Enhancing Degraded Color Images Using Fuzzy Logic and Artificial Bee Colony

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Abstract:
The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task and a specific observer. Many research works have been carried out to enhance the degraded images using many techniques including hybrid approaches such as fuzzy logic and Ant Colony Optimization (ACO). Besides, many works have adopted optimization techniques to improve the quality of the degraded images where convergence of optimizing parameters plays an important role. An approach has been proposed in this paper using fuzzy logic and Artificial Bee Colony (ABC) optimization technique to improve the convergence time as well as quality of the degraded images. This approach has yielded better results than ACO with respect to convergence time.

Keywords: ABC, ACO, Fuzzification, Gaussian membership function, Hue Saturation Value (HSV), Overexposed, Underexposed.

1. Introduction

Enhancing the visual clarity of an image is termed as image enhancement which helps to maximize the clarity of the captured image. Because of the limited capabilities of the hardware device which is used for image acquisition, the atmospheric effects such as mist, fog and cloud adds unwanted information which results the image to blur and so it is an essential factor in the imaging domain. In addition to this reason, image enhancement technique is needed in many areas such as remote sensing, robot navigation, textiles, military, film industry, document processing, graphic arts, printing industry, biomedical image analysis and forensic image analysis. Several techniques have been developed to serve this purpose. This research work contributes further to enrich the visual clarity of the degraded images.

2. Image Enhancement

Histogram equalization is a technique for adjusting image intensities to enhance contrast. In histogram equalization, the pixel will be uniformly distributed instead of original pixel distribution and hence the image gains more clarity. For color images, histogram equalization is more tedious due to the vectorial nature of color. Individual pixel value is represented by a vector in a proper color space i.e., (Red, Green and Blue) RGB in the RGB space with as many components as the color. Nikoletta Bassiou and Constantine Kotropoulos use probability smoothing and a multilevel smoothing to derive the transformations of the original intensity and saturation color components to uniformly distributed ones. This method produces more visually appealing images [1]. Duan has introduced a novel histogram processing algorithm which considers the original distribution of pixel in the equalization process [2]. Low-complexity algorithm for contrast enhancement was introduced by T. Arich in which histogram modification techniques such as adjustable histogram equalization, histogram smoothing, weighted histogram approximation, black and white stretching are done by computing histogram and by adjusting the level of enhancement [3]. But it cannot be applied to other types of degraded color images. Color image enhancement technique applied to RGB color space is not suitable for human visual system.

When boundary values are not clear for any image, it will lead to vagueness which means that there is a need for fuzzification and so operations of fuzzy sets like AND, OR, NEGATION are performed for fuzzification. Fuzzy classification is mainly done by conditions and rule based smoothing. For getting the crisp output values, defuzzification is done. For classification of image values fuzzy logic method is used [4]. In Khandelwal's algorithm, the fuzzy logic rules are generated which will differentiate between ambiguous colors [5]. The fuzzy sets are classified based on the HSV color components in Lior Shamir's approach. For example, the rule "Dark Orange, Medium, Medium Dark gives Dark Brown" is defined manually by classifying the HSV color component. Fuzzy logic-based method provides a more accurate color classification [6]. Sarode M.K.V have introduced a new algorithm to retrieve the features related to a specific tumor disease in which only hue is preserved, whereas saturation and value are changed. Author was able to detect the serious tumor regions and remove the noisy pixels by applying the fuzzy logic rules [7].

H.D. Cheng proposed a novel adaptive direct fuzzy contrast enhancement where the sigmoidal membership function is used to map an image from spatial to fuzzy domain. While transforming the image from one color space (RGB) to another color space (HSV, HIS, YIQ), only the intensity and saturation components were altered without modifying the hue component but it resulted in gamut problem [8]. S.K. Naik tried to keep the transformed values within the range of the RGB space so as to avoid the gamut problem [9]. B. Tang et.al in his approach has changed the color data into chromaticity and brightness and carried the processing further [10].

