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Low contrast image enhancement by implementation optical filter techniques

Murooj S. Tawfek *
Ghada S. Karam †
Ziad M. Abood §
Department of Physics
College of Education
Mustansiriyah University
Baghdad
Iraq

Abstract

Images have been a significant medium for information analysis in recent years. However, Occasionally, the collected image may suffer from poor light and become hazy due to technological restrictions imposed by the surrounding environment. This process may result in a decline in visual quality. Even though reducing deterioration is an essential step in image restoration, image processing researchers still encounter challenges during the restoration process. Image restoration is the process of restoring a damaged image to its most authentic state. Degradation can be caused by motion blur, Gaussian blur, noise, camera mismatch, uneven lighting, and photos with low contrast. To enhance image quality, the suggested approach incorporates the creation of a novel amplitude filter mask based on the pupil function methodology for pictures of point objects. By MATLAB, two filters were created to improve low-contrast and fuzzy photos. The performance of this algorithm has been computed based on the signal-to-noise ratio (PSNR), Enhancement Measure Estimation (EME), image entropy, depending on this statistical improvement measures, the results show that the apodization parameter β plays an important role of enhancing the degraded images.

Subject Classification: *Primary 93A30, Secondary 49K15.*

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* *E-mail:* **murooj_sabah@uomustansiriyah.edu.iq (Corresponding Author)**
† *E-mail:* **dr.ghada@uomustansiriyah.edu.iq**
§ *E-mail:* **dr.ziadmabood@uomustansiriyah.edu.iq**

1. Introduction

Image deterioration and loss of detail can arise from acquisition and recording shortcomings, leading to reduced informational content in the captured scene [1, 2]. Such degradations may stem from atmospheric turbulence, defocus, optical aberrations, nonuniform illumination, or insufficient lighting levels [3]. Debugging and contrast enhancement operations are two of the most popular and crucial methods for increasing image quality. As a result, it is necessary to raise the contrast to improve image quality. This work develops an amplitude filter mask directly derived from the pupil function so as to tailor the optical system's point spread function (PSF) and, in turn, improve contrast while suppressing degradations in the observed image. The implementation (MATLAB) integrates contrast enhancement with noise and blur attenuation. Earlier, Karam, Haleot, and Aliwi [4] introduced the levelset adaptive median filter for edgepreserving noise reduction, and Jähne [5] reported a restoration scheme for noisy, blurred color images combining a guided filter with inverse filtering. Reported evaluations in prior studies note that PSNR and SSIM tend to display higher sensitivity to Gaussian noise than to blur.

2. Theoretical Method

2.1 *Point Spread Function*

Under noisefree conditions, the response of the imaging system to a point object at the origin is the spatial function H(u,v), (the PSF) [6]. Its Fourier transform.

$$H(u,v) = |A(u,v)|^2 \qquad (1)$$

u, v: lack dimensions Coordinates, $H(u,v)$ is PSF, and $A(u,v)$ is the intensity in the image planes at the location (u, v).

The Fourier transform of the pupil function can be used to determine the amount of diffracted amplitude light when a point is far from the Gaussian focus plane $f(x,y)$ [7]:

$$A(u,v) = 1/a\int\int(x,y)e^{i2(ux+vy)}dxdy \qquad (2)$$

In addition to pupil function, three distinct amplitude filter types have been examined in this work. The following describes the distinctive pupil function of these filters and how they affect images [8].

1. function of Blackman filter pupil $f_B(r)$:

$$f_B(r) = 0.42 + 0.05\cos\beta\pi r + 0.08\cos\beta\pi r \qquad (4)$$

2. Cauchy filter pupil function $f_c(r)$:

$$f_c(r) = \frac{1}{1+\beta^2 r^2} \ldots \qquad (5)$$

where β: The normalized distance between an arbitrary location on the pupil and its center is denoted by r, and the apodization parameter shows the degree of non-uniformity of pupil transmission.

