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Image Resolution Enhancement for Parabolic Apodized Optical System

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Abstract.

The major information for the images, in general, is encoded in their structures, details, and, edges. These ingredients need to be processed in special ways to get proper image resolution enhancement as well as possible. In this paper, we have developed an algorithm that can yield significant enhancement of contrast and resolution in the image. We derived and investigated the intensity point spread function with the parabolic mask equation as a new technique to achieve image enhancement. We also investigate the connection between the apodized parabolic filter in the proposed intensity function and the images. First, solving the apodized intensity PSF problem by a sequence of forwarding problems. Secondly, by appropriately selecting the initial data, we try to minimize the poor resolution of the image. Preliminary results indicate that the numerical results seem to be an improvement over the standard method.

Keyword: Enhancement Image, Resolution, Parabolic Apodized filter, PSF.

Introduction

Resolution is often referred to as an important aspect of the image. Enhancement of image resolution is one of the classical research subjects of image processing, this can improve the contrast of input degraded images (such as low-brightness images) or non-uniform illumination, foggy or blurry image, and high dynamic range images [1, 2]. These situations occur due to poor light sources and improper focus during image capture. In addition to diffraction and lens aberrations, it can also cause an image of an ideal point to be smeared on a blurred point that occupies a limited area of the image plane [3]. The main purpose of image enhancement or enhancement is to modify the characteristics of an image to improve its quality so that it is more appropriate for a specific task and a specific viewer or viewer. For getting the desired improvement, we first, derived then solving formula to calculate the apodized IPSF [4] for optical imaging system with circular aperture depending on pupil function technique, then we enhance adaptively the intensity using parabola filtering [5] for a different amount of the apodization parameter (β) for different conditions of transmission (δ).second, [16-36]after investigated theoretically the performance of our optical system, by choosing the initial data for β and δ we applying the parabolic filtering to enhancement resolution of low light level images. Experimental results show that algorithm proposed to ensure the image details and obtains better visual results.

Literature Reviews

According to the properties of the optical system and output images, some works introduced priors to study and analyze these images to make a suitable enhancement. Liu et.al. [6] proposed a method to enhance noisy optical coherence tomography images based on collaborative shock filtering; they proved the sharpness denoised image by shock-type filtering for enhancement detail and edge. Bardish et.al. [7] Investigated the backward parabolic equation to obtain a smooth denoised image. Hasikin et.al. [8] Presented an image enhancement technique depending on fuzzy method to improved lighting, irregularity, and low-contrast images. Nandan et.al. [9] Made a comparison of various methods for image resolution enhancement. Their studies depend on enhancing the resolution of MR images taken by an orderly camera. Thirupathi et.al. [10] Studies the full width at half maximum FWHM of the intensity distribution for optical system involves a set of filters of Higher-Order parabolic. They demonstrate these filters are improving the resolving power of optical systems. Dzyuba [11] showed that it can increase the depth of focus for times less compared with the unapodized lens. By increasing the degree of the apodization function, it can reduce the point spread function distortions .

Methodology

1. Mathematical Formulation

The implementation of the imaging system can make quantified by computing its intensity distribution (IPSF) [4, 12]. The PSF encodes the incoherent light emitted by the intensity point source object within the optical system to the propagation of the photo detector array. To PSF measure it's essential to decide object size can be regarded as point. Mainly affected by pixel size of instrument. A pixel is the smallest element that recorded in space of image. The brightness value indicates the average radiation over the small portion for the scene of image. The Pixel size usually related to detector size. If only part of the detector is illuminated, the output stream equals that gained for the same total radiation energy absorbed by the detector but averaged on the entire indicator area. No details can be smaller than a pixel resolved in an image. In the same way, the intensity PSF of a goal can be portrayed as the spatial variety of the force of the picture got at the identifier plane when the point of convergence is edified by an ideal point source. Its qualities incorporate the accompanying standards: For a linear space invariant imaging system, the image can be calculated by convolving a function that characterizes the transmittance t (x, y) or reflectance r (x, y) of the sample with the PSF of the system [12, 13].

