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Impact of Optimization in Edge Detection using Adaptive Thresholding

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Abstract: Image has been processed to convert an image into digital form for implementing some of the operations on it, in order to get an intensify image or to excerpt appropriate information from it. To perform such operation the edge detection is one of the important method in image processing. Edges generally occur on the boundary between two different regions in an image. In this paper, comparative analysis of three prominent optimization algorithms has been takenup. The three algorithms considered are: Particle swarm optimization, Gravitational search algorithm and Genetic algorithm which are based on edge detection using adaptive thresholding. The performance evaluation of these algorithms is done in premises of Peak signal to noise ratio, Mean square error and Structural Similarity Index Metric.

Keywords: Edge Detection, MSE, PSNR, SSIM. Particle Swarm Optimization,

I. INTRODUCTION

In processing the images, the Edge Detection is in the forefront of image processing to process the images. The edges are illustrated as the sharp boundary between the objects and the background or the boundary between overlapping objects. If the edges are perceived correctly, the position of all objects in the image can be identified exactly and some essential traits, such as the surface and the geometry of the objects will be measured easily [1]. Noise is the gigantic barricade in detection of continuous edges; noise shows fine distortions in the pixel intensity. Other adversity is the distortion in the intensity of pixels by cause of discerns brightness which causes the edge intensity in the illuminated region to weaken. The last dominant dilemma is thresholding that is natural to all the detectors. It causes the fragile intensity pixel to be premised as a non-edge and through this they generate damaged edges. So, to abolish all this disputes this paper introduced edge detection using adaptive thresholding on three optimization algorithms. The conceptual issues have been taken care of to improve the detection methods and thresholding has been used for optimisaiton of the results to better the performance and enhance the capability of the system using edge detection in given image.

II. LITERATURE SURVEY

In [2] authors proposed a new GSA based image edge detection approach claiming that this approach was to detect edges using local variations of intensity with the help of minimal set of input data to be processed this makes process faster and memory efficient. However, it could not have impact on the result outcome as evident from other sources. Authors in [3] have reported the implementation of a technique for image edge detection based on Ant Colony optimization to display large number of true edges. Dongyue Chen *et.al.* proposed a new edge detect algorithm which uses PSO for detection of best fitness curve in an image that shows edges of objects. And this experiment was compared with Sobel and Canny operator which concluded that new edge detection has a good performance [4]. Om Prakash Verma *et.al.* presented a technique for edge detection using adaptive thresholding with ACO algorithm to acquire a perfect image edge map. For qualitative analysis of method the outcomes was analyzed by Shannon's Entropy function over the traditional edge detectors [5]. In [11] authors presented Comparative analysis of edge detection algorithms specifying the application on deep vein thrombosis diagnosis. In [13] authors presented findings on medical images and reported concept of improvement.

III. PARTICLE SWARM OPTIMIZATION (PSO)

PSO is a heuristic global optimization method, which was made known by in 1995. Eberhart and Kennedy depicted that, PSO algorithm is a population based search algorithm based on the simulation of the social behavior of birds within a flock. The populace in PSO is initialized inconstantly among association of particles and in this manner particular particle exhibits a result. In this way, the algorithm examines for an optimum solution using number of iterations to get better result. In every iteration, the particles are estimated using a fitness function and the value derived from this function is known as particle fitness value. In case the derived particle fitness value so achieved is the better one, then this particle reserves the location of this value as the best value, personal best (pbest). At the end of every iteration, the particle with the best fitness value is preferred as global best (gbest). The above mentioned criterion is important for navigating particles towards a better position. In the same way, the every particle alters its travelling speed by actively analogous with the flying action of itself based on particle and its companions based on gbest. Therefore, the consequent position of every particle is adjusted according to the following:-

- Current position of individual particle

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- Current velocity of individual particle
- The distance between his current position and pbest
- The distance between his current position and gbest

For every particle, the velocity (V) and position or location (pL) is revised using the formulas:
The equation of Velocity (V):

$$V_i = wV_{i-1} + c_1 \times rand() \times (pbest_i - pL) + c_2 \times rand() \times (gbest - pL) \quad (1)$$

The equation of position or location (pL):

$$pL = pvL + V_i \quad (2)$$

According to condition, the inertia weight (w) can be computed as:

$$W = \frac{(T_{max} - t) - (w_{start} - w_{end})}{T_{max}} + w_{end} \quad (3)$$

Where w stands for inertia weight, pvL refers to the position or location of the particle in the preceding iteration, pL refers to present location of the particle, V_i stands for present velocity for particle i, V_{i-1} stands for preceding velocity for particle i, c_1 and c_2 represents the acceleration constants, rand () refers a random number, p$best_i$ shows the best value for particle i and gbest I shows the best particle attain over all iterations. In the equation no. 3, T_{max} is the maximal iteration, w_{start} is the origin inertia weight, w_{end} is the finale inertia weight and *t* is the present iteration [6].

