

Removal of Radiometric Degradation Using Blur Invariants in Wavelet Domain

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Abstract—Radiometric degradation and geometric distortion is a general problem in the image restoration considering many applications. The goal of image restoration is to create complete description of the original image from a degraded observation. The degradation may include blur, losses of information due to testing, quantization effects and different source of noise, camera misfocus, and atmospheric turbulence. There are many researches going about effort to deblur such image. To manage this problem various blur invariants to exist. The wavelet domains blur invariants that are centrally symmetric to blur. Blur invariants are constructed from different wavelet function. In this paper, image registration is done by using blur invariants. Template image is chosen in the degraded images using similarity the template image is matched with the original image. Even in the severely degraded images the images are accurately registered using Daubuchies wavelet functions, compared to the spatial domain blur invariants which may result in misfocus registration of an image. The proposed method, image restoration is above using Daubechies and B-Spline Wavelet function. Then a regression based process is going about to produce an image convolved with near diffraction limited PSF, which can be shown as blur invariant. Eventually, a blind deconvolution algorithm carried out to remove diffraction limited blur from the linear image to create the final output. It is used in many different fields of application such as photography deblurring, remote sensing, medical imaging, and forensic science.

Index Terms: Image restoration, Blur Moment Invariants, Centrally Symmetric Blur, Image Registration and Wavelet Transform.

1 INTRODUCTION

Image restoration is a great issue in high level image processing. Image is continuously degraded during the data acquisition process. The degradation may include blurring; different source of noise, during testing information will be loss and quantization effects. The necessity of image restoration is to implement the real image from the degraded image. It is used in many different fields of application such as photography deblurring, medical imaging, remote sensing and forensic science etc. Images are used to store or display gathered information. Due to blur in the imaging and capturing process, the stored image always represents a degraded version of the real image. The unchangeable of these blur is involved to many of the following image processing work. There include an extent range of various degradation which are to be taken into process, for circumstance noise, geometrical degradation (pin cushion distortion), light and color blur (under/overexposure, saturation) and imperfections.

The blurring is a form of bandwidth instance of an ideal images till to the blur image formation process. It can produce an effect by comparing motion between the cameras and real image, or/by an optical system (i.e.) misfocus. When air photographs are produced for remote sensing necessity, blurs are introduced by air turbulence, aberrations optical system and compared motion between the camera and the earth such imperfection image is not kept to optical image for example electron micrographs are collapsed by spherical aberrations for electron lenses. In addition to these blurring effects, noise always collapses any stored image. The noise may be introduced by the medium through which the image is produced. (random absorption or scatter effect) by the storing medium (sensor noise), by scaling errors due to the acquisition of the storing system and by the quantization of the image for digital storage. The area of image restoration (sometimes called as image convolution or image deblurring) is concerned with the creature or implement of the encrypted image from imperfect and noisy image. Basically, it tries to do an operation on the image (i.e.) the reverse of the blur in the image formation system in this use of image restoration method, the properties of the degradation system the noise are pretended to be known priori. In live situations however one may not be able to observe this information directly from the image formation process. The goal of imperfections identification is to implement the attributes to if the blur imaging system from the obtained degraded image itself prior to the restoration process. The Imaging process is not correct if there is no control on the object. Photos of people under supervision and

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medical images are real-world objects that are uncontrollable during acquisition. The environmental facts also have a pessimistic effect on clarity of picture, for example, conditions due to atmosphere and the long distance between camera and scene can worsen the image quality. Distortion in images are classified into two types, they are, (i) geometric distortion (ii) radiometric degradation. The geometric distortions are used to change different forms, measuring and rotation. Radiometric degradations were developed in the image due to motion of the object, camera misfocus and non-standard image capturing nature. The basic model which generally used for observed signal is,

$$y(n) = Bx(n) + Z(n) \quad (1)$$

$y(n)$ is the observed signal, $x(n)$ and $z(n)$ are the actual signal and noise and B is distortion operator. If it is assumed that B is linear and space invariant, for 2-D discrete signals, the general model can be simplified to,

$$y[n_1, n_2] = b * x[n_1, n_2] \quad (2)$$

The suggested approaches are classified into two types. They are (i) blind restoration (ii) direct analysis. In the blind restoration method, an ill-posed problem exists. It is widely used method but it is costly. Direct analysis method, focusing on introducing descriptors that are inherently invariant to blur. These invariant descriptors were introduced in spatial domains which are based on geometric moment that believes that the blur operator exactly matches. The blur invariants are developed in the Fourier domain along with the spatial domain. Along with these domains the wavelet descriptors were also developed which are centrally symmetric blur systems. In wavelet domain blur invariants provide different alternative wavelet function and scaling function. Blur moment invariants are mainly used in image registration [1], remote sensing [2], forgery detection and recognition.

