Hybrid Optimization of Dual Tree Complex Wavelet Transform for Enhancement of Low Light Images

Eiti Jain, Navneet Agrawal

Abstract— In low light situation, the dynamic range of the occupied image is low due to the distortion of the contrast and results in heavy noise planes. So an efficient approach is needed to increase the performance in low intensity scenarios. In this paper, the authors have tried for optimizing the situation for the low intensity images using filtering and optimization approach. Firstly, the image is pre-processed using the bilateral filtering and then the Dual Tree Complex Wavelet Transform (DT-CWT) is performed for the normalization. Optimization is achieved by hybridization of Ant Colony (ACO) and Particle Swarm Optimization (PSO) to reduce the mean square error (MSE) rate and achieving high peak signal to noise ratio (PSNR). Using this approach we are getting very good result with enhanced quality parameters like Peak Signal to Noise Ratio, Mean Square Error, Discrete Entropy(DE) and Absolute Mean Brightness Error (AMBE) in addition to Colorfulness. PSNR gets improved by 14.26 dB, MSE by 6.28, DE by 1.44, AMBE by 5.49, and Colorfulness by 11.266.

Index terms— Ant Colony optimization, Bilateral filter, Dual Tree Complex Wavelet Transform, Hybridization, Image processing, light intensity, Particle swarm optimization.

1 INTRODUCTION

Image processing is among the growing technologies today, with its solicitations in various features of the commercial business. Processing of the image is a method to change an image into discrete form and achieve some processes on it to get an improved image or to abstract some useful data from the image. It deals with the core research zone within business and computer science area. In addition to the presentation in medical science and the space database arithmetical processes on the image processing techniques now are used in a comprehensive range of uses. Computer algorithms are used to improve the contrast or the other topographies of the image for the easier explanation of X-rays and the other imageries used in manufacturing, medicine and the natural sciences[1],[2].

Enhancements in the image and the development are one of the most stimulating and visually interesting areas of the image handling. The elementary idea behind image processing methods is to make particulars more observable or to simply focus on certain features of interest in an image [3]. There are numerous aspects of the image that are ambiguous and indeterminate. Contrast enhancement upgrades the quality of an image in contrast illumination characteristics, declining of the noise contents etc. Frequently, an image could be too dark accommodating blurredness and hence it is difficult to identify the different objects contained in the appearance [4].

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Contrast of an image is achieved by its dynamic spectrum, which is well defined as transformation among minimum and maximum intensity levels [5]. Contrast enhancement methods have various solicitation areas for increasing the visual excellence of low contrast descriptions. Various contrast enhancement methods have been established over the years. These algorithms are broadly classified into two groups: spatial domain technique and frequency domain techniques. In the first method i.e. spatial domain methods, the image enhancement is based on direct operations of the pixels in an imageries. Frequency domain practices are based on changing the image Fourier Transform. In this method, the image is first moved into frequency domain which deals with the Fourier transform computations [6],[7]. All the enhancement processes are than achieved on the Fourier transform (FT) and after achieving FT , the inverse Fourier transform is done as the last step to achieve the resultant image.

So , the main objective of the proposed approach is to study and analyze the image processing scenarios and their impact on contrast levels on processing of the images and also to implement filtration and hybrid optimization approach for enhancing contrast level of the image which will help us to evaluate the performance metrics in terms of contrast enhancement and noise reduction.

2. THE PROPOSED METHOD

This section deals with the methodology of developed algorithm for enhancement of low light images captured in the dark condition which have low and concentrated gray scale making the image of low dynamic range. The flowchart of complete process of proposed method is shown below in fig.1

The figure 1 shows the proposed methodology in which the user interface is developed in the MATLAB environment. The image is uploaded and is converted into the YUV color space which normalizes the image and after normalization the bilateral filtering is performed. Then image detailing is performed using wavelet transformation. The wavelet transform performs the segmentation of the image which deals with the boundaries segmentation and detects the edges of the image. The hybrid optimization i.e. Ant Colony and Swarm Optimization is achieved on high intensity image and low light enhancement is done. The optimization increases the efficiency of the system and reduces the error rate probabilities which increases the PSNR and reduces the MSE.

