A Review of Image Enhancement Approaches

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Abstract – The process of image enhancement is the key domain of digital image processing which attempts to produce as the output improved version of input image which is more suitable in terms of color, brightness or contrast. Image enhancement operations tend to reveal the covert details of the image and have multitude of choices to improve an image. That's why it is used in many domains such as de-noising, de- blurring, sharpening etc. This paper presents various techniques and approaches which are helpful for enhancement of a gray scale image. This paper presents that image enhancement methods using nature-inspired and meta- heuristics approach provide better results.

Keywords – Image enhancement, Cuckoo search, Meta- heuristics, Spatial and Frequency Domain.

I. INTRODUCTION

Image enhancement means the technique of improving the visual appearance of an image so that resultant image is more accurate and comprehensive as compared to the original one, as well as, is appropriate for human and machine discernment. This process finds application in various fields such aerial/satellite imaging, bio-medical imaging, remote sensing etc. It is done to enhance the visual appeal of the image. It performs operations like changing low contrast image to high contrast image, adjusting brightness of the image or to differentiate objects from its background etc.

Image enhancement techniques mainly belong to two domains: Spatial domain and Frequency domain [1, 2]. Spatial domain methods operate at the individual pixel intensities of the image. Main advantage of this method is that they are conceptually simple, comprehensive and lacks complexity which makes them useful in real time applications. There are two generally used techniques: One is Histogram Equalization and other is Linear Contrast Stretching (LCS). Both of them is used to improve images with low contrast. LCS can be accomplished using different techniques as max-min LCS, percentage LCS and piece-wise LCS [16] and also used in medical radiography [17]. But main problem with these methods is that they are not robust and take a lot of time in computation of transformed pixels of output image.

Frequency domain methods deal with analysis of mathematical functions with respect to frequency and manipulate transform coefficients such as Fourier Transform. These methods have big advantage like less computationally complex, robust and easy to observe and control frequency spectra of the image. The basic problem with these methods is that these methods cannot be easily automated and cannot enhance all parts of the image.

Different forms of enhancement are used depending on the given application domain. Images need to be mapped from one form to the other to emphasize the required features in the image. In all these methods, there is subjectivity in judgment about how the image has improved. All these methods require the human interpreter is required to evaluate whether the image has improved for the required task.

This problem of subjectivity in judgment was finally removed by the introduction of genetic and various meta-heuristic algorithms [5, 6, 8, 9]. In nature-inspired and meta-heuristic algorithms, image enhancement can be treated as an optimization problem which tends to generate the output image from given input image by using global or local transformation and also maximize the required fitness function.

Transformation function used attempts to map the image in non-linear fashion. Fitness function is an objective function which mathematically defines the quality of the image. Fitness function is the one that makes enhancement procedure, an objective process. Genetic algorithms started the optimization of image enhancement that overcomes the human judgment disadvantage of previous enhancement techniques [3, 4, 17]. This work gave an impetus to the introduction of other meta-heuristic algorithms in the field of image enhancement.

Other advances were made in this field of meta-heuristic algorithms to improve the existing techniques. It was observed that with the improvement in the algorithm, efficiency of the enhancement procedure also improved which eventually produced a better emphasized and enhanced image.

Genetic algorithms (GA) were succeeded by Particle Swarm Optimization (PSO) [8-11] and then by Cuckoo Search Optimization [13-15].Cuckoo search finds its applications in various domains such as in medical imaging, fingerprint analysis etc[18].Cuckoo Search has been confirmed to perform better both GA and PSO [15] in achieving the optimized result in lesser time.

II. LITERATURE SURVEY

Many techniques and algorithms have been designed for better image enhancement. This review gives a detailed summary of various approaches and algorithms designed by various researchers in field of image enhancement.

Gonzalez and Woods [1] defines image enhancement as practice of producing the output image which is more apt and fitting than the given input image. The suitability of the enhancement method depends on the type of the image. Enhancement operation works in two domains: spatial and frequency domain. Spatial methods manipulate the image by operating pixel by pixel while frequency domain methods are aimed at transforming the Fourier Spectrum of the image which requires less computation than the spatial domain methods.

Pratt [2] suggests that improvement in the overall contrast can be brought by rescaling the amplitude of each pixel in such a way that value of pixels in resultant output image will have lower range. Gray scale contouring may follow this process. Window level transformation can also be applied to the image for contrast improvement. Noise and interference from multiple sources can affect an image such as noise which creeps in from sensors, noise from photographic equipments, or errors may result from channel disturbances. Classical statistical filtering technique can be employed to remove or decrease these effects.