In practical applications image consist of different degradations due to the state of distortions with blur, which can result from impression turbulence, misfocus or with reference to motion between camera and the picture. The degradation perform is given as a linear shift-invariant system, the relation between ideal image $f(x, y)$ and an observed image $g(x, y)$ is given by,

$$g(x, y) = f(x, y) * h(x, y) + n(x, y) \quad (3)$$

Where $h(x, y)$ is the point spread function of the system, $n(x, y)$ is noise and $*$ denotes 2D convolution the point spread function $h(x, y)$ denotes blur during other degradation are captured by the noise term $n(x, y)$. All the image registration methods are easily offended to blur, which may result in distortion registration. To the excellent of our knowledge, the

only proposing blur invariant 2D registration method are based on the blur-invariant features (BIF) originally proposed by Flusser and Suk in [3, 4]. They used these spatial BIFs under image moment for matching template to a bigger blurred image. In this paper, wavelet domain blur invariants [5, 6] are proposed for image registration. The two dimensional image registration captured from the same scene at different from times, viewpoints or sensors is a fundamental image processing. Including all surveys about the briefly recognized 2D image registered in [7]. The image registrations are registered using feature based method i.e. wavelet based method. This wavelet domain blur invariants are demonstrated are discussed. Ojansivu and Heikkilä [11], however, proved that Flusser's invariants are sensitive to noise when applied in the Fourier domain because of their use of a tangent operator. They proposed a different representation of invariants in the Fourier domain. Subsequently, they made them invariant to the affine transform as well [12].

In this paper, wavelet domain descriptors are proposed, which are invariant to centrally symmetric blur. The merits of these invariants will include the exploration of a directional extension of the multidimensional wavelet transform called wavelets. The rest of the paper is organized as follows. In Section-2 the preliminary definition is described. Section-3 and Section-4 covers the existing method and proposed method. The experimental results are presented in Section-5. Finally, the related conclusions are given in Section-6.

2 REVIEW OF DEFINITIONS

In this section, the some of the common definitions [6, 7] are examined.

Definition 1: Image is a true discrete function

$$x \in L^1(Z^2) \quad (4)$$

Definition 2: The general geometric moment of order $(p + q)$ of x in the spatial domain is described by,

$$m_{p,q}^x = \sum_{n_1 \in N_1} \sum_{n_2 \in N_2} n_1^p n_2^q x[n_1, n_2] \quad (5)$$

Definition 3: The centroid of signal x is

$$c_1^x = \frac{m_{1,0}^x}{m_{0,0}^x}; c_2^x = \frac{m_{0,1}^x}{m_{0,0}^x} \quad (6)$$

Definition 4: The central moment of order $(p+q)$ of x is described by,

$$\mu_{p,q}^x = \sum_{n_1 \in N_1} \sum_{n_2 \in N_2} (n_1 - c_1)^p (n_2 - c_2)^q x[n_1, n_2] \quad (7)$$

Definition 5: The moment of wavelet function $\Psi(x)$ is zero still to order $M_{\Psi-1}$, it is told $\Psi(x)$ has M_{Ψ} vanishing moments.

3 EXISTING METHOD

Blur invariants main idea is to describe object by a set measurable quantities called invariants. Blur invariants are used in the image registration. Initially it is explained how the blur operator represents itself in the wavelet domain. Then ordinary and central moments are developed in wavelet domain. The relation between the moments of signal and moments of wavelet transform of signal was extracted. Then the relationship between the moments of wavelet transform of blurred signal and those of wavelet transform of original signal are extracted. We must choose proper wavelet to construct blur and moments. The invariants are constructed using different wavelet function. WDBI allows, the blur system to be centrally symmetric,

$$b[n_1, n_2] = b[-n_1, -n_2] \quad (8)$$

This is ordinary format for various blur system, e.g., misfocus, atmosphere distortion and linear motion. From the above function the images are registered.