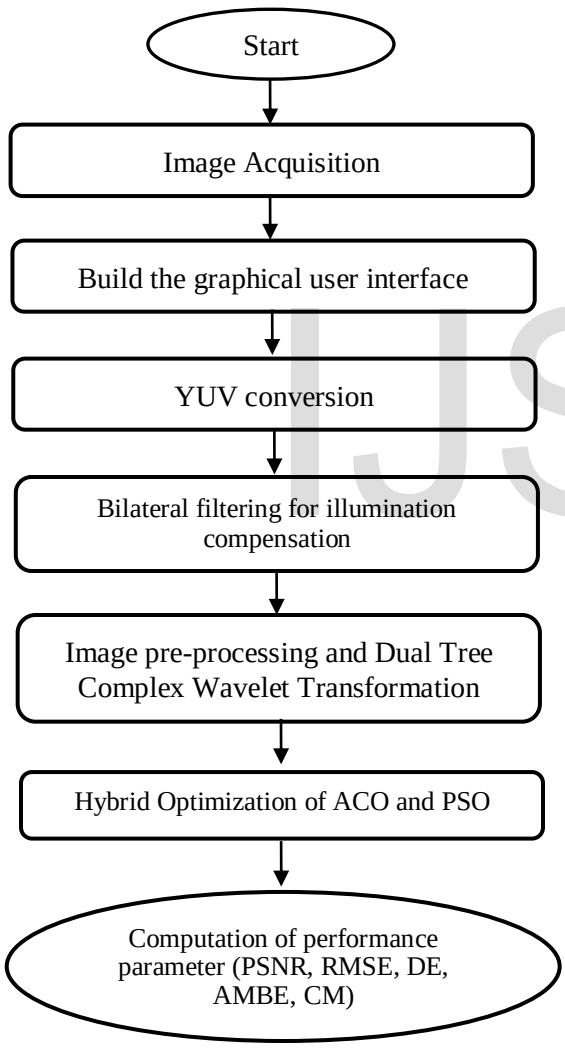


Fig 1: Flowchart of Proposed Low Light Image Enhancement Technique

2.1 RGB to YUV Conversion

The RGB color space in the input image is converted to the YUV color space to get the Y channel for noise reduction and contrast enhancement. We use the Y channel because chrominance channel U and V provides relatively less amount of information in low light condition compared with luminance channel Y [8].

$$Y = 0.299 * R + 0.587 * G + 0.114 * B \quad (1)$$

where R, G, and B are three channels in the RGB color space.

2.2 Bilateral Filtering for Illumination Compensation

Image acquired under poor illumination condition suffers from a low dynamic range, that results in losing much detailed information in low light images. To solve this problem Illumination compensation is performed. For enhancing of detail information, bilateral filtering is used for decomposition of Y channel into base and detail layers. Base layer Y_b is obtained through smoothing by bilateral filtering. It preserves region boundaries and other structures in the luminance channel (Y). Detail layer Y_d which contains detail information in images, is obtained by subtracting Y_b from the Y channel. The obtained enhanced detail layer Y'_d from Y_b and Y_d as follows:

$$Y'_d = (1 + Y_d) \log (Y+1) - \log(\log(Y_b + 1)+1) \quad (2)$$

where the range of Y is [0, 1].

2.3 Image Preprocessing and Dual Tree Complex Wavelet Transform

In this step we perform contrast level adaptive histogram equalization and de-noising for the pre- processing of the image. After pre-processing of the image we perform Dual Tree Complex Wavelet Transform on the Image. DTCWT is real valued wavelet filters produced real and imaginary parts of transform in parallel decomposition tree. It has high degree of directionality, shift invariance, and no aliasing property. Both the trees of DT-CWT are orthogonal or biorthogonal to each other which means that they are Hilbert transform pair i.e. they are shifted by 90 degree in complex plane [9] The wavelet $\Psi_c(t)$ is composed of two sub wavelet : Real wavelet = $\Psi_r(t)$ and Complex wavelet = $\Psi_i(t)$