The amplitude PSF of the lens, H(x, y) defined as transverse spatial variation of the amplitude of an image received on the detector plane when the lens is illuminated by a point light source. Make Fourier transforming to pupil function [14] $f(x, y)$; the complex amplitude can be expressed in point (u, v) for image plane (u, v).

$H(u,v) = \frac{1}{y}\iint f(x,y).e^{i2\pi(ux+vy)}\,dxdy \ldots (1)$

u, v: Refers to the dimensionless coordinates; y refers to the area of the exit pupil. $f(x,y)$: Pupil function of optical system which can be expressed by parabolic filter:

$f(x,y) = (\delta+\beta(x^2+y^2))^N \ldots (2)$

β: Denote the apodization parameter.

δ: Numerical constant less than one which controls the transmittance of the aperture.

Now the distribution intensity for images formed by an optical system apodized can compute depending on the squared modulus of equation (1).

$I(u,v)= |H(u,v)|^2 \ldots (3)$

$I(u,v) = F|\int\int(\delta+\beta(x^2+y^2))^N\, e^{i2\pi(ux+vy)}dxdy|^2 \ldots (4)$

And For circular apodized aperture, the limits of the integral can be expressed by:

$I(z) = F|\int_{-1}^{1}\int_{-\sqrt{1-y^2}}^{\sqrt{1-y^2}} (\delta+\beta(x^2+y^2))^N\, e^{izx}\,dxdy|^2 \ldots (5)$

In Eq. (5) F is a constant, which is usually chosen so that the maximum value of H(x, y) is equal to 1.

2. Formation of filter mask and the proposed algorithm

After the determination of intensity distribution for an apodized optical system. We check the effect of our apodized filter to improve the quality of visual images through subjective assessment to be able to apply the mask properly. The proposed algorithm using the integral image is summarized in Algorithm 1.

Step 1: The first step in our image enhancement algorithm is to perform the Fourier Transform of the input image; the result from this step is the image in frequency domain.

Step2: the second step is to generate the mask depending on equation 2, then the filter is applied to each pixel in the original image (i.e., proportional to the mask size). Finally, applied IFT to the tested images. Combine the text filter with the result from this last step, we then can generate the final output image. The proposed algorithm using parabolic filer is summarized in Algorithm 1.

Algorithm 1: an algorithm for enhancement image using parabolic filter
Step 1: Read image of proper

Step 2: Save input image size (pixels)
Step 3: make input image of Fourier Transform
Step 4: Assign the parabolic equation: $f(x,y) = (\delta + \beta(x^2 + y^2))^N$
Step 5: Designing filter
Step 6: image of Fourier Transformed Convolve with filter mask
Step 7: Make Inverse Fourier Transform for convoluted image
Step 8: Display output image of resulting

3. Numerical Results

This section is divided into two parts: first, the aim of calculating the intensity distribution of optical systems is to manifest numerical results of the proposed apodized IPSF model and its behavior for the various value of δ, β values. Second, to verify our optical method, we investigate the behavior of the parabolic filter on five test degraded images. Computed the intensity distribution values implemented using the MATHCAD program, while MATLAB programming was used in the enhancement processing step. The intensity distribution is plotted as a function of distance in Figure 1 and figure 2 for the evaluation of (full width at half intensity FWHM for some typical values of δ (0, 0.25, 0.50 & 0.75) and β (0, 0.2, 0.4, 0.6, 0.8 & 1). For forth-order N, the FWHM criterion is very suitable for measuring the resolution of apodized optical system [12], these criteria is defined, as the name suggested, as the Full-Width at Half- Maximum point source response.