Ahmed, Zain and Ahmed [3] suggest that histogram equalization (HE) and its variants are much relied technique of image enhancement. Histogram equalization attempts to generate a uniform histogram of the image by distributing the intensity levels uniformly throughout the image. This is done with aim of improving the overall contrast of the image. It was suggested to fragment the HE into its rudimentary blocks and understand their fractal nature. These blocks are then critically analyzed to find out the exact nature of the contrast improvement. But this concluded that histogram equalization is not full-proof method for enhancement.

Yao, Wang and Zhang [4] proposed a linear contrast method for image authentication. Linear mapping operation used generated artifacts in the histogram. Algorithm was proposed to estimate the variables of poly-line mapping function. In this method, linear contrast stretching (LCS) introduced periodical bins in the histogram which are used to estimate threshold value. As it used three-section poly-line mapping, it didn't work for higher slopes.

Munteanu, Rosa [5] projected a new enhancement method based on hard-coded Genetic algorithms. This involves the mapping of gray levels of an image. This method removed the subjectivity of human interpreter by using a fitness function. It exposed various shortcomings of the previous techniques, as that they were global in nature. But the proposed method was based on local enhancement and requires no user interaction in algorithm execution. Enhancement is viewed as optimization problem which considers parameters of transformation function and aims to find the best optimized populace of the parameters so that fitness function is maximized. Parameters are represented as chromosomes and various genetic operators such as mutation or crossover etc. are applied in the algorithm to find the optimized values. Results were proved to be better than results of HE and LCS.

Saitoh [6] proposed new approach for the low-contrast images. Images were acquired by image capturing device or a camera. Proposed method was based on a look-up table (LUT).Here, relation was defined to co-relate input and output gray levels of the image, by which image with better contrast can be produced. It used subjective and objective evaluation to determine quality of the image.

Munteanu and Rosa [7] suggested that image enhancement is the difficult procedure as it requires human judgment. It was proposed to enhance the given image using natural evolutionary optimizing approach. A novel criterion function is used and best candidate solutions are selected that yield best value of criterion function. It used global search strategy to enhancement problem and proposed method was better than automatic enhancement methods.

Kennedy and Eberhart [8] proposed a new method of optimization known as particle swarm optimization that uses swarm intelligence. This method is effective for dealing with non-linear optimization problems whose corresponding functions may be non-continuous. Optimization problem is considered as collection of particle swarms where each particle has a certain velocity associated, with which it travels, or at certain time changes its position. Population for next iteration is determined on the basis of best solutions of the previous iterations.

In every iteration, solution satisfying the criterion function is selected and new populace is generated by using present state of solution and next step which is signified as velocity and hence, new populace for next iteration is generated. This method was proposed to solve optimization problem using population based stochastic technique using non-linear function.

Clerc and Kennedy [9] suggested the analysis of particle's trajectory as it moves in space. Optimal regions in complex search problems out of number of particles through iterations. This method used five dimensional depiction of the complete system. This method suggests the possible ways of manipulating the existing algorithm to eliminate potential problems and increase the swarm finding ability to find the local optima for the different functions

Gorai and Ghosh [10] proposed the application of particle swarm optimization in area of image enhancement which proved to produce far better results than previous existing techniques. Parameters of transformation function are viewed as populace to generate optimized solution that satisfies the objective function and produce an improved and enhanced image. Objective function used takes into account the entropy and amount of image edges to quantify the image quality. This method was used on various gray level images and results were put through both subjective and objective evaluation which showed that PSO outperformed GA, HE, LS.

Singh, Kaur and Singh [11] proposed the application of PSO in image enhancement by using a transformation function that use global as well as local enhancement and its parameters are optimized using PSO algorithm. Each randomized solution has a velocity which defines its value in the next iteration. At the end, best particles satisfying criterion function are selected to generate the enhanced image. Entire process is parameter dependent and results are governed by effective selection of the parameters.

Chunxia and Youhong [12] proposed a new type of particle swarm optimization technique in which original method incorporated a chaotic optimization and new constriction factor is defined for the algorithm. Distribution factor of particles for next iteration is regarded as constriction factor. Chaotic sequence has periodicity property and varies stochastically. This type of distribution makes particles to overstep the local extremism. This algorithm has been proved to produce better results than simple particle swarm optimization algorithm.

Yang and Deb [13] formulated a nature-inspired algorithm known as Cuckoo Search Algorithm to deal with optimization problems. This algorithm was inspired by breeding behavior of cuckoo birds while incorporating the levy flight behavior which is exhibited by some birds. This research also validated the results obtained by cuckoo search against GA and PSO for optimization problems. There are three rules as first, Eggs are laid by cuckoo at a time and these eggs are put it in a randomly selected nest. Secondly, only eggs satisfying the criterion function will be taken to the subsequent iteration. Third, count of existing host nests is kept constant. Probability of detection of egg by host bird is taken as random variable in the interval [0, 1]. Quality of eggs is determined by using a fitness function.