A HVS Controlled Color Image Enhancement and Evaluation (HCCIEE) algorithm was proposed by K.-Q. Huang which mostly concentrated on the visual effect and the image is enhanced without ringing or halo artifacts [11]. D. Yu have introduced hue preserving correction algorithm named normalized SI correction appropriate for different kinds of enhancement [12]. Fuzzy intensification method was proposed by M. Hanmandlu in which the hue value is preserved, and changes made only on saturation and value and by minimizing the fuzzy entropy. This has resulted in more visual quality image in the contrast enhancement perception [13].

In order to enhance the image, many optimization techniques are used such as greedy, genetic, fuzzy, bacterial foraging and ACO. It is used for optimizing the parameters in color image enhancement techniques [14]. Knowledge about various color image enhancement techniques are gained through a survey on color image enhancement technique [15]. ABC optimization [16-19] is used to optimize the objective function in the proposed approach. The rest of this paper is organized as follows: Section 3 covers the proposed system and the working of the optimization algorithm with its results and analysis of this work. Conclusions are given in Section 4.

3. Proposed Methodology

In this proposed methodology, a degraded image which is either underexposed or overexposed is enhanced by using fuzzy logic and ABC technique. The RGB color value of the image is converted into HSV color value. Only the value and the saturation components of the image changed whereas the hue component remains unaltered. The diagrammatic representation of the proposed approach is shown in Figure 1.

3.1 Fuzzy Approach

The word 'Fuzzy' means vagueness. Fuzziness occurs when the boundary of a piece of information is not clear. In [14], the degraded images are enhanced by combining fuzzy logic and ACO optimization technique. In this approach, a degraded image is taken as input. The image is categorized into underexposed, mixed-exposed and overexposed regions. In [14], only the luminance compponent is fuzzified by preserving the hue component. Guassian membership function has been used to fuzzify the underexposed and overexposed regions. The parameters in the membership function are optimized using ACO optimization techniques. The fuzzy approach followed in this research work is mainly based on the work adopted in [14].

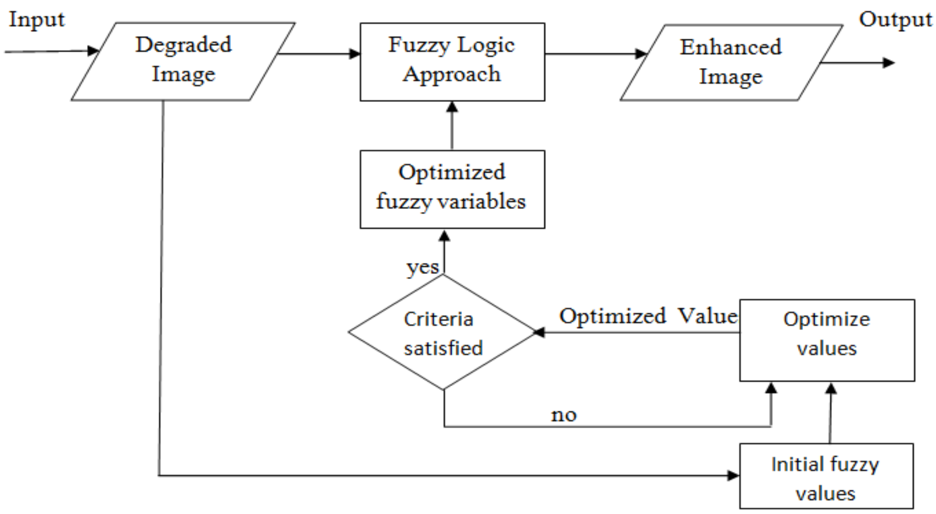

Figure 1: Block diagram of Proposed Methodology

3.2 Optimization using ABC

The revolution of Bee's algorithm is started during 2005 for optimizing parameters [16-19]. This technique is based on intelligent foraging behavior of honey bee swarms. The purpose of bees is to find the places of food sources where high amount of nectar is present. It consists of three phases: employee bees, onlooker bees and scout bees. The overall flowchart of the ABC algorithm is shown in Figure 2 [20].

3.2.1 The employed bees

It flies around the multidimensional search space and find food sources depending on their experiences and their neighbor bees. The colony size consists of sum of same number of employee bees and onlooker bees. Initially the food source positions are randomly generated by using the equation (1). Then by using the fitness function the fitness value is calculated [17]. If the current fitness value is higher than that of the previous fitness value then the current value is replaced by the previous one. Otherwise the value is not replaced and remains the same. By using greedy mechanism the process of comparing and replacing the value is done.

