OUT OF FOCUS BLUR ESTIMATION USING GENETIC ALGORITHM

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Keywords: Blur identification, Out of focus, Wiener Filter, Genetic Algorithm.

Abstract - Blur identification is the most important step of image restoration. Since now, many researchers have presented methods to estimate out of focus blur, but most of these methods suffer the additive noise. In this paper, a method is presented to estimate out of focus blur in noisy images precisely. Proposed method uses two rough estimate of blur function parameter, and then the real parameter is calculated using a genetic algorithm. The structure of out of focus blurring function was analyzed in frequency domain to develop a precise method. Experimental results showed proposed method was very precise.

1. INTRODUCTION

Blurring procedure is modeled as following equation in literature [3]:

\[ g(x, y) = h(x, y) * f(x, y) + n(x, y) \]  \hspace{1cm} (1)

In this equation, \( g, f, n \) and \( h \) are observed image, original image, additive noise (usually Gaussian), and PSF of blurring system, respectively. To restore original image using the observed image, the blurring function \( h \) should be estimated. The employed procedure to estimate this function is called blur identification [2]. There are two categorize of image restoration methods; in the first group, the restoration method restores images without exact estimation of blur and noise (these methods usually are called Blind Restoration). These methods are not dependent on the blur type. The EM (Expectation - Maximization) method belongs to this group. Second group of restoration methods use estimated blur. The restoration process in this group of algorithms is more precise than the first ones. Out of focus blurring is the most famous blurring function that occurs frequently in images. Several methods have been presented to estimate out of focus blur. The proposed method uses the properties of wiener filter restoration and Bessel function to estimate out of focus blur. To identify real parameter, two rough estimate of blur parameter are employed. To restore blurred image wiener filter is used. With Regards to the properties of out of focus blur function in frequency domain and structure of wiener filter a genetic algorithm estimates out of focus blur parameter. We have supposed that the noise model is Gaussian with zero mean. Also, we presented exhaustive experimental results in statistical form which can be used in method evaluation.

The rest of paper is organized as follows: In section 2 blur model and its parameter are presented. In section 3 the blur estimation method is proposed. Experimental results are introduced in section 4 and finally we have concluded our conclusion in section 5.

2. OUT FOCUS BLUR MODEL

In most cases, the out of focus blur caused by a system with circular aperture can be modeled as follow [3]:

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1 This paper has been supported by research fund of Shahid Beheshti University based on the contract no 600//1719/1103
In this equation $R$ is the radius of COC (Circle of Confusion). It has been shown in [9] that an accurate and complex physical model does not result in significantly restoration than this geometric model. By considering equation (2) to find blurring function it is significant to find $R$. The frequency response of (2) which is called OTF (Optical Transfer Function) is defined in (3) that is based on a Bessel function of the first kind [10]:

$$H(u, v) = \frac{J_1(R\sqrt{u^2 + v^2})}{R\sqrt{u^2 + v^2}}$$  \hspace{1cm} (3)

Where $J$ is the Bessel function of first kind and $R$ is radius of COC. "Fig.1" shows the frequency response of equation (2) with specified radius.

### 3. Blur Estimation Method

With Regards to (2) to estimate blurring function, it is enough to estimate the $R$ parameter that is radius of COC. To do it, we need some mathematical observations. Suppose that the radius of COC in equation (2) is $R$. If we consider another blurring function that its parameter is $R_1$, then with regards to (3):

$$H_{1(u,v)} = \frac{J_1(R_1\sqrt{u^2 + v^2})}{R_1\sqrt{u^2 + v^2}}$$  \hspace{1cm} (4)

Using (3) and (4) we can conclude that:

$$\frac{H(u, v)}{H_{1(u,v)}} = \frac{J_1(R\sqrt{u^2 + v^2})}{J_1(R_1\sqrt{u^2 + v^2})}$$  \hspace{1cm} (5)

The equation (5) concludes the following equation at the frequency center [1]:

$$\lim_{(u,v)\to 0} \frac{H(u, v)}{H_{1(u,v)}} = \frac{R}{R_1}$$  \hspace{1cm} (6)

At now, Wiener filter is employed to restore degraded image. The wiener filter equation in frequency domain looks like the following equation:

$$W(u, v) = \frac{H^*(u, v)}{|H(u, v)|^2 + K}$$  \hspace{1cm} (7)

Or

$$W(u, v) = \frac{1}{H(u, v)} \cdot \frac{|H(u, v)|^2}{|H(u, v)|^2 + K}$$  \hspace{1cm} (8)

In these equations $W(u, v)$ shows wiener filter in frequency domain, $H(u, v)$ shows the frequency response of degradation function and $K$ is a constant that models signal to noise ratio. As it is shown in (7) and (8) wiener filter works in frequency domain; therefore, equation (1) should be converted to frequency domain version as following equation [2]:

$$G(u, v) = F(u, v).H(u, v) + N(u, v)$$  \hspace{1cm} (9)

In this equation, $G$, $H$, $F$, and $N$ show the frequency response of observed image, blurring function, original image, and additive noise respectively. To restore a degraded image; the following equation can be used:

$$F'(u, v) = G(u, v).W(u, v)$$  \hspace{1cm} (10)

$F'$, $G$ and $W$ show restored image frequency response, observed image frequency response, and wiener filter in frequency domain respectively. Because observed image is already available; $W(u, v)$ that is based on $H(u, v)$ and $K$ should be estimated. The restoration process can be completed using these estimated parameters. Therefore, frequency response of degradation function ($H(u, v)$) and $K$ should be estimated.