IV. GRAVITATIONAL SEARCH ALGORITHM

Gravitational Search Optimization is under the category of a heuristic optimization method, which has been introduced in the year 2009. Gravitational Search Algorithm is basically inspired from Newton's theory, which defines in a way that every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of distance between them. The main parameter in this law of gravity in GSA is that to asset the optimum solution by a set of agents known as masses. This algorithm possess different features, which includes lower memory usage, fast convergence and the usage of some parameters. In this algorithm there exist a particular mass, which is known as agent and consists of four attributes they are: position, inertial mass, active gravitational mass and passive gravitational mass. These four attributes play a major role in algorithm to determine a fitness function with the use of gravitational and inertial masses same as the position of mass correlates to a solution of problem [7]. The steps undertaken in GSA are:-

1) Identify search space.
2) Initialization step
3) Assessment agent using fitness function after initialization
4) Update G(t) ,best(t) ,worst(t) and M_i (t) for i=1,2,..N.
5) Computation of the total force in all feasible directions.
6) Computation of acceleration and velocity.
7) Updating agent's position.
8) Repeat steps 3 to 7 before the stop criterion is reached.
9) End.

Assume a system with N masses in which location of the i[th] mass is described as:-

$$X = \left(x_i^1, \dots x_i^d, \dots x_i^n\right), for\ i = 1,2, \dots, N \quad \dots (4)$$

x_i^d shows the positions of the i[th] agent in the d[th] dimension, and n is the space dimension.

At the same time, mass of all agents is determined after computing present population's fitness as:

$$©m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \quad \dots (5)$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{N} m_i(t)} \quad \dots (6)$$

Where, M_i(t) and fit_i(t) shows the mass and the fitness value of the agent i at time t, respectively. In term of minimization problem, worst (t) and best (t) are exemplified as:

$$worst(t) = \max_{i \in \{1, \dots N\}} fit_i(t) \quad \dots (7)$$

$$best(t) = \min_{i \in \{1, \dots N\}} fit_i(t) \quad \dots (8)$$

The net force which is enforced by mass j on mass i, f_{ij}(t) is computed as,

$$f_{ij}(t) = G(t) \frac{M_i(t) M_j(t)}{R_{ij}(t) + \epsilon} \left(x_j - x_i\right) \quad \dots (9)$$

Here, x_i refers to the location vector of the i[th] agent, ∈ is a small threshold, and G (t) refers to the gravitational constant which is initialized at the starting of the algorithm. The G (t) is reduced with time to restraint the search accuracy. R_{ij} (t) is the Euclidean distance among two masses i and j. According to Newton's second law of motion, the total gravitational acceleration on the i[th] agent is computed as: $a_i(t) = G(t) \sum_{j=1}^{n} rand_j \frac{M_j(t)}{R_{ij}(t) + \epsilon} \left(x_j - x_i\right) \quad \dots (10)$

Where, r and j represents random number within the interval [0, 1]. The velocity and position of the agents are revised as:

$$v_i(t+1) = rand_i\, v_i(t) + a_i(t) \quad \dots (11)$$

$$x_i(t+1) = x_i(t) + v_i(t+1) \quad \dots (12)$$

k_{best} represents to the set of first K agents with the best fitness value and gigantic mass, which is a function of time, initialized to k_0 at the starting which decreases with time. k_0 refers to a set to N (total number of agents) which decreases linearly to 1 [2].