Therefore we can write the equation as –

$$\Psi_c(t) = \Psi_r(t) + \Psi_i(t) \quad (3)$$

$$\Psi_i(t) = HT\{ \Psi_r(t) \}$$

$$= \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{\Psi r(\tau)}{t-\tau} \partial\tau$$

$$= \Psi_i(t) * \frac{1}{\pi} \quad (4)$$

2.4 Hybrid Optimization

After performing the wavelet transform, hybrid optimization is done by ACO and PSO. PSO applies the approach of social interaction for problem solving. PSO is simple and efficient technique and yet very powerful technique. In this algorithm there are various numbers of particles which are moving in space to search for the optimum and the best value. These particles are provided with constants, values, and initial velocities at the beginning. In the basic PSO particles has a neighborhood pixels affiliated with it. Fitness of those neighborhood pixels is known by the particle. This knowledge is used further to know the better optimization solution or the

position. This method combines the social experience as well as self-experience[10]. Therefore, in PSO each particle in space is accelerated towards gbest and pbest locations with random weighted acceleration in each iteration. Each particle changes its position according to its current velocity, its current position, the distance between its current position and pbest, the distance between its current position and gbest as shown in Figure 2.

ACO is meta-heuristic in which a group of ants are capable of finding best solution to difficult optimization problem. Ants communicate with each other through chemical pheromone trails, which empower them to find shortest path between their food sources and nest. The main work of pheromone is to guide others artificial ant towards the target points. ACO comprises of three main phases- initialization, pheromone update, and solution phase. These three phases makes the complete search to the global optimum. At the start of the first iteration, all ants searching randomly for best solution of a given problem among the feasible solution space and old ant colony is created at the first stage. In the second stage, quantity of pheromone is updated. In the last phase i.e. solution phase, new ant colony is generated based on the best solution from old ant colony. Then both the two colonies are compared based on best solution. By the end of the first iteration, feasible solution spaced is reduced by the vector. Now the optimum solution is researched in reduced space during the algorithm process [11]. The process of ACO is shown in Figure 3.