Estimating signal to noise ratio which can be used in wiener filter to restore original image is addressed in [6]. The method presented in [6] employed a genetic algorithm with MSE (Mean Square Error) and IAWE (Image Activity Weighted Error) as its measure to estimate $K$. A genetic algorithm in a similar way will be presented here to estimate out of focus parameter. To present this genetic algorithm: At first, a arbitrary COC radius ($R_0$) is used to create a degraded function ($H_d$). If $H_d$ is used to restore original image, then

$$F_d(u, v) = G(u, v) \frac{H^*(u, v)}{|H(u, v)|^2 + K}$$  \hspace{1cm} (11)

With regards to (11) and (9); (12) should be concluded:

$$F_d(u, v) = (F(u, v).H(u, v) + N(u, v)) \frac{H_d^*(u, v)}{|H_d(u, v)|^2 + K}$$  \hspace{1cm} (12)

It is obvious that DC part of degradation function ($H_d(0, 0)$) should be 1, therefore, if additive noise average is assumed as zero, with regards to (6); the following equation can be concluded:
\[ F_a(0,0) = \frac{R\cdot F(0,0)}{(1+K)\cdot R_a} \] (13)

It is obvious that \( H(0,0) = 1 \), therefore, \( F(0,0) = G(0,0) \) can be concluded. However, in the equation (13) the \( F_a(0,0) \), \( K \) and \( R \) are unknown parameters and \( R_a \) and \( F(0,0) \) are known ones. If the equation (13) is solved to find \( R \) then:

\[ R'_a = \frac{F_a(0,0) \cdot R_a \cdot (1+K)}{G(0,0)} \] (14)

\( R'_a \) is the estimated \( R \) using \( R_a \). If a proper \( K \) for wiener filter is estimated, \( F_a(0,0) \) can be calculated. Therefore, finding the \( R \) is possible by using \( F_a(0,0) \). The proposed genetic algorithm can estimate \( K \) and \( R \) simultaneously. To create a proper fitness function, another arbitrary parameter \( R_b \), its degradation function \( h_b \), and its corresponding restored image are needed. With Regards to (13) we can conclude that

\[ F_b(0,0) = \frac{R\cdot F(0,0)}{(1+K)\cdot R_b} \] (15)

Consequently

\[ R'_b = \frac{F_b(0,0) \cdot R_b \cdot (1+K)}{G(0,0)} \] (16)

The proposed genetic algorithm is presented as below:
1. Randomly generates some zero and ones values. The created string is called gentype.
2. Normalize the value of gentype.
3. Use the value of normalized gentype as estimation of \( K \) and apply wiener filter on corrupted image using \( H_a \) and \( H_b \) to find \( F_a \) and \( F_b \).
4. Calculate \( R'_a \) and \( R'_b \) by using (14) and (16).
5. select and keep the best \( K \) that minimizes \( \text{abs}(R'_b - R'_a) \)
6. Cross over and or mutate the gentype to obtain new generation.(The cross over rate was selected as 0.3)
7. Repeat above steps till finding the best result of \( K \).

After running this algorithm, we have found the \( K \) value regarding to optimized \( R \). Estimated values of \( R'_b \) or \( R'_a \) shows estimated value of \( R \).

4. EXPERIMENTAL RESULTS

To validate proposed method; a test bed that consist of more than 100 images was created. This test bed consists of standard images like Lena, Baboon, Barbara, etc that were degraded randomly by out of focus and additive Gaussian noise. The interval of random degradation parameter \( (R) \) was \([2::16]\) and the random noise variance \( \sigma^2 \) was \([0.01::0.6]\). The resolution of all images in the test bed was 256*256. After creating this test bed, proposed algorithm ran on these images. Table 1 shows some real parameters and their estimated values using proposed algorithm and Table 2 shows the average error and its standard deviation in presented method. This algorithm was able to estimate degradation parameter in images with high level of noise. “Fig.2” shows a blurred image and its corresponding estimated parameter using presented method. “Fig.3” shows a degraded image and its restored result using wiener filter.

![Image](image1.png)

**Fig. 2.** Columbia picture which was degraded by \( R = 11 \) pixel and \( SNR = 55 \) dB pixels. Estimated values for this image using our algorithm were \( R = 11:1 \) pixels.

![Image](image2.png)

**Fig. 3.** (a)-Baboon picture which was degraded by \( R = 8 \) pixel and \( SNR = 35 \) dB pixels. (b)- Restored image of (a) using wiener filter and our algorithm

| Real R | Estimated value | Noise Variance |
|--------|----------------|----------------|
| 4      | 4.78           | 0.15           |
| 6      | 7.5            | 0.25           |
| 8      | 9.7            | 0.32           |
| 10     | 10.4           | 0.1            |
| 12     | 10.5           | 0.35           |
| 14     | 16.3           | 0.4            |

Table 1. value of some estimated parameter v.s real ones

| Error Average | Error Std | Noise Average variance |
|---------------|-----------|------------------------|
| 1.76          | 1.5       | 0.3                    |

Table 2. Average and Standard Deviation of Errors in parameter estimation in proposed algorithm
5. CONCLUSION

In this paper, a precise and robust method is presented to estimate the out of focus blur function. In spite of other presented method since now, our method has no constraints and it can work on all defocused noisy images. This method estimates precisely blur parameters by using a genetic algorithm which was designed base on analysis of the image frequency response. The genetic algorithm estimates signal to noise ration and degradation parameter. To test this method some degraded images that additive noise were added to them were used. The type of image degradation was known and the presented method was used to estimate its parameter. The experimental results were satisfactory. In future work we are going to develop a method that can estimate the parameter more precisely.

ACKNOWLEDGMENT

We are appreciating to thank research chancellor of Shahid Beheshti University for financial support of this research.

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