V. GENETIC ALGORITHM

The Genetic Algorithm is non-deterministic stochastic search and optimization method, which promotes the theories of evolution and natural selection to deal with a problem within a search space. Genetic Algorithm was refined by Goldberg and inspired through Darwin's theory of Evolution. Genetic Algorithm consists of: Selection, Crossover, and Mutation. Selection figure outs and keeps the fittest ones in the populace. A crossover recombines two individuals remaining and then is evacuated from the current populace. Mutation operator includes changes in chromosomes units. Its intent is to maintain the populace. Using genetic for edge detection, GA has the ability to deal with complex, large search spaces when minimum knowledge is available. GA takes all edges as chromosomes and after selection process operators are applied on it. The method used for selection as well as reproduction is matter of choice. Either crossover or mutation or both operators can be used [8]. In the intermediate step fitness function is computed. Based on the fitness function Suchendra M. Bhandarkar *et.al.* [9] proposed edge detection using GA. Chromosomes in the populace are described by two dimensional binary arrays of 1's and 0's, where 1 shows the edge and 0 shows the non-edge pixel. With every chromosome in the populace relates a cost $F(S) = \sum l \sum iw_i C_i(S,l)$. Then, fitness value of every chromosome is calculated based on its related ranking in the unified populace:

$$fitness[i] = (cost[worst] - cost[i])^n \quad \ldots (13)$$

where, worst stands for the least fit chromosome found in the present generation.

The adaptive thresholding is a local and dynamic thresholding, which is used to isolate desirable foreground picture objects from the background based on the difference in pixel intensities of particular region. On the other hand Global Thresholding handles a rigid threshold for all pixels in the picture and thus can't accord with pictures consisting of changeable intensity gradient. Adaptive thresholding prefers a single threshold for particular pixel based on the range of intensity values in its local neighborhood. Adaptive thresholding generally consider an input as a color picture or gray scale picture, and performs straightforward implementation which results a binary image in the output which depicts the edge information. If the pixel value is below the threshold it is set to the background value, otherwise it assumes the foreground value [10]. The adaptive thresholding has been popular now a days to be used in such processing and improve upon the performance.

VI. PERFORMANCE EVALUATION

Performance of the optimization algorithms has been analysed based on various performance parameters, which has been investigated in this section.

(a) Mean Squared Error (MSE):- MSE has been defined as the deterioration function and statistical features of noise on the edge detected image. Main function is to measure the average squared difference among the estimator and the parameter. MSE enumerates the average differences of the pixels for original ground truth image with the edge detected image. MSE should be lesser with image restoration, reconstruction and compression. Hence, in premises of edge detection, the MSE could be lower to assure further edge points are found in the image and capable to identify the fragile points.

$$MSE = \frac{\sum_{M,N}[I_1(x,y) - I_2(x,y)]^2}{M,N} \quad \ldots (14)$$

Where, M, N are size of image, x refers to height of image, y refers to width of image, I1 is original image and I2 is edge detected image [11].

(b) Peak Signal to Noise Ratio (PSNR):- It refers to the ratio among the maximal feasible power of a signal and the power of corrupting noise that alters the fidelity of own depiction. It is generally expressed in premises of the logarithmic value. Higher value of PSNR is good as it means that the ratio of signal to noise is higher. It is easily calculated based on the MSE value. PSNR is calculated by using this equation[12]:

$$PSNR = 10 \log_{10}(R^2/MSE) \quad \ldots (15)$$

(c) Structural Similarity Index Metric (SSIM):- SSIM is a technique used for measuring picture index quality. It measures picture aspect which is depending on an original compressed or distortion-free picture as reference. The SSIM values vary between 0 & 1. The values close to 1 shows the maximum correspondence with the original images. The SSIM depends on the estimation of three premises which are luminance, contrast and structural. The comprehensive index is a multiplicative aggregate of the three terms [13]

$$SSIM(x,y) = [l(x,y)]^\alpha . [c(x,y)]^\beta . [s(x,y)]^\gamma \quad \ldots (16)$$

VII. PROPOSED METHODOLOGY

In the proposed methodology, adaptive threshold generally takes input as a color or gray-scale image and outputs a binary image representing the edge information. For computing, an optimal threshold value the optimizations methods has been used. Hence, PSO, GSA and GA are proposed to use along with adaptive threshold and performance is evaluated through parameters.

Algorithm

Step 1 Read an Original Image.