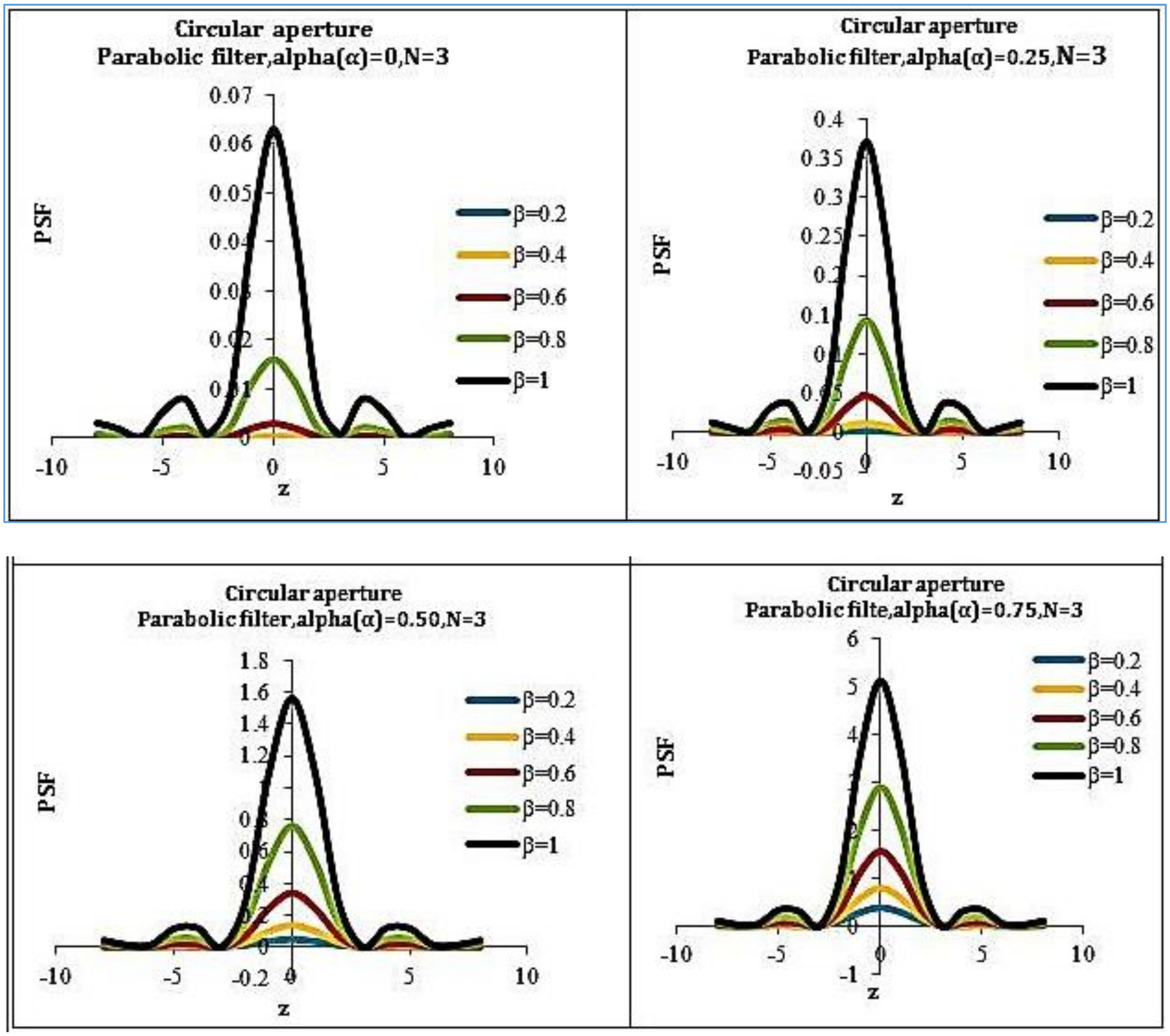

Figure (1): Variation of IPSF Curves with α for Various Values of β, N=3.