2.2 *Blur Models of Digital Images*

Noise reduction is a crucial stage in picture processing:

1. Conventional The scene is out of focus when projected onto a 2-D picture plane. The circle of confusion (COC) is a small disk that represents the picture of any point source that is out of focus in a three-dimensional scene [9].
2. Air turbulence blur: During the remote sensing process, a number of factors, including exposure duration, temperature, and wind speed, can result in air turbulence [10].
3. Linear motion blur: when an object moves in relation to the camera during exposure, this type of blur occurs. There are several ways to categorize motion blur, but they are all caused by relative motion, rotation, or a transition between the scene and the recording device [11].
4. Inadequate lighting (nighttime photos or dark scenes): Pictures with inconsistent lighting and low contrast result in a lot of intensity variation [12].

2.3 *Image Quality Measurement Parameter*

- **PSNR (Peak Signal-to-Noise Ratio)** is a standard quantitative indicator for benchmarking and comparing image processing or reconstruction algorithms; higher PSNR values usually signify that the reconstructed image departs less (in an MSE sense) from the reference, and thus suggest better fidelity [13].
- **(EME): Enhancement Measure Equation** The difference in squared intensity of each pixel in the original and enhanced photos is

measured by an equation that may be computed by computing the average differences [13].

- **Entropy:** One important step in the preprocessing procedure is entropy. methods for image processing that divide a picture into its constituent parts based on the density of its core pixels, a greater score indicates a higher level of clarity and information produced in the image [13].

3. Proposed Methodology

In this section, we first introduce a general framework for our enhancement technique. The proposed method applies experimental procedures to the test images based on the Point Spread Function (PSF). The algorithm for enhancing degraded images, which relies on the application of a filter mask, is illustrated in Figure 1.

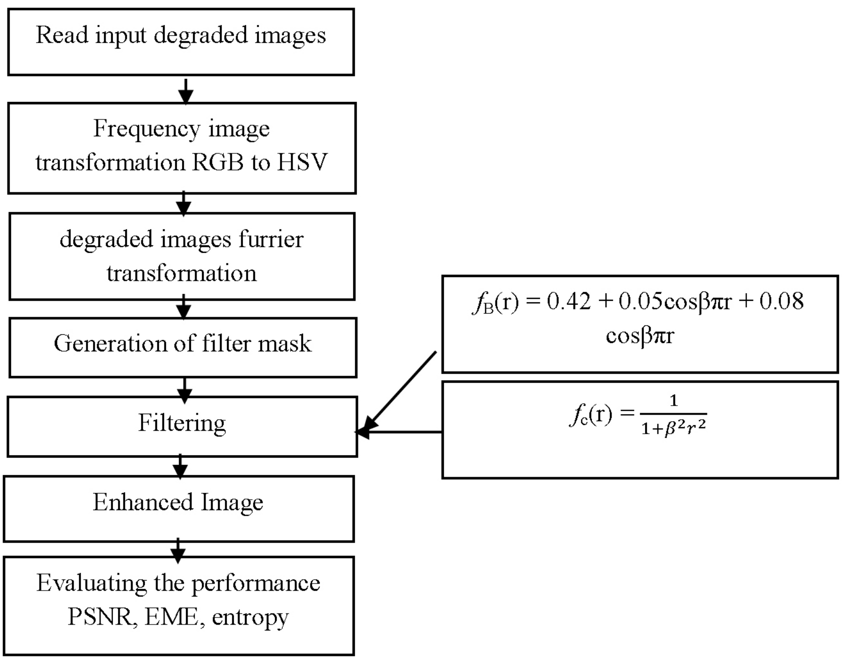

Figure 1

Diagram of the suggested imagine enhanced technique based on filter mask implementation

A stepwise description of the proposed algorithm is as follows:

Step 1: Make a fusion of images in different spaces (1^{st} and 2^{nd} Algorithms), with two images fusion (3^{rd} Algorithm).