A. Blur in wavelet domain:

The wavelet transform of a blurred image with wavelet function Ψ_L is,

$$W^{\Psi_L} y[n_1, n_2] = b * W^{\Psi_L} x[n_1, n_2] \quad (9)$$

Where,

B=point spread function

B. Moment in wavelet domain:

Ordinary and central moments are developed in that domain and relationship between the moments of the wavelet transform of signal. The ordinary moment of order $(p+q)$ of $W_x^{\Psi_L}$ is,

$$m_{p,q}^{W_x^{\Psi_L}} = \sum_{i=0}^p \sum_{j=0}^q \binom{p}{i} \binom{q}{j} (-1)^{i+j} m_{p-i,q-j}^x m_{i,j}^{\Psi_L} \quad (10)$$

C. Wavelet domains blur invariants:

The blur system is assumed to be centrally symmetric ($b[n_1, n_2] = b[-n_1, -n_2]$) which is a general format for different blur systems, e.g., Defocus, atmosphere turbulence, and linear motion. Image registration is done by using these invariants as shown in Fig1.

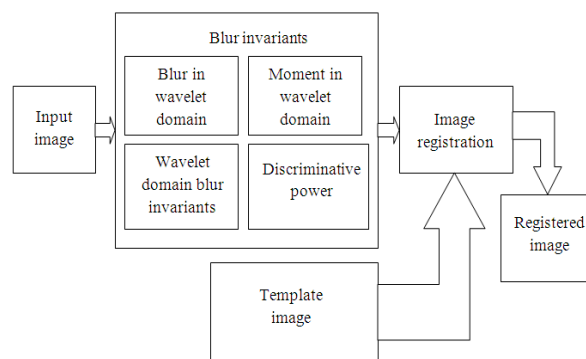


Fig. 1. Block Diagram of Image Registration

D. Discriminative power:

It is mainly used to avoid null spaces by applying another wavelet function. Blur invariants are zero when signal and wavelet function are both centrally symmetric.

E. Image registration:

Image registration is the process of changing different sets of data into one coordinate system. Data may be multiple photographs, data from different sensors, from different times, or from different viewpoints. Registration is done by using different wavelet function.

Wavelets and multiresolution have many applications related to the Biometric area such as data compression and noise removal. The Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and is characterized by a maximal number of vanishing moments for some given support. Daubechies has shown that it is impossible to obtain an orthonormal and compactly supported wavelet that is either symmetric or anti symmetric except for Haar wavelets. B-Spline is a spline function that has minimal support with respect to a given degree, smoothness, and domain partition.

B-Spline wavelets are capable of being applied to signals and functions of any smoothness. A fundamental theorem states that every Spline function of a given degree, smoothness, and domain partition can be uniquely represented as a linear combination of B-Spline of that same degree and smoothness, and over that same partition. B-Spline is a function of unusual property. B-Spline of a given order can be cleared as a linear combination of measured and translated version of itself.

Based on this wavelet function image registration task is done. Using these wavelet functions the image can be accurately registered when compared to the spatial domain blur invariants. The measure used to calculate the similarity of the template to every Section of the image is Similarity Index and it is given by,

$$s_{i,j} = \exp \left(- \sum_{n=1}^N \left| \frac{B^{y_{i,j}}(n) - B^x(n)}{B^x(n)} \right| \right) \quad (11)$$

B (n) is the array of calculated invariants, x is the template and $y_{i,j}$ is a section of the target photo with its center at (i, j).

4 PROPOSED METHOD

The main aim is to restore the image by using wavelet transform in order to obtain high PSNR values. The template image is marked from the degraded image. This is registered using Daubechies and B-Spline wavelet function.

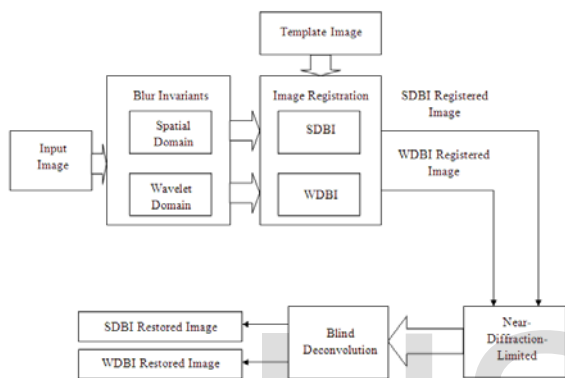


Fig. 2. Block Diagram of Image Restoration

It is found that images can be registered clearly and accurately using WDBI than SDBI. This template image is now restored using near diffraction limited and blind deconvolution algorithm in the proposed work. Followed by registration, near diffraction limited image reconstruction restores a single image from the registered image. At last, blind deconvolution algorithm based on real image statistics is estimated to take away the diffraction limited blur and to increase image quality.