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}) \tag{1}$$

Where *Vij* is the new food position, *k* and *j* are the randomly chosen parameters of different values, where *k* € [1,2,…,*SN*] and *j* € [1,2,…,*D*] .(*Xij – Xkj) is the* difference between two old food source positions. *D* is the number of optimization parameters and *SN* is the number of employed bees. Φ*ij* is a random number between [-1, 1].

3.2.2 The onlooker bees

It gets the information of food sources from the employed bees and selects one of the best food position which is having high nectar amount. Then by using equation (2) the probability value is calculated. Now based on the probability information the current and previous value are compared by using greedy approach. If the present value is higher than the previous then the current value is replaced by the best value. During this process a limit value is assigned. Each time when the values are compared and if best result is obtained then the counter is set to zero otherwise the limit value will be incremented. Similarly the process is repeated for other bees.

$$p_i = \frac{fit_i}{\sum_{j=1}^{SN} fit_j} \tag{2}$$

Where, P_i is the probability value associated with i^{th} food source. fit_i represents i^{th} food source's nectar amounts. *SN* is the number of food source which is equal to the number of employed bees.

3.2.3 Best food source

The best value that is obtained from the above process is stored in the memory.

3.2.4 The scout bees

It finds the new food positions randomly without any experience for the exhausted food sources and the iteration are repeated. The scout bee finds a new random food source position using the equation (3).

$$x_i^j = x_{\min}^j + rand(0,1)(x_{\max}^j - x_{\min}^j) \tag{3}$$

where *xj*min and *xj*max are lower and upper bounds of parameter *j*, respectively.

3.2.5 Stopping criteria

1) If the previous value is equal to the current value while comparing the value by using greedy mechanism then the algorithm is stopped. 2) A particular limit value is assigned while comparing the value by using greedy if until the limit, the value obtained is not best then the algorithm is stopped. 3) If the maximum numbers of iterations are executed then the algorithm is terminated.

3.3 Defuzzification:

By using the optimized values of the parameters, the fuzzy membership values are enhanced in the under and overexposed regions. After enhancing membership values defuzzification is done in the underexposed and overexposed regions of the image using inverse functions. By combining the under and overexposed region and applying the original histogram in the middle region gives an image which is then converted from HSV to RGB to get the final enhanced image.

3.4 Results and analysis

The degraded image such as underexposed and overexposed images and the histogram of the original image is shown in Figure 3(a), Figure 4(a), Figure 5(a) and Figure 6(a). The over and underexposed region in the original image is classified by two threshold values and then it is fuzzified. After that the intensification and exposure parameters are optimized using ABC, and then defuzzification is done on the image to get the enhanced image. The enhanced image and their histogram are shown in Figure 3(b), Figure 4(b), Figure 5(b), and Figure 6(b). The time taken by proposed approach is compared with ACO based approach and is found to be better ie, faster than ACO and is shown in Table 1.