Step 2 Apply the Preprocessing on Original Image.
Step 3 Now, Edge Detection using Adaptive Thresholding.
Step 4 Using Optimization Algorithms.
Step 5 Get the Edge detected image.
Step 6 Evaluate performance parameters i.e., PSNR, MSE and SSIM.

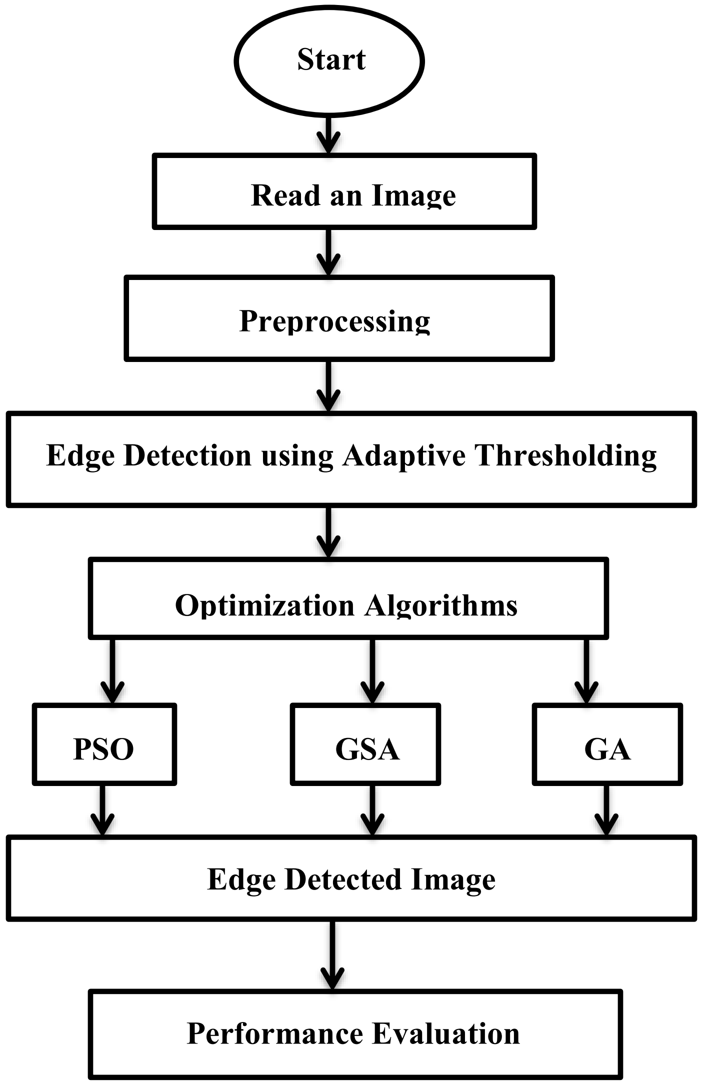
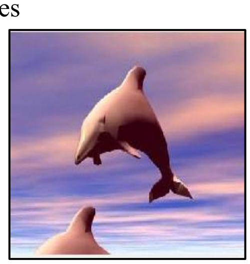


Fig: 1 Flow Chart of Proposed Method

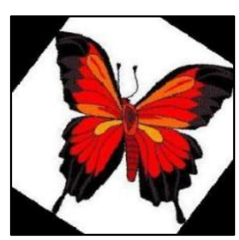
VIII. EXPERIMENTAL ANALYSIS

Table: 1 Original Images

Img1.jpg

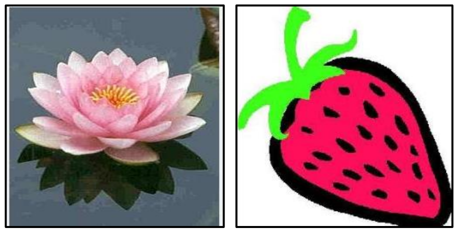


Img2.jpg



Img3.jpg

Img4.jpg



Img5.jpg Img6.jpg

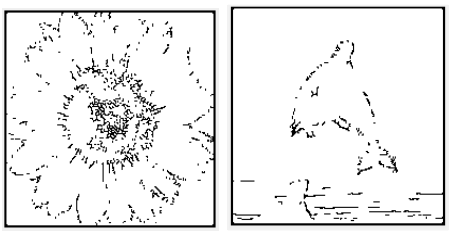
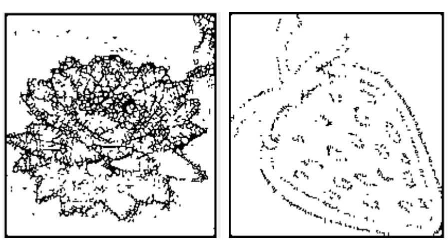