A. Near diffraction limited image reconstruction:

Near diffraction limited image reconstruction is mainly used to obtain high resolution of an image.

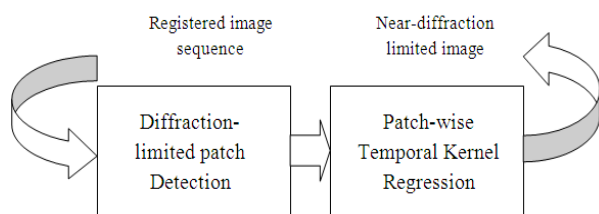


Fig. 3. Block Diagram of Near Diffraction Limited Image Reconstruction

Reconstruction Procedure:

1. The given registered sequence $\{R_k\}$, is divided into $L \times L$ overlapping patches centered at each pixel,

and calculates the intensity variance of each patch as a local sharpness measure.

2. For a patch sequence $\{r_k\}$ centered at location x, detect the sharpest one r_{k^*} by maximizing local sharpness measure.

3. Set r_{k^*} as a reference patch, and restore its center pixel value using temporal kernel regression. Assign this value to the pixel $Z[x]$.

4. Go to the next pixel and return to step 2.

The kernel regression is a non-parametric technique in statistics to estimate the conditional expectation of a random variable. The general model of the kernel regression method is,

$$\hat{z}(x) = \arg \min_{z(x)} \sum_j [r_j(x) - z(x)]^2 U(l, j) \quad (12)$$

$$U(l, j) = \exp \left(- \frac{\|r_l - r_j\|^2}{\mu} \right) \quad (13)$$

$U(l, j)$ - Weights measure the similarity.

μ - is the smoothing parameter

Final solution is,

$$\hat{z}(x) = \frac{\sum_j U(l, j) r_j(x)}{\sum_j U(l, j)} \quad (14)$$

In the proposed method all the weights are positive. When the diffraction limited value, hence it was restored image as near diffracted image.

B. Blind deconvolution:

In image processing, blind deconvolution is a deconvolution technique that permits recovery of the target scene from a single or set of blurred images in the presence of a poorly determined or unknown Point Spread Function (PSF). Finally, a single image deblurring algorithm is need as a post-process to deconvolve the near diffraction limited image z.

Blind deconvolution algorithm can be characterized by following equation is,

$$\langle \hat{F}, \hat{h} \rangle = \arg \min_{F, h} \|Z - F \otimes h\|^2 + \lambda_1 \phi_1(F) + \lambda_2 \phi_2(h)$$

ϕ_1 is the Natural image statistics

ϕ_2 PSF Regularization

Finally restored image is obtained by using blind deconvolution algorithm shown in experimental results.

5 ALGORITHM

Step 1: Load the input image.

Step 2: Introduce motion blur.

Step 3: Choose template image from the degraded image.

- Pick out which part of template from degraded image by using cropping option for any image size.

Step 4: The template image is matched with original image, (i.e.) using similarity. Image is registered by Spatial Domain Blur Invariants (SDBI) and Wavelet Domain Blur Invariants (WDBI).

- In SDBI high pass filter is used to register an image.
- In WDBI Daubechies and B-Spline wavelet functions is used to register an image.

Step 5: Now template image is restored using ND Image Reconstruction.

Step 6: Finally blind deconvolution algorithm is used to obtain restored image.

6 EXPERIMENTAL RESULTS

In this experiment, the real world degraded images are gained by own ability and the invariants are utilized by registration. The spatial domain blur invariants are used for a comparison of wavelet domain blur invariants. In this experiment Daubuchies wavelet function are excited and moments of order up to $10(r + s = 10)$ is chosen. An original image of size 256×256 and its degraded image affected by motion blur are taken into account as shown in the figure 4.a and figure 4.b respectively.

Template image of size 96×91 is taken from the degraded image which is shown in the figure 4.c. The template image is matched with the blur image by the similarities. After using similarity the image is registered by SDBI and WDBI. The results of SDBI and WDBI image registration is shown in figure 4.d and figure 4.f respectively. In WDBI the image was registered accurately, where as the exact location is missed by SDBI registration. The robustness of the method was also verified for images with severe blurs.