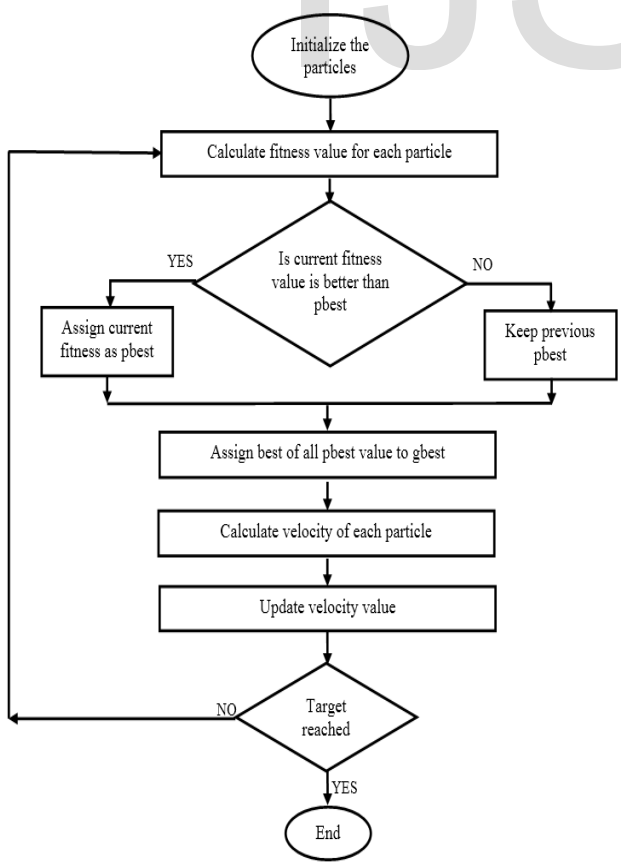


Fig 2: Flowchart of Particle Swarm Optimization

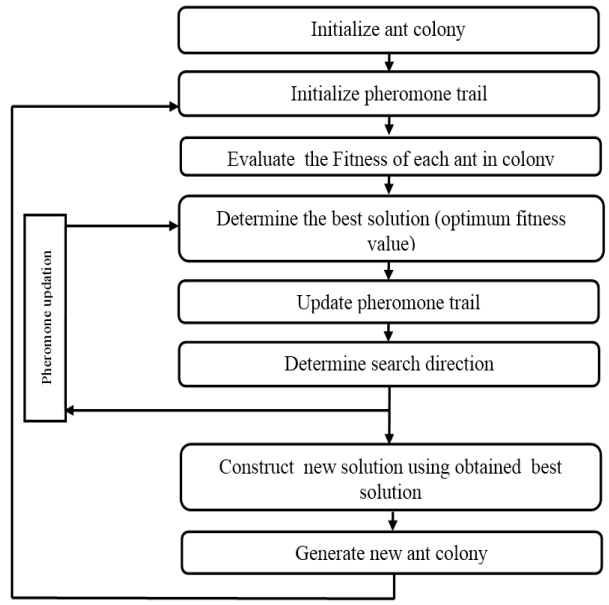


Fig. 3: Flowchart of Ant Colony Optimization

3. EXPRIMENTAL RESULTS

The experimental results present the performance analysis of proposed method of enhancing image by optimizing complex wavelet transform. The simulation and implementation of this research work is performed on MATLAB 2016b. In this work, evaluation of hybrid optimizing algorithm with Dual Tree Complex Wavelet Transform for enhancement of low light images has been observed.

Performance of the algorithm is analyzed on the basis of five performance metrics.

3.1 Peak Signal to Noise Ratio

It is the ratio between the reference signal and distorted signal in an image. Higher the value of PSNR, the distorted image is more nearer to the original image.

$$PSNR=10\log10\left(\frac{MAX^2}{MSE}\right) dB \quad (5)$$

where MSE is the mean square error between the original image and distorted image,

MAX is the maximum pixel value of the image that is MAX=255.

3.2 Root Mean Square Error

Mean square error is the summative squared error between original image and compressed image. Root mean square error is square root of MSE.

$$MSE=\frac{\sum_i\sum_j\{Y(i,j)-X(i,j)^2}{M * N} \quad (6)$$

where M*N represents the size of an image.
X denotes the restored image.
Y denotes the original image.

3.3 Discrete Entropy

It computes the amount of information in an image. Large Value of Discrete Entropy indicates that the image contains more details.

Mathematically, discrete entropy is written as-

$$H(P) = -\sum_{i=0}^{L-1} p(i)\log_2^{p(i)} \quad (7)$$

3.4 Absolute Mean Brightness Error

It is the absolute difference between input and output means. Mathematically it is written as-

$$AMBE(X, Y) = |X_M - Y_M| \quad (8)$$

Where X_M is mean of input image and Y_M is mean of output image.

3.5 Colorfulness Metric

CM is used to calculate the perceived color of an image and it is measured on the basis of mean and standard deviations where α = R-G and β = 0.5*(R + G) – B

$$M = \sqrt{\sigma_\alpha^2 + \sigma_\beta^2} + 0.3\sqrt{\mu_\alpha^2 + \mu_\beta^2} \quad (9)$$

The summary of the results is obtained in given table 1.

Table 1: Objective evaluation results of test images in terms of PSNR, DE, AMBE, and Colorfulness

Metric	Method	Greenwich	Landrover	Memorial	Ramp
PSNR	Existing	39.88	46.10	41.82	41.71
	Proposed	54.14	60.86	62.84	60.73
MSE	Existing	6.52	1.54	4.26	1.55
	Proposed	0.231	0.011	0.031	0.018
DE	Existing	10.48	2.57	5.64	2.57
	Proposed	9.04	1.24	9.045	5.89
AMBE	Existing	55.49	35.43	27.77	60.59
	Proposed	60.98	87.05	119.43	96.78
Colorfulness	Existing	42.014	13.09	28.78	23.70
	Proposed	53.28	60.54	69.76	59.34

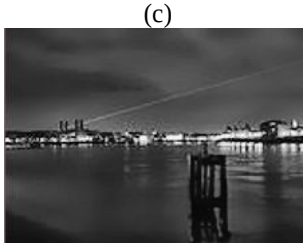
The qualitative analysis of proposed approach for the low light enhancement of image is shown in Figure 4.

(a)

(b)

(c)

(d)



(e)

(f)

Fig 4: Experimental results in Greenwich image (a) Original image (b) Y Channel image (c) Detailed Layer image (d) Filtered image (e) Enhanced layer image (f) image after hybridization

4. CONCLUSION

Image based on CWT and optimization hybridization is proposed. Low light description has low range, poor quality contrast, and high noise. In this paper, we have put light on hybrid filtration and optimization approach to divide the image which was applied as input into low pass filtration sub- bands. Then, the optimization is performed for high signal to noise rate and low error rate performance. In the proposed approach, noise reduction scenario is performed in the channel of luminance. However, the noise in the chrominance channels remains as it is not negligible. So our future scenario deals with the color distortions investigations caused by distortions.

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