1^{st} Algorithm

Converting from RGB image to HSV image [12]

Input: color space image RGB

Output: HSV color space

Step 1: Read the images x_1 & x_2

Step 2: v =the Max. of x_1 (R, G, B)

$\Delta = M_1$-Min. of x_1

O = (M_1=0, Δ * 255/ v)

If O=0

H value=0

Else

If R value=v

H' = (G - B)/ D

elseif G_{reen}=M_1

H' = 2 + (B - R)/ D

Else

H' =4 + (R - G)/ D

End

If H'>0

H'=6

End

H'' = H'* 255/6

End

Step 3: final output HSV image

2nd Algorithm

Refine the source image according to the combined appearance of the two images.

Input: color space image RGB

Output: make Fusion of image

Step 1: Make read the original input image.

Step 2: Make Save size of all original RGB image's in pixels.

Step 3: Image conversion RGB to HSV

Step 4: Apply CLAHE to the HSV images (image #H).

Step 2: Involves applying the mask filter on each pixel in the source image after producing it by eqs. (4, 5).

3rd Algorithm

Use the suggested three filters to improve the image from step 1.

Input: Load the image H

Output: Calculate Entropy, PSNR, and EME.

Step 1: Perform Fourier Transform (FT) on the input image H

Step 2: Implement the Blackman filter using the equation:

$$fB(r) = 0.42 + 0.05\cos\beta\pi r + 0.08\ \cos\beta\pi r$$

Step 3: Create the filter mask.

Step 4: Convolve the Fourier-transformed image with the designed filter mask to obtain image G.

Step 5: Apply the inverse Fourier Transform (IFT) to image G.

Step 6: Display the processed image.

Step 7: Calculate the Entropy, PSNR, and EME metrics for all input images.

Step 8: Provide an enhanced quality rating of the processed images.

To apply Cauchy, filter the same previous algorithm is applied and replace step 2 with equation (5).

4. Enhancement process result and discussions:

This study targets illumination and contrast enhancement through pupilfunction derived filters, with the algorithm implemented and evaluated in MATLAB. The test images (240 × 240 pixels, 8bit intensity) were sourced from publicly available online repositories. Figure 3 illustrates representative results: the first column lists the degraded inputs, whereas the subsequent columns show outputs produced using a Cauchy pupilfunction mask tuned at the optimal β values.

Tables 1 and 2 show the effect of different β values on deteriorating photos (Figures 2, 3) as well as the extent of improvement based on the quality criteria PSNR, EME, and Entropy that were applied.

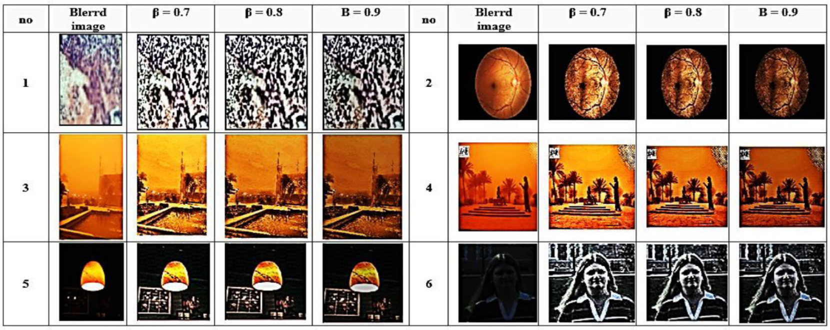

Figure 2

Different effect (β) values on images using the equation Blackman filter's pupil function (no. 4)

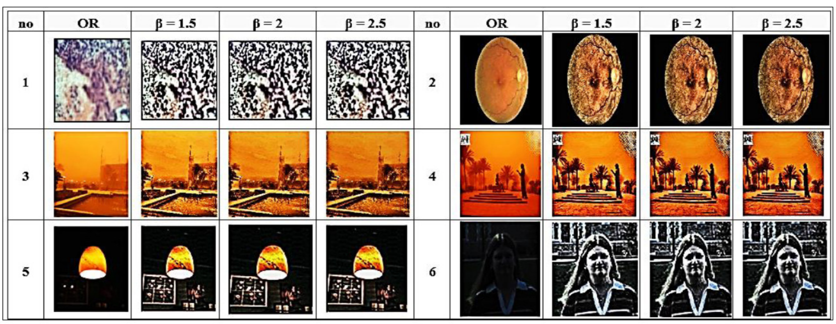

Figure 3

The effect of different (β) values on images using equation Cauchy filters pupil function (no. 5)