The registration by WDBI has been perfectly performed despite of severe blurs compared to SDBI registration method. This template image is now restored using near-diffraction limited image reconstruction and blind deconvolution algorithm as shown in figure 4.f to 4.i. At last, blind deconvolution algorithm based on real image statistics is estimated to remove the diffraction limited blur and to increase image quality. For blind deconvolution, the PSF is estimated from the image or image set, allowing the deconvolution to be performed.

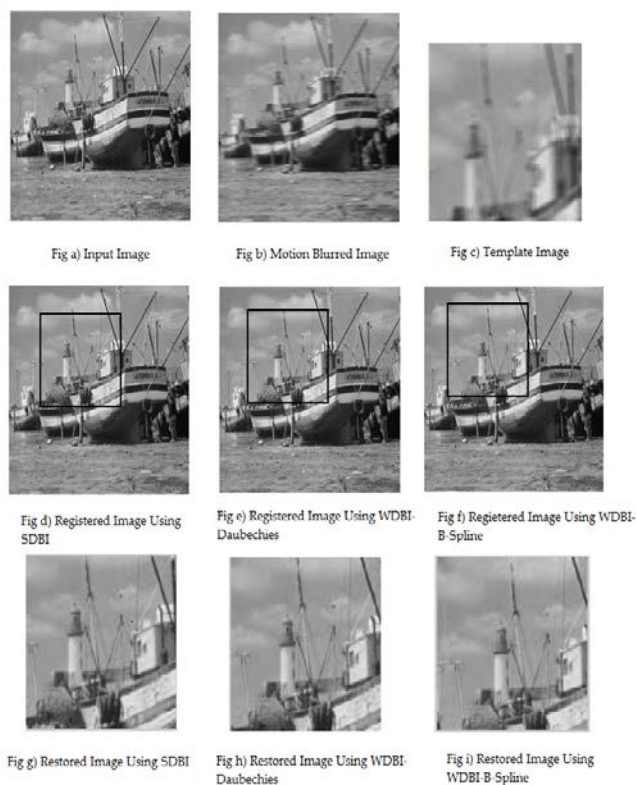


Fig. 4. Boat Image a) Input Image b) Motion blurred image c) Template image d) Registered image Using SDBI e) Registered image Using WDBI-Daubechies function f) Registered image Using WDBI-B-Spline function g) Restored image Using SDBI h) Restored image Daubechies function i) Restored image Using WDBI-B-Spline function

Here Wiener filter is used for image restoration. Wiener deconvolution is an application of the Wiener filter to the noise problems inherent in deconvolution. It works in the frequency domain, attempting to minimize the impact of deconvoluted noise at frequencies which have a poor signal-to-noise ratio.

The Wiener deconvolution method has widespread use in image deconvolution applications, as the frequency spectrum of most visual images is fairly well behaved and may be estimated easily.

The results obtained are tabulated in Table 1 and Table 2. For the image quality to be high and clear, the PSNR values must be high.

A. PSNR:

This PSNR is often used as a quality measurement between the original and a reconstructed image.

Table 1.1 and Table 1.2 shows the PSNR values of SDBI and WDBI Restored image used for different template image using blind deconvolution algorithm respectively.

$$PSNR = 10 \log \left(\frac{255^2}{MSE} \right) \quad (16)$$

Where,

MSE=Mean Square Error value.

It is defined as,

$$MSE = \left(\frac{1}{M \times N} \right) \sum_{i=1}^M \sum_{j=1}^N (X_{ij} - Y_{ij})^2 \quad (17)$$

Where,

M×N=Size of the Blur Image,

X_{ij}, Y_{ij}=pixel values of the original image and Blur image respectively.