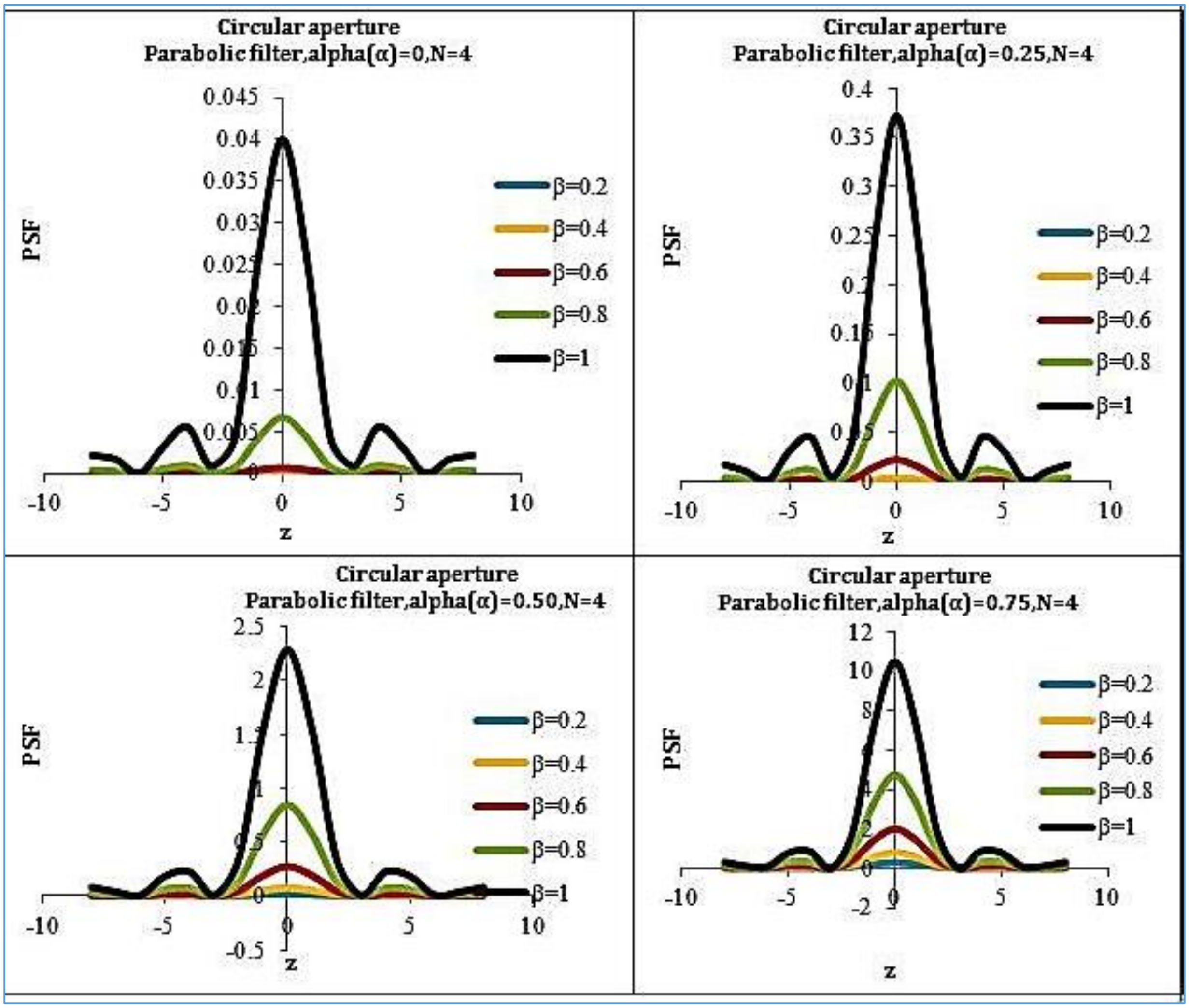

Figure (2): Variation of IPSF Curves with α for Various Values of β, N=4.

