3) **Model Based Techniques:** These methods can be used to recover the original image and use a mathematical model to describe the degrading process. Inverse filtering, constrained least squares filtering, and Lucy-Richardson deconvolution are a few examples of model-based methods.

4) **Hybrid Techniques:** To improve restoration performance, these techniques combine spatial and frequency domain techniques. Wavelet-based filtering and total variation-based filtering are two examples of hybrid techniques.

The type of degradation present in the image and the desired level of restoration depend on the technique chosen for image restoration. Image restoration methods are still being developed and improved upon by researchers to increase their effectiveness and domain-specific applicability.

### III. IMAGE PROCESSING ALGORITHMS

1) **Inverse Filtering Method:** To restore images that have been damaged by linear degradation, such as blurring or distortion, use the straightforward image restoration technique known as inverse filtering. Applying the inverse of the degradation function to the degraded image in order to recover the original image is the fundamental concept behind inverse filtering.

The degraded image can be mathematically represented as:

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

where the original image is  $f(x,y)$ , the degraded image is  $g(x,y)$ , the point spread function (PSF) representing the linear degradation is  $h(x,y)$ , and the noise in the degraded image is  $n(x,y)$ .

Applying the inverse filter to the frequency domain degraded image yields the restored image  $f^{\wedge}(x,y)$ ,

$$F^{\wedge}(u,v) = G(u,v) / H^{\wedge}(-1)(u,v)$$

where the Fourier transforms of the degraded and restored images, respectively, are  $G(u,v)$  and  $F^{\wedge}(u,v)$ .

Inverse filtering, on the other hand, can be extremely noise-sensitive and can amplify any noise that was already present in the degraded image, producing a noisy restored image. Researchers have suggested several inverse filtering modifications, including regularization and constraint-based techniques, to address this issue.



Fig.1. (a) original image, (b) blurred image, (c) deblurred image by inverse filter

2) **Constraint Least Squared Filtering:** Image degradation brought on by blur or other linear distortions can be repaired using the model-based image restoration technique known as constrained least squares filtering (CLS). In order to obtain the restored image, the CLS method involves minimizing a quadratic cost function under certain restrictions.

The cost function can be defined as:

$$J(f) = \|g - h * f\|^2 + \lambda * R(f)$$

where  $f$  is the restored image,  $g$  is the degraded image,  $h$  is the point spread function (PSF) that represents the linear distortion, and  $\lambda$  is a regularization parameter that regulates the trade-off between the regularization term  $R(f)$ , which imposes some constraints on the restored image, and the data fidelity term  $\|g-h* f\|^2$ .

Depending on the desired constraints for the restored image, the regularisation term can be defined in a number of different ways. The smoothness constraint, for instance, can be enforced by defining  $R(f)$  as follows

$$R(f) = \|L * f\|^2$$

where the image  $f$  is subjected to the smoothing operation  $L$

Using a numerical optimization algorithm like gradient descent or conjugate gradient, the CLS method minimizes the cost function  $J(f)$  subject to the constraints to solve the optimization problem.

The optimization issue can be resolved to produce the restored image  $f^{(x,y)}$

$$F^{(x,y)} = \operatorname{argmin} J(f) \text{ subject to } R(f) = C$$

where  $C$  is the constraint on the restored image.

The CLS method can handle noise in the degraded image to some extent and is effective in restoring images with blur or other linear distortions. However, non-linear distortions like motion blur or lens distortion may prevent it from successfully restoring photographs.

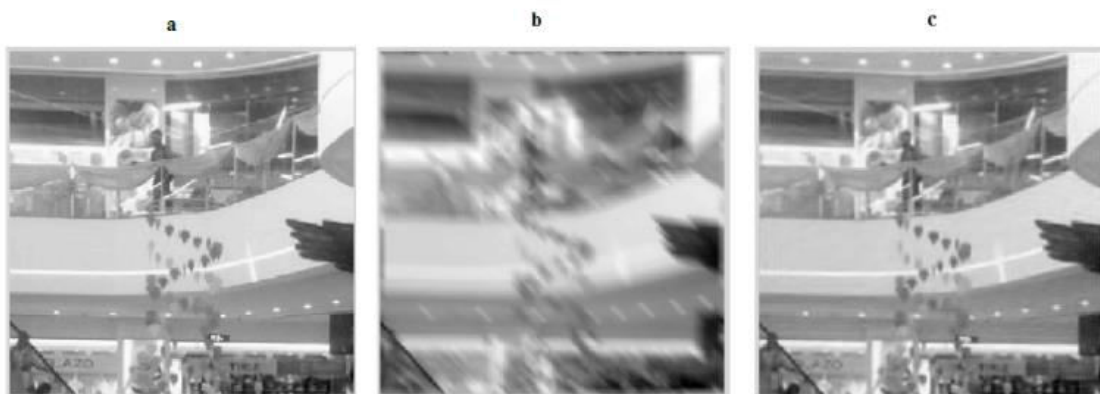


Fig. 2. (a) Original image; (b) Noisy blurred image; (c) Restored image.

- 3) **Wiener Filtering:** Using a linear filter that minimises the mean square error between the estimated signal and the true signal, Wiener filtering is a technique for estimating a signal from a noisy observation of that signal. Signal processing, image processing, and communication systems all often use the Wiener filter.

The Wiener filter's equation is as follows:

$$h = (R_{xx} + \lambda I)^{-1} * r_{xy}$$

where  $\lambda$  is a regularization parameter to prevent overfitting,  $I$  is the identity matrix,  $R_{xx}$  is the autocorrelation matrix of the noisy signal,  $r_{xy}$  is the cross-correlation between the noisy signal and the desired signal, and  $h$  is the Wiener filter coefficients.



Both the frequency domain and the time domain can be used with the Wiener filter. The following is the formula in the frequency domain.

$$H(f) = R_{xy}(f) / R_{xx}(f)$$

where  $R_{xy}(f)$  is the cross-spectral density between the noisy signal and the desired signal,  $R_{xx}(f)$  is the power spectral density of the noisy signal, and  $H(f)$  is the frequency response of the Wiener filter.

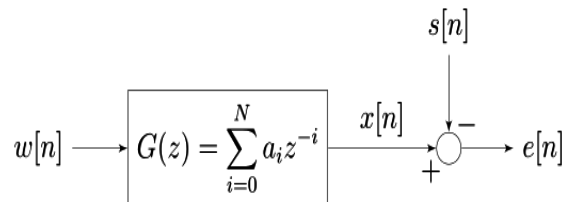


Fig.3. An input signal  $w[n]$  is convolved with the Wiener filter  $g[n]$  and the result is compared to a reference signal  $s[n]$  to obtain the filtering error  $e[n]$

#### IV. CONCLUSION

New algorithms and techniques are frequently created, and the field of image restoration is constantly changing. Despite the significant progress made, there are still a number of issues that need to be resolved, including dealing with complicated noise models, non-linear distortions, and the lack of readily available data. These difficulties offer fascinating chances for upcoming research and invention in this area.

#### V. ACKNOWLEDGMENT

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