Comparative Study of Major Image Enhancement Algorithms

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Abstract—Image restoration is a process of reconstruction or recovery of an image that has been corrupted or degraded by any degradation phenomenon. Image restoration techniques are inclined towards modeling the degradation and applying the inverse process in order to recover the original image. The critical goal of restoration techniques is to improve the quality of an image in some predefined manner. This present paper is a comparative study of image enhancement techniques used for improving the quality of a given image and evaluate it against the quality of a given image and evaluate it against SNR, PSNR, MSE, and SSIM as metrics.

Index Terms—Degradation; Enhancement Techniques; Image; Noise

I. INTRODUCTION

An image restoration is a process of reconstruction or recovery of an image that has been degraded by a degradation incident. Image restoration techniques are focused towards modeling the degradation, and applying the inverse process in order to recover an original image. The main goal of restoration techniques is to improve an image in some predefined sense. It involves heuristic procedures designed to manipulate an image in order to satisfy human visual system. Existing methods of image enhancement can be classified into two categories: Spatial Domain and Frequency Domain Enhancement techniques [1],[2]. The limitation of these methods is that, it has neglected the techniques to reduce noise for underwater images in general, and also the problem of uneven illumination is not much focused.

Image Enhancement methods can also be classified as Non model and Model based. Non Model method is further classified as Global Histogram Equalization, Adaptive Histogram Equalization (AHE), CLAHE, Retinex and Wavelet based. In this paper, authors present an overview of major enhancement techniques, CLAHE, Homomorphic Filter, and Wavelet method that can be used for the enhancement of image processing to both reduce the problem of noise and uneven illumination in an image [3],[4].

Homomorphic filter: It is a filtering technique that takes into account both, an illumination function and the reflectance function at every point. Homomorphic filtering is used widely in the applications related to satellite image processing, identification of fuzzy prints, speech processing and in geo signal processing fields. Based on this fact, it can be modeled as

\[ H(x, y) = i(x, y) * r(x, y) \] (1)

Where \( x \) and \( y \) denotes the pixel coordinate values, \( H(x,y) \) is the output image, \( i(x,y) \) is the illumination component and \( r(x,y) \) represents reflectance model.

The method above is the advancement to one of the basic image processing methods, which is, Fourier transform. Fourier Transform is associative and linear under addition, but is not associative under multiplication [1]. Thus, Fourier methods are appropriate for removing noise from images only when the noise can be modeled as a additive term to the original image. On the other hand, if the defects of an image, for example, if uneven lighting, have to be modeled as multiplicative rather than additive, direct application of Fourier methods is inappropriate [1]. In terms of the illuminance and reflectance of an object, an image of the object might be modeled as the equation below:

\[ f(x, y) = i(x, y) * r(x, y) \] (2)

In this case, some method of converting multipication into addition must be employed before trying to apply Fourier filtering. This is achieved using Homomorphism.

CLAHE algorithm: CLAHE (Contrast Limited Adaptive Histogram Equalization) algorithm is a suitable approach for underwater images, whose distribution of brightness usually changes in dissimilar parts of the image, leading to an enhancement for the local contrast and the visibility of details for images in addition to histogram equalization [3]. This is different from Histogram Equalization because, this technique computes several histograms and then uses them for further processing of the image. CLAHE based method establishes a maximum value and redistributes the maximum value and redistributes the clipped pixels equally to each gray level image. CLAHE algorithm is a three step approach:

i. The color images captured by camera in a hazy atmosphere, is converted from RGB (Red, Green and Blue) color space to HSI space [1],[2]. HSI represent colors in the way similar to the way in which human eye sense colors.

ii. The intensity component of the image is processed by CLAHE. Hue and Intensity value remain unchanged. A new HIS image is obtained.

iii. This new image in HIS color space is converted back to RGB color space to get the original image without degradation.

Published on July 13, 2017.

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DOI: http://dx.doi.org/10.24018/ejers.2017.2.7.389
Wavelet method: Wavelet Transforms (WT) is a substitute to the Short-Time Fourier Transform (STFT) for non-stationary signal analysis. Both the transformation methods, STFT and WT, results in a signal decomposition into two-dimensional function of time and frequency respectively \cite{1},\cite{2}. The basic difference between these two transforms, is in the construction of the window function which has a constant length in the case of STFT (including rectangular, Blackman and other window functions). The basic insight behind denoising is that, it tries to keep transform coefficient of high PSNR (Peak Signal-to-Noise Ratio) while zeroing out coefficients having lower PSNR \cite{5},\cite{6}.