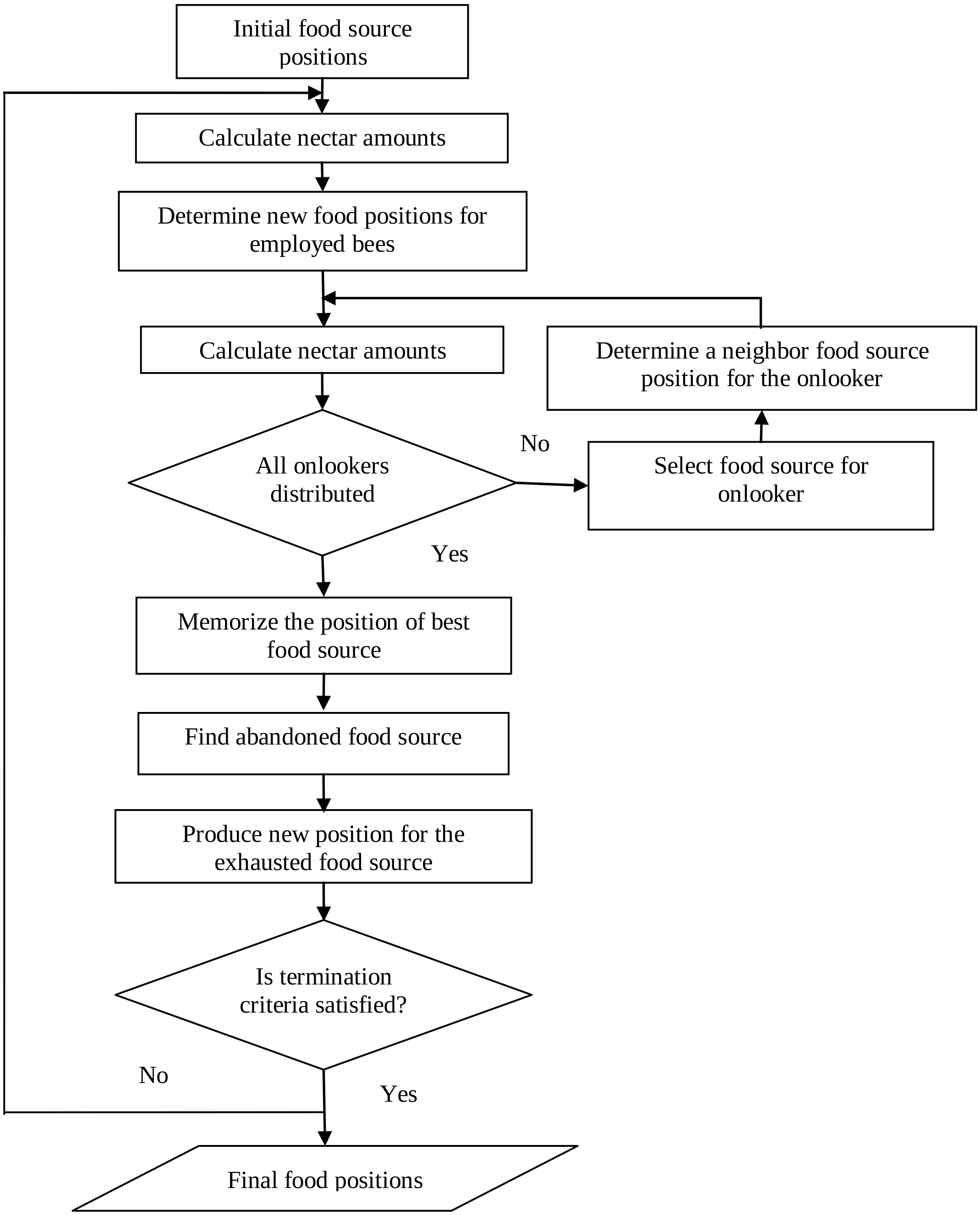

Figure 2: Flowchart of ABC algorithm [20]

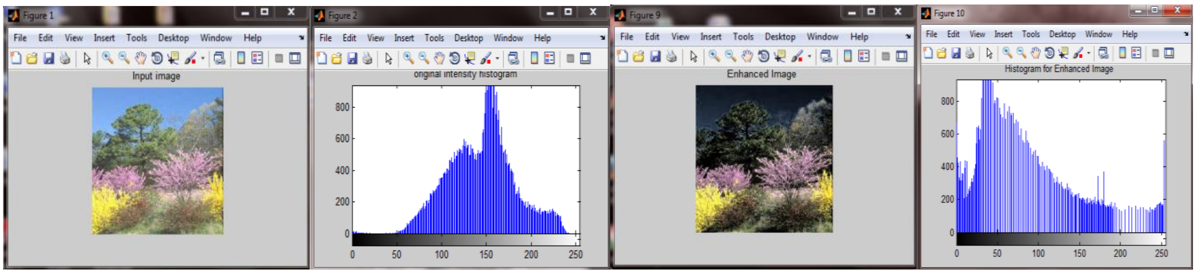

Figure 3(a): Tree image (over exposed image) and its histogram, (b): Enhanced image and its histogram with the proposed approach.