The Figure (1-a), has pointed out method to FWHM value evaluate from the corresponding IPSF curve. It’s evidenced from tables (1, 2) is depending on the fact that the average of the third-order FWHM is 2.466 diffraction units, and the average of the fourth-order FWHM is 2.385, which is smaller than the Raleigh classic resolution limit (3.83 units) of an ideal or diffraction-limited optical system.

Table (1): FWHM values at N=3

β	**α=0**	**α=0.25**	**α=0.50**	**α=0.75**
0.2	2.3	2.7	2.9	2.9
0.4	2.3	2.6	2.7	2.8
0.6	2.4	2.5	2.7	2.7
0.8	2.3	2.5	2.6	2.7
1	2.3	2.5	2.6	2.6

Table (2): FWHM values at N=4

Circular aperture		**Parabolic filter**		**(FWHM), N=4**
β	**α=0**	**α=0.25**	**α=0.50**	**α=0.75**
0.2	2.2	2.5	2.7	2.8

0.4	2.2	2.4	2.5	2.6
0.6	2.2	2.3	2.4	2.5
0.8	2.2	2.3	2.4	2.4
1	2.2	2.2	2.3	2.4

To observe enhancement effects by our method more obviously. We tested our algorithm computationally by evaluating the performance our algorithm proposed on the low-quality image captures in different atmospheric conditions considered in Figures 2,3 which consists of the images of five different subjects. We chose the fourth-order of the parabola filter because it gets more resolution than other orders, as we indicate in computing the proposed optical model. Figure (3) shows the resultant of images after apply the fourth-order parabolic mask as in equation (2), the values of $\delta\ and\ \beta$ chosen to get biter result for output images.

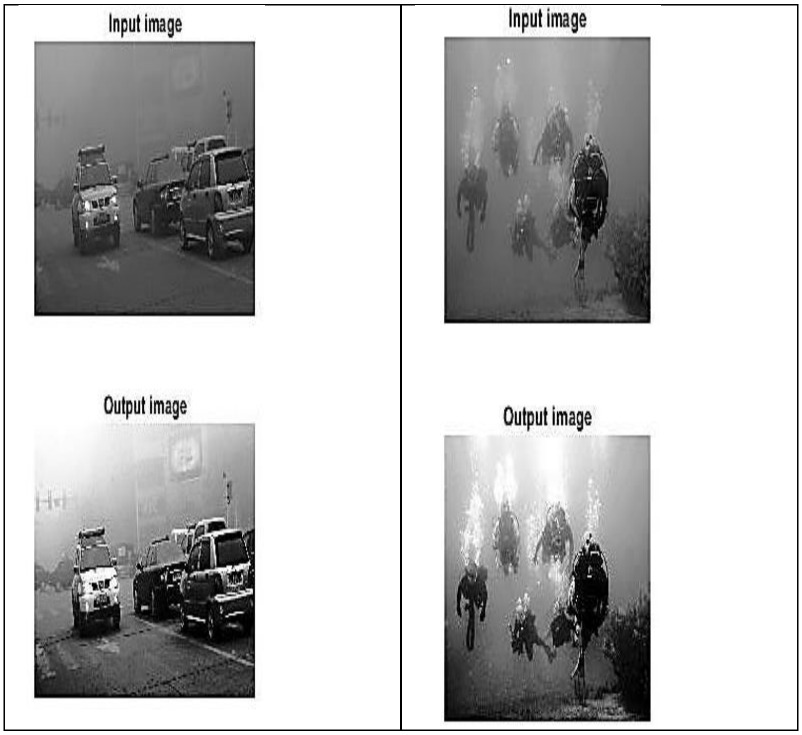

Figure (2) Original image and image after applying parabolic filter.