Fig 1. Input Image

Fig 2. Motion Blurred Image



Fig 3. Template Image



Fig 4. Registered Image Using SDBI



Fig 7. Restored Image Using SDBI



Fig 5. Registered Image Using WDBI Daubechies Function



Fig 8. Restored Image Using WDBI Daubechies Function



Fig 6. Registered Image Using WDBI B-Spline Function



Fig 9. Restored Image Using WDBI B-Spline Function

Fig. 5. Experimental Results for Car Image



Fig 1. Input Image



Fig 2. Motion Blurred Image



Fig 3. Template Image



Fig 4. Registered Image Using SDBI



Fig 7. Restored Image Using SDBI



Fig 5. Registered Image Using WDBI Daubechies Function



Fig 8. Restored Image Using WDBI Daubechies Function



Fig 6. Registered Image Using WDBI B-Spline Function



Fig 9. Restored Image Using WDBI B-Spline Function

Fig. 6. Experimental Results For Group Image

TABLE 1.1 PSNR values of SDBI and WDBI Restored image for template image of size is 97x96

Template Image of size (97X96)	Spatial Domain	Wavelet Domain	
		Using Daubechies Function	Using B-Spline Function
Lena	19.9137	21.6663	26.5944
Boat	16.4451	19.2594	24.9335
Group Image	20.3878	22.1617	27.6022
Elaine	22.5224	24.7847	30.0970
Barbara	26.8935	28.8421	34.2108

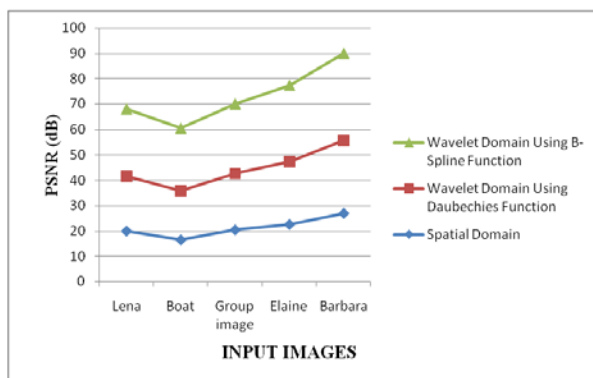


Fig. 7. Comparison Graph of Restoration Results in PSNR (dB) of SDBI and WDBI for template image of size 97x96

Fig 7 and Fig 8 shows that comparison graph of restoration results in PSNR (dB) of SDBI and WDBI used for various template image of size.

TABLE 1.2 PSNR values of SDBI and WDBI Restored image for template image of size is 97x96

Template Image of size (93X91)	Spatial Domain	Wavelet Domain	
		Using Daubechies Function	Using B-Spline Function
Cameraman	13.6545	16.1917	22.8769
Baboon	14.8503	17.5936	23.2173
Car	21.2428	22.2389	26.4360
Parrot	22.3629	24.7278	26.3749
Group Image	20.3878	22.1617	27.6022

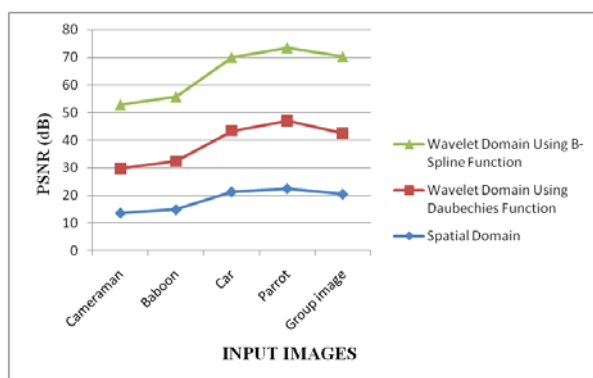


Fig. 8. Comparison Graph of Restoration Results in PSNR (dB) of SDBI and WDBI for template image of size 93x91

6 CONCLUSION AND FUTUREWORK

In this paper, new set of blur invariant descriptors has been proposed. These descriptors have been advanced in the wavelet domain 2D and 3D images to be invariant to centrally symmetric blur. First, Image registration was done using wavelet domain blur invariants. The method uses

Daubechies and B-Spline wavelet function which was used to construct blur invariants. The template image was chosen from the degraded image. The template images and the original images were matched with its similarities.

This wavelet domain blur invariants accurately register an image compared to spatial domain blur invariants which might result in misfocus registration of an image. Despite of the presence of harmful blurs, the image registration has been correctly performed. The experiments carried out by using SDBIs, were failed in some of the image registration.

Then regression based process is done about to produce an image convolved with near diffraction limited PSF, which can be shown as blur invariant. Eventually a blind deconvolution algorithm is carried out to remove the diffraction limited blur from fused image the final output. Finally, image was restored by using blind deconvolution algorithm and also PSNR values are calculated. Hence the image quality is improved.

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