II. EXPERIMENTAL SETUP

MATLAB version 2016Ra was used as simulation software in Windows 10 Operating System. The parameters that were used for evaluation of various images were SNR, PSNR, MSE and SSIM. Brief definitions of these metrics are listed below:

SNR (Signal to Noise Ratio) is defined as the ratio of, signal to the noise power, in decibels. A ratio higher than 1:1, indicates more signal than noise. Larger value of SNR indicates better image quality.

PSNR (Peak Signal-to-Noise Ratio), is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. PSNR is usually expressed in terms of logarithmic dB scale. Higher value of Peak Signal to Noise Ratio indicates better image quality.

MSE (Mean Squared Error) of an estimator, is the average of the squares of the errors or deviations, that is, MSE is defined as the disparity between the estimator and what is estimated. It is a risk function, corresponding to the expected value of the squared error loss or quadratic loss. This difference is due to randomness or because the estimator doesn’t account for the information that could produce a more accurate estimate. Lower value of MSE indicates better image quality \cite{6},\cite{7}.

Structural SIMilarity (SSIM) index is a technique for measuring the similarity between two images. SSIM index is a full reference metric; in other words, the measuring of image quality based on an initial uncompressed or distortion free image as reference.

III. CONCLUSION

Simulation results shows that CLAHE filter gives a better quality image with respect to SNR and PSNR, whereas Homomorphic and Wavelet gives almost same results with respect to the metric MSE and SSIM. Following are the graphs drawn using gnu plot, for the metric SNR, PSNR, MSE, and SSIM for the randomly chosen 10 images. The graphical representation of the same is shown in Fig. 1,2,3 and 4.
## TABLE I: EXPERIMENTAL RESULTS

| Image | MSE | CLAHE | Wavelet | SNR | CLAHE | Wavelet | PSNR | CLAHE | Wavelet | SSIM  | CLAHE | Wavelet |
|-------|-----|-------|---------|-----|-------|---------|------|-------|---------|-------|-------|---------|
| Image1 | 68.92 | 1.38 | 1.65 | 14.95 | 11.48 | 8.51 | 29.75 | 46.17 | 5.95 | 0.92 | 0.0019 | 0.0164 |
| Image1 | 13.68 | 0.99 | 1.66 | 11.93 | 11.4 | 9.33 | 36.77 | 48.19 | 6.44 | 0.9988 | 0.0018 | 0.0013 |
| Image2 | 0.71 | 2.07 | 1.7 | 9.71 | 12.21 | 9.02 | 49.6 | 45 | 5.85 | 0.9999 | 0.0006 | 0.0356 |
| Image3 | 1.2 | 1.81 | 2.22 | 11.3 | 13.18 | 8.31 | 47.33 | 45.5 | 4.69 | 0.9713 | 0.01 | 0.0179 |
| Image4 | 0.15 | 1.68 | 1.48 | 12.4 | 13.96 | 9.05 | 56.3 | 45.9 | 6.47 | 0.9942 | 0.0073 | 0.0407 |
| Image5 | 0.56 | 2.29 | 1.29 | 9.7 | 13.79 | 9.69 | 50.59 | 44.5 | 7.05 | 0.999 | 0.0012 | 0.0014 |
| Image6 | 0.26 | 1.85 | 1.45 | 8.99 | 12.3 | 10.02 | 54.03 | 45.49 | 6.56 | 0.9998 | 0.0014 | 0.0012 |
| Image7 | 0.21 | 1.72 | 1.83 | 12.16 | 14.35 | 11.84 | 58.87 | 45.81 | 8.23 | 0.999 | 0.0068 | 0.0495 |
| Image8 | 0.59 | 2.72 | 1.25 | 8.68 | 11.95 | 10.72 | 50.41 | 43.8 | 7.2 | 1 | 0.0071 | 0.0199 |
| Image9 | 0.36 | 2.61 | 1.65 | 9.24 | 12.11 | 8.55 | 47.67 | 45.44 | 7.11 | 0.9971 | 0.0018 | 0.0164 |
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