Blind Restoration Method for Satellite Images using Memetic Algorithm

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ABSTRACT
Restoration of degraded satellite images are in demand. The sources of degradation can be aliasing, blur, noise and atmospheric turbulence, which are usually an ill-posed in nature. This paper introduces Memetic algorithm for image restoration. Previous restoration techniques have been investigated, but except for certain special cases the maximum cases solve the resulting criterion approximately only. So there is a requirement of more demanding optimization methods. A Memetic algorithm herein proposed give efficient image representation by using hill climbing method for population initialization and using extended neighborhood search. The algorithm is performed on a quickbird test satellite image for the optimization of result. The optimization codes are written in Matlab. The proposed method shows 25% improvement from degraded image. Competitively our new approach performs better than some best existing methods. to demonstrate the effectiveness of the proposed method, comparisons are given from the existing methods.

General Terms
Image restoration, Hill Climbing, Fitness Function, Genetic Algorithm

Keywords
Memetic Algorithm, PSF, Extended neighborhood Search, PSNR

1. INTRODUCTION
Images are generated to produce the useful information but due to imperfections in imaging and capturing process, recorded or generated images represent a degraded version of original image or scene [1, 2, 4]. These imperfections are very difficult to remove. It is crucial task in image processing. The bandwidth of an ideal image is reduced due to blurring and making an image into the imperfect image. Degradation can be caused by motion between the object and camera, an out of focus optical system, aberrations in optical system and atmospheric turbulence [3]. Noise is also always present to corrupt the signal. Noise can be introduced by random absorption of optical system and the image is created by which medium that is also responsible. Noise is also a major source of degradation. Image restoration of these degraded images are long standing problem in image processing for remote sensing images. Image restoration can also be known as image deblurring or image denoising. Locating an edge of an image is known as edge detection process. Edges are containing very meaningful information. Edge detection is an important step in image processing feature extraction [4]. Sometimes a satellite image is itself sufficient to acquire the information. Satellite image is usually corrupted by blur, aliasing and noise. To reflect the better radiometric & Geometric quality of image, it needs to be processed [5]. Image restoration is performing a inverse operation of the imperfections on the image in the image forming system. Plain FIR filter have limitation to remove the noise [6]. Assuming the characteristics of the noise and degrading system are a priori. The estimation of the features of the imperfect imaging system from the observed image is called blur identification [7]**.** Blurring function can also be known as *point-spread function d (n, k)* is time independent variable. It is assumed that the point-spread function is constant throughout the image or spatially independent.

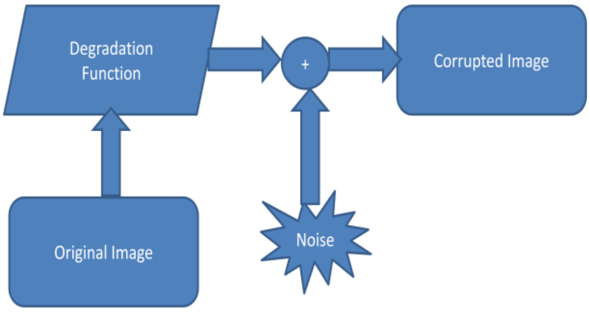

Fig. 1 Degradation Model

These assumptions can be mathematically described as follows.

$$g(n,k) = d(n,k) * f(n,k) + w(n,k) \qquad (1)$$

The original discrete image is denoted by *f (n, k)* that does not have any noise and blur and the degraded image is modeled as *g (n, k)* [8]- [10].

The *w (n, k)* is the additive Gaussian noise. It corrupts or destroys the blurred signal. The goal of image restoration process is making an approximate *f' (n, k)* of the original signal *f (n, k)* from the corrupted or degraded signal *g (n, k).* The noise is considered to be white and having zero mean [10].

2. IMAGE RESTORATION
There are many algorithms and techniques that are used for image restoration. Every algorithm and technique has its own features and attributes. Generally image restoration techniques have been classified into two categories. These techniques estimates both PSF h and the desired image f, from the given degraded image g. and allows the reconstruction of original images from degraded images no knowledge about PSF. These techniques are very difficult to implement and a little bit complicated as compared to non blind restoration. When there is a priori knowledge about the degradation function or about the PSF. Then this technique is very much useful. Reconstruction of image with full iteration is insensitive to noise and able to reconstruct the image with partial data but these algorithms are very challenging and would take so much time. Now a day's DWT is become the standard tool for image compression [11, 12].

