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Hybrid Algorithm Edge Detected DICOM Image Enhancement and Analysis based on Genetic Algorithm for Evolution and Best Fit Value

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ABSTRACT

The segmentation of a DICOM standard medical image is a necessary technique which is essential for feature extraction, object edge detection and classification of the segments of the image. The DICOM image is partitioned based on the Hybrid ACO-CPM algorithm, based on the edges in the image, for analysis. The edges are seen as the boundaries within the image which differentiates different regions in the image. The factors that links to the boundary discontinuities that co-exists between the pixels of DICOM image, like texture, intensity and gradient are rendered redundant and are taken care with the application of the Hybrid ACO-CPM algorithm. DICOM image features correspond to that of meta-heuristic characteristics, which are considered during the application of Hybrid ACO-CPM algorithm. The results obtained from this non-deterministic behavior needs to be optimized over a large space called as the search space, wherein the lists of all possible solutions are provided. Each solution is to be marked as a value fit to be termed problematic and needs to be synthesized for an optimized solution. Among various techniques that provide solutions in obtaining an equitable optimization solution, Genetic Algorithms (GA) corroborates as one of the persuasive techniques in a large search space.

In this paper we propose an efficient and effective workflow based on a methodology, that provides an overview of the image enhancement and object classification for a DICOM image using Genetic Algorithm (GA). The edge detected medical standard DICOM image obtained from the Hybrid ACO-CPM algorithm is modified with respect to critical edge data. With the application of GA methodology, the process of enhancing the image ultimately suffices by rendering an image suitable for a specific application with an improved visual quality of the segmented image. A Figure-of-Merit is constructed to differentiate between the image metrics and their best fit values obtained for the images with respect to the Ant Colony Optimization (ACO) algorithm and proposed Hybrid ACO-CPM algorithm, upon enhancing the images using GA

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1 Introduction

The mechanism of natural selection and genetics are based on the principles of selecting and evolving the solution with respect to the global search space, and produce results at each genetic evolution cycle termed as generation. This is one of the most widely accepted and adaptive parallel search techniques that speculate with the potential solutions for the search points correlated within the search space. The Genetic Algorithm (GA) [1, 2, 3] improves the performance of a search algorithm using the genetics that are using the exhilarated operators corresponding to the attributes for the seizure of potential solutions iteratively. GAs tends to provide optimization solution to the stochastic optimization methods over conventional optimization methods without and priori information about the functions of the optimization algorithms. This is performed based on the operators used by the GA such as;

i. Selection
ii. Cross-over
iii. Mutation

An algorithmic model with a providently large population of entities operating in retrieving certain information for a designated analysis purpose is considered as a major concern, wherein the amount of solutions provided will be huge. In image processing, during the image segmentation process based on the information contained within the edge image, suitable optimization algorithms are applied in retrieving the edge information from the image for various analytical purposes. These optimization algorithms, stochastic in nature and continue to adapt to perform with the change in the image environment. The complex behavior of the optimization algorithms, with an undefined population set of operators performing the search operation in finding the edge within the image appeals for sourcing of enormous amount of possibilities of solutions. Such an instance is provided with the application of Ant Colony Optimization (ACO) [6] algorithm, wherein the edge detected by defined set of ant population results in a functional form of image sets, without the prior knowledge of the image statistics. Similarly as with the case of Hybrid Ant Colony Optimization-Critical Path Methodology (ACO-CPM) [5], the pre-defined populations of ants are being segregated as real and virtual ants in optimizing the image edge information retrieval process provides with huge set of solutions, with the information of the Critical Path identified for a particular population set. This has to be improved with the extraction of finer details in the images as obtained from these optimization algorithms.

The DICOM image is a medical standard digital image, used for various telemedicine applications. This kind of an image is exposed to the optimization algorithms in retrieving the information about the edge contained within the image. These edges in the DICOM images contain valuable information about the image, used during object classification for image analysis, for various diagnostic purposed. Hence the resultant quality of the image obtained from the optimization algorithms bearing the necessary information about the image has to be improved with their visual quality attributes. And also it is required to optimize the solution set from the global search space, a space with collection of solutions in detecting the edge of the image. There is zero impact on the image data content with the application of GA. The application of GA and its operators increases the dynamic range of the features contained within the image, thereby improving the visual appearance of the image and also remove the noise from the image. This process also highlights the objects edge in the selected DICOM image. The process which optimizes the global search by selecting an appropriate image enhancement parameter from the image data, automatically, is also demonstrated in this paper.