Table 1

Numerical values of quality measurement parameter using Blackman filter's pupil function equation (no. 4)

QS	No.	OR	β = 0.7	β = 0.8	β = 0.9	No.	OR	β = 0.7	β = 0.8	β = 0.9
PSNR	1	Inf dB	10.984362	12.354506	11.616720	2	Inf dB	20.555671	21.493341	18.459782
EME		189.83440	189.91488	189.91488	189.91488		287.00000	286.99668	286.99668	286.99668
Entropy		6.95216	6.70405	6.55893	6.26513		4.60790	4.79403	4.71314	4.45113
PSNR	3	Inf dB	18.079023	18.059273	13.751811	4	+ Inf dB	17.311357	18.291841	14.563864
EME		160.77629	160.78134	160.78134	160.78134		285.99943	286.22790	286.22790	286.22790
Entropy		7.66008	7.03828	6.97722	6.59130		7.43969	6.96407	6.89587	6.51534
PSNR	5	+ Inf dB	16.186464	17.921932	18.062628	6	+ Inf dB	9.807616	12.217927	15.728926
EME		176.25949	175.04335	175.04335	175.04335		189.21874	190.04695	190.04695	190.04695
Entropy		4.71338	6.23461	6.00192	5.67188		5.66479	7.25225	7.01342	6.66578

Table 2

Numerical values of quality measurement parameter using equation Cauchy filter's pupil function equation (no. 5)

QS	No.	OR	β = 1.5	β = 2	β = 2.5	No.	OR	β = 1.5	β = 2	β = 2.5
PSNR	1	+ Inf dB	11.855443	12.206863	12.391595	2	+ Inf dB	22.482810	22.197430	21.251940
EME		189.83440	189.91488	189.91488	189.91488		288.88232	288.87948	288.87948	288.87948
Entropy		6.95216	6.66186	6.60105	6.52077		4.79151	5.37283	5.16868	5.22250
PSNR	3	+ Inf dB	19.017527	18.677614	17.64073	4	+ Inf dB	18.55825	18.61831	18.007923
EME		160.77629	160.78134	160.78134	160.78134		285.99943	286.22790	286.22790	286.22790
Entropy		7.66008	7.06611	7.00013	6.89369		7.43969	6.98317	6.91851	6.81287
PSNR	5	+ Inf dB	7.38743	7.30781	7.21047	6	+ Inf dB	10.91272	11.644317	12.542634
EME		169.57176	169.38216	169.3821	169.38216		189.21874	190.04695	190.04695	190.04695
Entropy		4.71338	6.13078	6.05754	5.96722		5.66479	7.14718	7.07076	6.97707

Qualitative inspection confirms that the apodization parameter β is pivotal: tuning β strongly influences the visual outcome for both filters. For the Blackmanbased mask, the overall best setting is β=0.8; however, for lowlight enhancement (Images 5 and 6) the highest entropy is achieved at β=0.7. The highest EME occurs for the poorly illuminated case (Image 6), indicating a contrast gain. Entropy values further show that the proposed mask preferentially improves lowcontrast / lowillumination images (e.g., Images 2 and 6), whereas EME varies only marginally across β. For the Cauchy mask, the optimal quantitative performance is obtained at β=2.5. PSNR is also sensitive to β\betaβ, changing as the parameter is varied

5. Conclusion

In this paper, un explored and successfully implemented of novel enhancement technique for optical images in different illumination and poor contrast. We proposed a physical pupil function technique based on the amplitude of the point spread function. To correctly the light, and enhance the contrast we develop a robust two filters based on the pupil function. The proposed filters have the benefits of preserving edges and reducing low lighting. Our experiments showed that the proposed methods are suitable for poor optical imaging. Depending on the highest values of PSNR, EME, and Entropy, the first technique. In our experiments, we found that depending on the value of apodization parameters β for constant (r).

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