In early applications of image restoration [13] is widely used and adopted. The wiener filter is having very high efficiency that is why still it is widely used. [14]. After that projections onto convex sets, the regularization and maximum posterior (MAP) are also very popular for image restoration. Sparse restoration and nonlocal means are also used for image restoration. Recently a method used is marginal likelihood optimization (MLO) method which estimates the PSF first, then making the estimation of image. Maximum methods fall into the joint methods category. Image and blur are estimated in frequency domain in an iterative blind deconvolution algorithm (IBD) method. Maximum likelihood methods and MAP method is proposed in wavelet domain. It is worth to note that majority of blind restoration methods are having an assumed size of set PSF [15]-[22].

2.1 Genetic and Memetic Algorithm

In this paper we are presenting a Memetic algorithm in which population is initialized by hill climbing method and local search is based on the extended neighborhood search. The more fit individuals are produced in the beginning phase because of using hill climbing method for selective initialization. This optimization converges to a minimal point because a global as well as local search criterion is used. Genetic algorithms are based on natural selection and evolution. Genetic algorithm is a early search algorithm. It starts with random initialization of population .if the population initialization is good then good results come while poor initialization of population are tending to give poor results. Convergence of the algorithm is possible globally in case of poor initialization. In genetic algorithm population is generated by iteration process [23].

Memetic algorithm is introduced by Dawkins and it is inspired by memes. Meme is the unit of information. In Memetic algorithm memes are the carriers to propagate part of mental ideas like stories, knowledge, information and gossip. Memetic algorithm is the hybridization of genetic algorithm with local search.