2 Elements of Genetic Algorithm and the need for Evolution

Genetic Algorithms are evolutionary computation methodologies [4], which considers the following aspects; population of chromosomes, selection based on fitness value, cross-over for the production of new off-springs, cross-over rate and mutation rate. GA is a kind of search algorithm that computes the single solution considering multiple solutions, from the search space. In Genetic Algorithm (GA), terms like chromosome, mutation, cross-over are clearly defined. The term chromosome in GA refers to an optimal solution that corresponds to a problem defined. This chromosome is considered as a bit string that is encoded. The term gene correspondingly refers to single bits or short blocks of adjacent bits that are used to encode a particular element in a solution as obtained by the processing algorithm. The bits that encode a parameter in the stochastic optimization algorithms are regarded to be genes. Similarly, cross-over means that bit string which is obtained during the exchange of genetic information between the parents information (i.e. the information contained in the file before the application of the GA). Mutation is the basic process of flipping the bit at a randomly chosen locus point with the new bit.

The basic idea behind the application of GA in any domain is to obtain an optimized solution among a set of solutions which is repeated with a factor being common among them. The search space is a context wherein an infinite set of all possible solutions are accumulated. The terms under which the solution set is optimized, an assumption that there shall be a representation within the search space, wherein all the possible genotypes with their fitness values are being considered for sorting. The sorting is done if there happens to be a correlation between the quality of each of the neighboring solutions with the same fitness values are to be sorted and segregated as the optimized solution. Here the fitness values are plotted and can be seen with some evolution. Meaning, the population set tends to move along the pane towards the local peaks, by means of adaptation. The evolution is necessary as the environment in which the population is inhabited with certain fitness values, independent of the other, may be induced with an increase in their population value. This result in the change of the fitness values of the genotypes and the set with the best fit values are to be retained in contention among the other population set. Most often, GAs assigns the fitness scores to the number of chromosomes in the current population based on the fitness function defined. It is also dependent on the GA operators which are of three types;

i. ***Selection:*** This value is set by the operator to decide upon the reproduction factor from the population set. The more fitter is the chromosome; it is likely to reproduce more number of times.

ii. ***Crossover:*** The locus is chosen randomly and the bit strings are exchanged from the latter and former local points from the current locus. This exchange is between the chromosomes from the latter and former local points from the current locus, which results in the generation of two off-springs.

iii. ***Mutation:*** The operator which randomly flips the bits in the string of the chromosome. This is a random process which might happen with a infinitesimally small probabilistic value.

The GA basically provides a methodology with which the highly fit strings with a comparatively fitness values in the search space are searched and identified as the best possible optimized solutions.

3 Literature Survey

The application of the concept of Genetic Algorithm (GA) in image processing problems [7, 8, 9], in order to achieve an optimal solution upon the performance of an efficient and effective search in the complex search space. The image contrast enhancement for an image obtained through gray-level modification with certain image statistics, can be performed as proposed by Sankar K Pal et.al [10], with the application of GA. The important aspects in digital image processing is to enhance the visual quality of the image, much better than that of the original image that can be used for specific applications was proposed by Shivangini et.al [11]. They had considered a gray-scale digital image and its enhancement with the consideration of N-point crossover as improvised against the generic GA. Additional noise from the image was successfully removed and the resulting imaging was restored with originality without any change in the data content of the image. The effect of increasing gray intensity with a dynamic range in the input image was improvised with the proposal of contrast enhancement technology. This technology was based on the Histogram Equalization (HE), called Adaptively Increasing Histogram Equalization (AIVHE). This was successfully demonstrated and proposed by S Palanikumar et.al [12] for Palm-print Enhancement. They used the optimized gamma and beta parameters based on their entropy values, in order to obtain an enhanced palm-print and also maintained the integrity of the data content of the image. Here in this proposal they considered the entropy values as the basis of fitness functions. The soft computing method of GA was proposed and implemented by Komal R Hole et.al [13]. This method was used to enhance the quality of the image and to convert the image into segments to retrieve more meaningful image for analysis using GA.

With an increase in digital imaging in the field of medicine, tumor detection is an important and challenging task that needs to be addressed. Amanpreet Kaur et.al [14] proposed a methodology in reducing the population set of brain tumor images by clustering and genetics, thereby reducing the area of concentration. The genetics are re-implemented for an effective detection of tumor from the concentrated area.