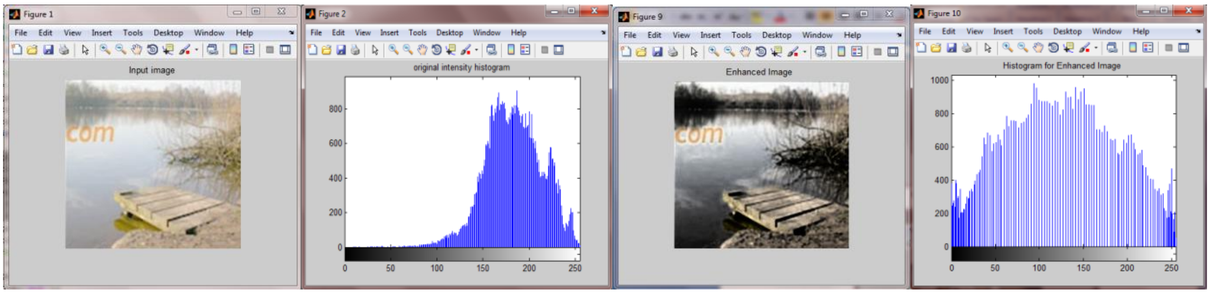

Figure 4(a): Scenery image (over exposed image) and its histogram, (b): Enhanced image and its histogram with the proposed approach.

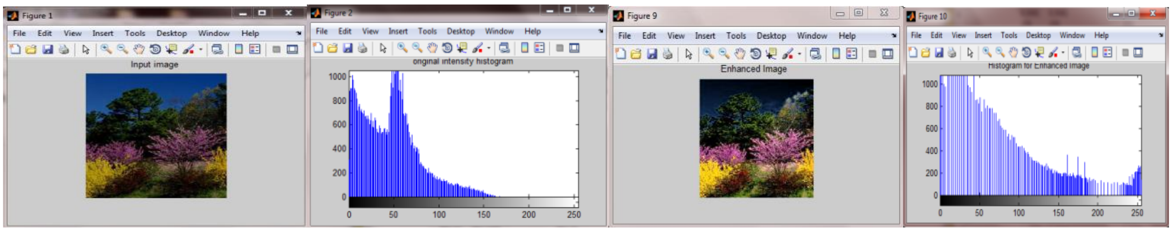

Figure 5(a): Tree image (underexposed image) and its histogram, (b): Enhanced image and its histogram with the proposed approach.

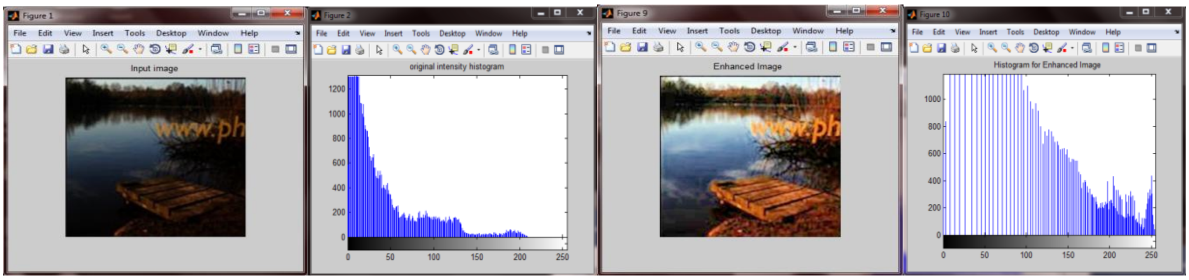

Figure 6(a): Scenery image (underexposed image) and its histogram, (b): Enhanced image and its histogram with the proposed approach.

Table 1. Comparison of time taken by ABC (proposed approach) with ACO.

Test Image	Time taken by ACO (sec)	Time taken by ABC (sec) proposed approach
Figure 3(a)	195.73	19.73
Figure 4(a)	194.40	11.49
Figure 5(a)	197.79	13.82
Figure 6(a)	173.95	12.42

4. Conclusion

In this paper a degraded image is taken as input and divided into underexposed, mixed-exposed and overexposed regions. Guassian membership function has been used to fuzzify the underexposed and overexposed regions. The parameters in the membership function are optimized using ACO and ABC optimization techniques. Based on the simulation results, it has been found that ABC has given better results than ACO approach.

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