Yang and Deb [14] presented a broad comparison of the Cuckoo search algorithm by performing validation of the proposed algorithm against some standard functions which can be used for benchmarking and testing. These functions were stochastic in nature. CS algorithm is applied to various design optimization problems and it was proved that

optimized results generated using CS are far better than PSO algorithm.

Ghosh, Roy, Kumar and Mallick [15] proposed the application of CS algorithm in image enhancement Here, Image enhancement is considered to be a optimization problem varying non-linearly. Transformation function is defined whose parameters are optimized according to CS algorithm. Each parameter is viewed as cuckoo eggs which are first randomly initialized and then through iterations using levy flight distribution, optimized result is obtained. Fitness function employing number of edges and entropy is defined Results are compared with results of image enhancement using HE,LCS,GA and PSO and it is proved that CS outperforms all the algorithms in terms of value of fitness function.

III. COMPARATIVE ANALYSIS OF ENHANCEMENT TECHNIQUES

The table given presents the comparative study of various enhancement approaches namely Histogram Equalization, Linear Contrast Stretching, Genetic Algorithm based enhancement Particle Swarm Optimization (PSO) and Cuckoo Search Algorithm based enhancement. Comparison is done on the basis of their method, extent/level of enhancement, type of distribution used. Table also lists their advantages and disadvantages. Table 1, shows the comparison of various techniques.

Table 1: Comparison of Image Enhancement Approaches

Enhancement Approach	Description of method	Level of enhancement	Type of distribution used	Computation Time	Advantage	Disadvantage
Histogram Equalization [1]	Distribute intensity levels uniformly over entire intensity scale	Uses global level of enhancement	Tends to produce uniform histogram of the image	Higher computation time as it operates over every pixel individually	Simple method and easy to compute	Suffers from contrast inconsistency and uncertainty
Linear Contrast Stretching [1,4]	Widens the range of output intensity values for the image	It works at global level in the image	Use three methods: Min-max LCS, Percentage LCS, Piecewise LCS	Computation time is higher as individual pixel is operated on	Simple and straight-forward and easy to compute	It also suffers from uneven contrast/ intensity distribution in the image
Genetic Algorithm based enhancement [5]	Based on natural selection for search and optimization problems	Uses local enhancement approach	Use genetic operators like mutation, cross-over etc.	Lower computation time as compared to HE or LCS	Produce better results than HE and LCS	Suffers from random convergence and no assurance that global optimum will be achieved
PSO based enhancement [10]	Meta-heuristic algorithm that use mathematical operators	Performs local as well as global enhancement	Velocity of particles(candidate solutions) determine the next populace of solutions	Lower computation time as compared to GA based enhancement	Easy to implement and require fewer parameters to adjust	Location and velocity of particles can get uncontrolled and suffers from low convergence
Cuckoo Search based enhancement [15]	Based on blood parasitic behavior of cuckoo bird and used for optimization	Performs global as well as local search for optimization of enhancement operation	Levy Flight distribution determines the next populace of candidate solutions for next iteration	Better computation time than both GA and PSO	Provide better optimization results than GA and PSO	Flight patterns are not erotic and true convergence to global optimum isn't certain

IV. GAPS IN EXISTING WORK

The review has shown that existing work has certain limitations as under:

a. GA's are very time consuming. Also the results depend on selection of poor population can lead to worse results for enhancement
b. PSO proved to be superior to GAs also has certain limitations as sometimes, state of particles can become un-exact and uncontrolled. This hampers the ability of the algorithm to arrive at global convergence
c. Cuckoo Search Algorithm produce comparatively better results than GA and PSO but also suffers from problem as it does not guarantee the global optimum. Moreover, it suffers from problem of slow convergence and low accuracy.

V. CONCLUSIONS AND FUTURE WORK

Image enhancement is the method which aims to enhance or emphasize the important characteristics of the image. HE and LCS are conventional techniques and suffer from unpredictable contrast problem. GAs are evolutionary algorithm but suffers from low convergence. PSO tried to solve the problem of GA but also has a limitation that it can become uncontrolled.

CS algorithm poses a problem that true convergence to optimal solution cannot be guaranteed. So to overcome the limitations, other meta-heuristic algorithm can be used for image enhancement in different application domains. Other direction that this work can take is to tweak the levy flight distribution and to use another form of distribution so that better convergence can be achieved. Overall objective is to improve the convergence rate of the algorithm. Lowering the complexity and computation time should also be considered.

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