Table: 2 PSO Edge Detected Images

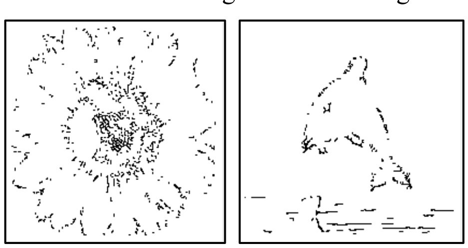
Img1.jpg Img2.jpg

Img3.jpg Img4.jpg



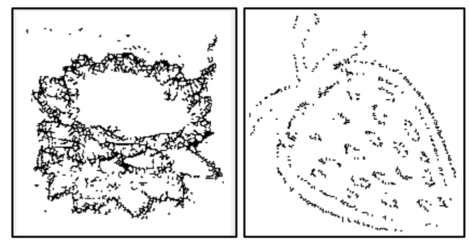
Img5.jpg Img6.jpg

Table: 3 GSA Edge Detected Images



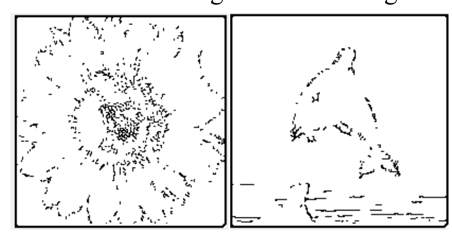
Img1.jpg Img2.jpg

Img3.jpg Img4.jpg



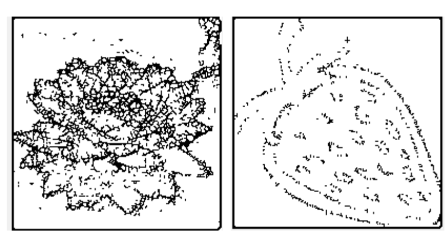
Img5.jpg Img6.jpg

Table: 4 GA Edge Detected Images



Img1.jpg Img2.jpg

Img3.jpg Img4.jpg



Img5.jpg Img6.jpg

IX. RESULT ANALYSIS

Table: 5 Experimental values of Structural Similarity Index Metric (SSIM)

S.No	Images	PSO	GSA	GA
1	Img1.jpg	0.68902	0.84179	0.64730
2	Img2.jpg	0.66651	0.83994	0.61678
3	Img3.jpg	0.69267	0.82609	0.51386
4	Img4.jpg	0.91162	0.96323	0.89345
5	Img5.jpg	0.75765	0.88665	0.71841
6	Img6.jpg	0.63697	0.79881	0.59625

Table: 6 Experimental Result of PSNR

S.No	Images	PSO	GSA	GA
1	Img1.jpg	23.3255	23.8987	23.0980
2	Img2.jpg	22.7165	23.5164	23.2331
3	Img3.jpg	22.9456	23.1650	23.0103
4	Img4.jpg	22.9886	23.4438	23.0321
5	Img5.jpg	22.9866	23.4438	23.3724
6	Img6.jpg	23.3255	23.6151	23.1203

Table: 7 Experimental values of Mean square error (MSE)

S.No	Images	PSO	GSA	GA
1	Img1.jpg	0.0046	0.0041	0.0049
2	Img2.jpg	0.0053	0.0045	0.0047
3	Img3.jpg	0.0051	0.0048	0.0050
4	Img4.jpg	0.0050	0.0045	0.0050
5	Img5.jpg	0.0050	0.0045	0.0046
6	Img6.jpg	0.0046	0.0043	0.0049

X. CONCLUSION

Paper has presented the comparative analysis of optimization methods using adaptive threshold for related to edge detection. The experimental results clearly establishes the Gravitational Search algorithm as better algorithm, which has shown good results in comparison to particle swarm optimization algorithm and genetic algorithm. The Gravitational search algorithm along with adaptive thresholding has the better performance when evaluated with different parameters. The edge detection techniques need further improvement to have more application oriented accuracy and sustainability. The work is satisfactory for the image detection i.e. face detection and applications.

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