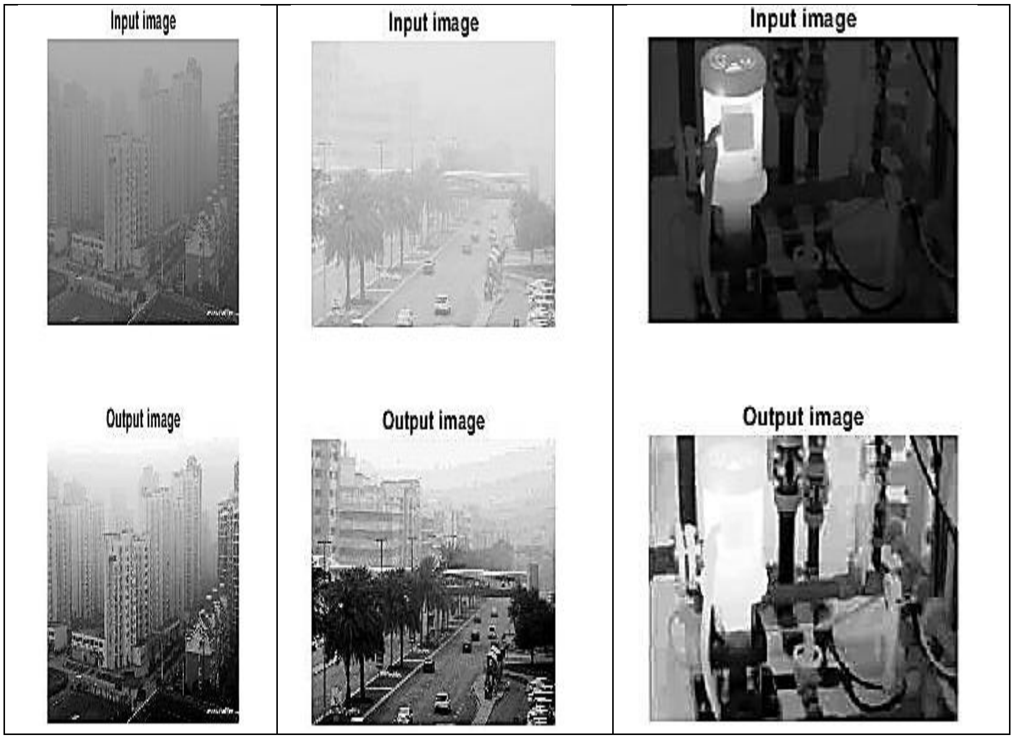

Figure (3) shows the image before and after applying of parabolic filter.

Image Analysis

Not only implementation of the proposed algorithm evaluated by the perfection of image appearance, but also by quantitative terms measure. The conception of improveing image quality in the human visual system is internal. Therefore, this paper uses effective enhancement of image quality metrics (EME) [15] to analyze the improvement of the algorithm. Obtained by dividing the image into multiple blocks and using the equation:

$$\text{EME}= 1/M_1M_2 \sum_{l=1}^{M2} \sum_{M}^{M1} 20 \log \frac{I_{\max(M.L)}}{I_{\min(M.L)}} \ldots (6)$$

M_1, M_2: Horizontal number with vertical blocks in images.
$I_{max}(M, L)$, $I_{min}(M, L)$: Maximum and minimum pixel values for given block [16].

Table3. The EME measure values computing by using eq.6 for five tested images, and the applied parabola filter provides better enhancement.

Image #	**EME input image**	**Proposed Method**
1	8.03	8.89
2	10.52	11.70
3	9.09	14.29
4	4.58	5.24
5	17.25	26.27

Conclusions

Theoretical apodized PSF models are derived from modeling the low light optic images using a parabolic equation to offers the best brightness preservation as well. The procedure is based on pupil function techniques. We also investigated the connection between the order of the parabolic equation and the FWHM. With this connection established, we found that the average values of FWHM become less as the order of the parabolic equation is increases which indicates increasing the image resolution. Last, we tested our algorithm computationally to five tested low-light images. The result of the EME measure shows that the applied parabola filter for the fourth-order provides better enhancement.

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