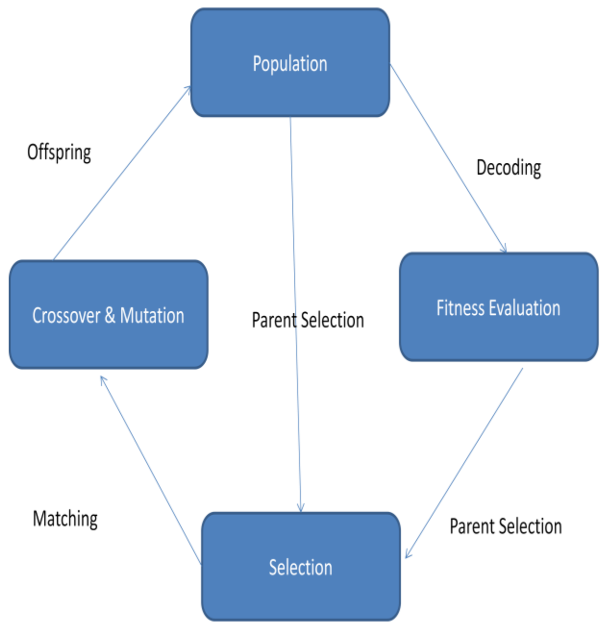

Fig 2.Flow Chart of Genetic Algorithm

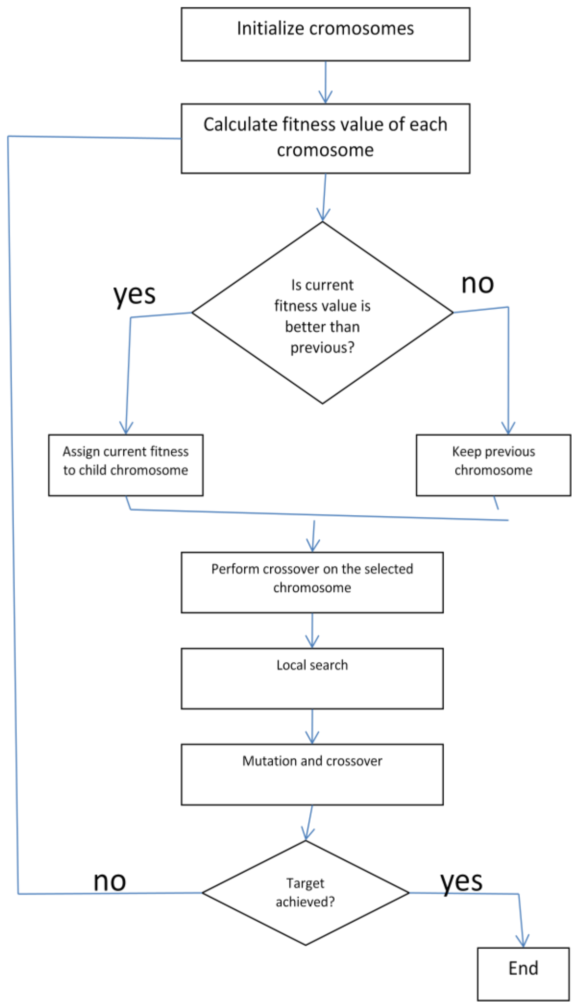

Fig.3 Flow Chart of Memetic Algorithm

Hill climbing algorithm consists of following steps [24].

1. Start. Randomly generate population of solutions.
2. Generate neighbours till better solution not found (better) solution depends upon fitness value of each individual.
3. New solutions become the parent solutions.
4. Repeat step 2 for new solutions.
5. Terminate if no improvement in parent solution.

The generated new population are called offspring population. Each offspring individual is further optimized by a local search method called extended neighbourhood search. Firstly it will search a small area near the current solution and after reaching to the local optima the search step size increase to reach the global optima.

3. PERFORMANCE EVALUATION

The quality of image can be evaluated by two methods, subjective assessment and objective assessment. Visual observation is generally comes under the subjective assessment and one or more parameter of the model come under objective assessment. The proposed method is tested on quickbird test image. Two performance metrics are used to evaluate the objective assessment of recorded image .Those are peak signal-to-noise ratio and the metric Q, used for the comparison. The ideal value of PSNR is $+\infty$. Metric Q reflects the amount of noise and blur blindly. Image quality will be higher with high value of Q.

$$MSE = \frac{1}{M\,X\,N}\sum_{i}^{n}\sum_{i}^{n}\left(\hat{f}(i,j) - f(i,j)\right)^2 \qquad (2)$$

$$PSNR = 10\,X\log\frac{(f_{max} - f_{min})^2}{\text{MSE}} \qquad (3)$$

Where M x N is the size of image , $\hat{g}(i,j)$ and $f(i,j)$ are the pixel values at $(i,j)^{th}$ position of restored and original image respectively. f_{min} and f_{max} are the minimum and maximum intensity values of the gray image. Ideally the minimum and maximum values of gray image are 0 to 255.
For the gray images having 300 x 300 pixels and intensity values between 0 to 255, the PSNR is given as

$$PSNR = 10\,X\log\frac{255^2}{\frac{1}{300\times 300}\sum_0^{299}\sum_0^{299}\left(\hat{g}(i,j) - f(i,j)\right)^2} \qquad (4)$$

According to the Memetic Algorithm the initial population is formed first and the image is converted into two dimensional gray image having 256 colors.

A particle is denoted by the image and the dimension of the particle is denoted by gray value of an image. If, to generate the initial population all possible gray values are used, then the total possible images will be $2^{8\times M\times N} = 2^{300\times 300}$ is very large in number, where M number of lines, N number of columns and gray value 256 is used. The possible numbers of images are very large for a small 300 x 300 image. So it becomes necessary requirement to preprocess the initial population. Hill climbing method is used to preprocess the initial population and preprocessing of degraded image they represent only a part of initial population. If the degradation model is assumed to be linear then the equation (1) can be written in matrix form as.

$$g = H * f + n \qquad (5)$$

$$\|n\|^2 = \left\|g - H * \hat{f}\right\|^2 \qquad (6)$$

Where $\hat{f}$ denotes the estimate of original signal f, * is convolution operator and $H * \hat{f}$ is restored image .fitness function can be describe as

$$fitness(f_i) = \left\|g - H * \hat{f}\right\|^2 \qquad (7)$$

Where f_i the restored value and g is denotes the degraded value. The aim of restoration is to find the best restored value f_i. To store the best result f_i and f are compared but both these values are unknown..The information is available only about the degraded image. The generation of g_i will be same as that of f_i and both the values are compared .The smallest value is selected as restored image f that is close to original image. The smallest value of $fitness(f_i)$ function decides the best restored value and restoration will reach at optimal value [25].

4. SIMULATION RESULTS

The simulations are done on a real pre-processed high quality quickbird remote sensing image. The original and blurred images are shown in fig.4 (a) and fig.4 (b) respectively.

Fig. 4(a) Original Quickbird Test Image

Fig. 4(b) Blurred Image

The experiments are performed with standard deviation σ = 2.1 and 5x5 Gaussian blur. Subimages are formed by cropping the images into 300x300, for the restoration process. Fig. 4(b) is a blurred image having 5x5 Gaussian blur with standard deviation σ = 2.1.

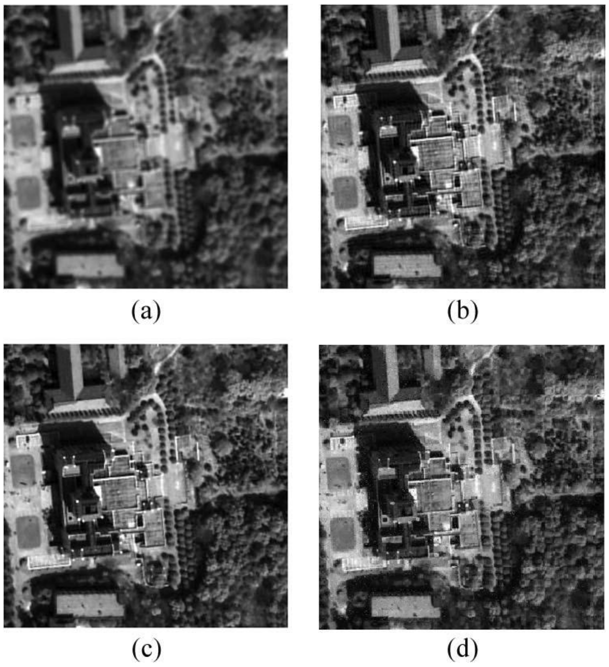

Fig.5 Restored Results of Noise free Case (a) Degraded Image (b) IBD Method (c) MLO Method (d) Restored Result of Proposed Method

Fig 6. Restored Results of Noisy Case (a) Degraded Image (b) IBD Method (c) MLO Method (d) Restored Result of Proposed Method

5. COMPARATIVE ANALYSIS

The proposed method is iterative and it is tested on noisy and noise free images. Noise free image is obtained by adding Gaussian blur of 5 x 5 and standard deviation σ = 2.1 to the original image whereas noisy image is generated by adding Gaussian noise (PSNR=20dB) into the blurred image. To validate the performance of proposed method, comparisons are done with IBD method and MLO method. The restored results of noise free and noisy case are shown in fig.5 and fig.6 respectively. Evaluated results are shown in bar chart. It can be seen in fig.7 and fig.8 that in either the absence or the presence of noise, the proposed method works well and it is less sensitive to noise.

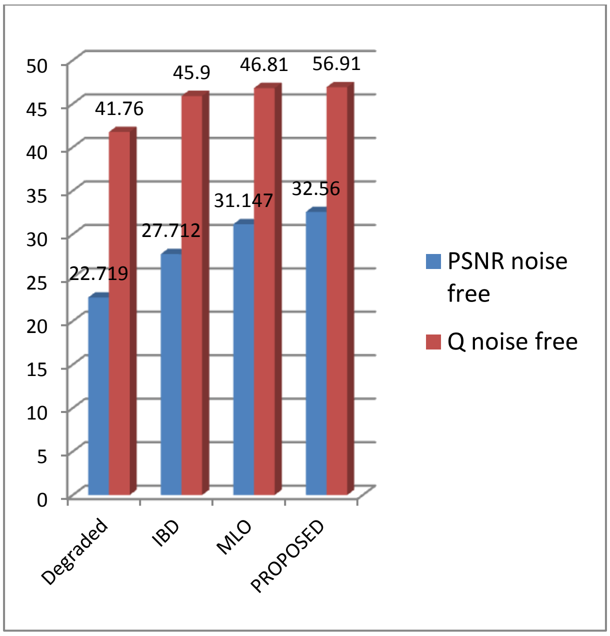

Fig. 7 Bar Chart of Noise Free Case

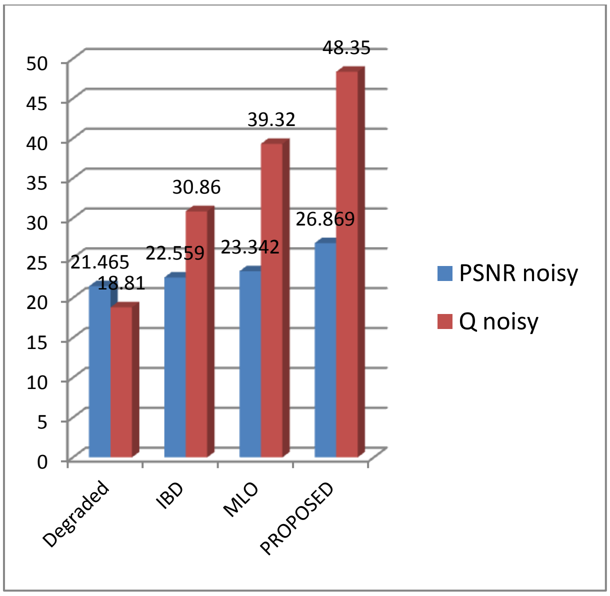

Fig. 8 Bar Chart of Noisy Case

The value of PSNR is higher in comparison to MLO and IBD methods. From the fig.5 and fig.6 one can see that proposed method is much effective than other methods because the restored images of the proposed method are very sharp and effective. Fig.9 shows the percentage improvement of PSNR for IBD, MLO and proposed method from the degraded image in the noisy case. The proposed method shows 15% higher PSNR from the MLO and 16% higher PSNR from IBD method.

Table 1 Quantitative Results of Noise-Free and Noisy Case

Image	Noise Free Case		Noisy Case	
	PSNR	Q	PSNR	Q
Degraded	22.719	41.76	21.465	18.81
IBD	27.712	45.90	22.559	30.86
MLO	31.147	46.81	23.342	39.32
Proposed	32.56	56.91	26.869	48.85

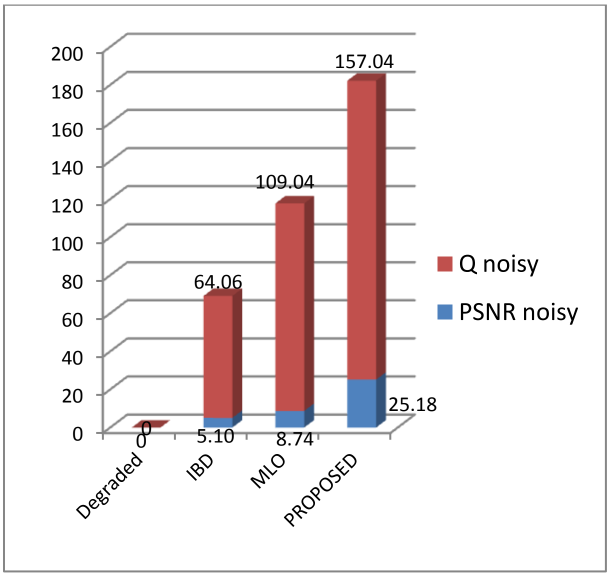

Fig. 9 Bar Chart of % improvement in Noisy Case

6. CONCLUSION

The proposed technique exploits the Memetic algorithm with extended neighbourhood search that does not require large number of iteration. The optimal results are obtained with less number of iteration. The proposed method provides the flexibility to restore results degraded by linear and non –linear function. The proposed method has analyzed the reason of degradation and reviewed some of the restoration techniques. The proposed method gives new restoration technique using Memetic Algorithm and the local search is done by extended neighbourhood criterion**..** This method is performed well on visually as well as quantitatively and it can be seen by experimental results. Through the experimental results one can see that proposed method performs visually as well as quantitatively. It is showing 25% improvement in PSNR from the degraded image while MLO and IBD show 9% and 5% improvement respectively. However this proposed method is considerable amount of computationally expensive.

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