4 Methodology and Workflow

The concept of image enhancement promises with the process of improvising the visual quality attribute of the digital image. The noise from the image is removed and the qualitative features of the image are identified and enhanced with the application of GA. The methodology proposed in the paper considers the edge detected image processed from the Hybrid ACO-CPM algorithm, proposed by Chetan S et.al [5]. The DICOM standard medical image is converted into bitmap format (.bmp) and processed by Hybrid ACO-CPM upon Image Approximation [15]. The processed image from the hybrid algorithm which is also in the bitmap format (.bmp) is considered as an input into the GA. The behavior of the ants in this Hybrid ACO-CPM in detecting the edge of a DICOM image is considered as a combinatorial problem.

Here in this GA for the edge detected DICOM image, the shortest possible route and the entropy values of the images are obtained using Critical Path Methodology during the implementation of Hybrid ACO.

The population set of the ants which is an empirical value, based on the resolution of the image segregated into two categories as real and virtual ants helps in detecting the edge of the image based on the intensity values of each pixels, It traverses across the entire image with the concept of 8-pixel neighborhood and considering the intensity values on all the 8 neighborhood cells from the current pixel cell. This is done once exactly in the by an ant during the iteration monitored by the Method functions in ACO. The chromosomes are assigned with different permutation values from 1 to n in the GA, as the number of pixels traversed by the ant will be based on the order of their visit to each every local pixel/cell in the image. We also assume that the ant traversing path is restricted to the resolution of the image and thus the distance between the pixels are considered to be fixed values as C_i and C_j, where i,j ϵ n. This is considered to be a closed combinatorial problem well within the prescribed resolution of the image, considered as the boundary.

The chromosome value representing the solution to the problem is being solved by the GA. Each solution in the array is encoded as an array and is processed for optimization by the GA. The problem with N_{par} dimensions are encoded as N_{par} element array, as in

chromosome = [p_1, p_2, …. , p_{Npar}]

Here in the above expression, the parameter values are devised as per the specification of the problem as chromosomes. Each parameter value is converted into bit string making suitable for digital imaging solutions across the combinatorial problem solving algorithm, as in DICOM image fitness value calculation and image enhancement. The GA implemented in this paper uses the randomly chosen chromosomes and is evaluated for the fitness value by the fitness function to make it suitable of solving the combinatorial problem. The selection operator in the GA chooses the chromosome for reproduction based probability distribution, p_c. The equation that monitors this distribution is as given below,

$$P(C) = \left|\frac{f(C)}{\sum_{i=1}^{Npop} f(Ci)}\right|$$

The selection operator chooses the replacement for the chromosomes and this might allow for the same chromosome to be chosen more than once. The crossover operator recombines the chromosomes by swapping the chosen chromosomes and creates off-springs. The mutation operator randomly flips individual bits in the bit string of the newly generated chromosome. The mutation probability is also considered here in this case. This is monitored by setting the suitable value for p_m. Preference of calling the operators like, selection before the crossover can be set. Selection and crossover operators reproducing the newer chromosomes reproduce only fitter chromosomes making the GA to converge with an optimized solution too quickly. Thus the algorithm can also stop at the local optimum before the global optimum. This is overcome with the help of the mutant operator which helps in maintaining the diversity and integrity among the chosen population.

The initial population corresponding to the initial off-springs produced by the operators like selection, crossover and mutation by GA will be replaced with a new set of off-springs by the initial off-springs. This is repeated upon each iteration cycle and will be continued until the global optimum solution is obtained. The next new generation of chromosomes produced is tested by the fitness function. This is repeated for each generation. The iterations repeat till the GA produces the chromosomes with best fit values and the fitness value stabilizes and does not change for generations reproduced by the new chromosomes. The factors such as probability of crossover, mutation probability and the size of the population are being considered. The methodology involved in GA uses traditional search methods, within the search space to obtain optimized solutions.

i. ***Search for stored Data –*** Retrieving the stored information from the storage device has to be precise. The binary search methodology befits the efficient and effective way of searching the correct binary data and analysis.

ii. ***Search for paths to achieve optimized results –*** This search methodology is similar to the methodologies opted in various artificial intelligence algorithms. A partial search tree kind of a structure is formed which guides I searching for the best fit solution. The root of the tree represents the initial state while the nodes branching out represent all the possible results with its updating from one state to another. This also resembles as the methodology for identification of the shortest path.

iii. ***Search for solutions - This*** is more suited for GA wherein the search for the solutions subsumes the search for the path in identifying the best optimized solutions. The proposed algorithm is as shown below in Table 1.

Table 1 Genetic Algorithm Workflow

1. Input bitmap image (.bmp)

2. Set the population size to that of the image resolution bounds, as round($\sqrt{rows * columns}$) of the input image

3. Set the probability of the crossover, p_c = 0.8

4. Set the probability of mutation, p_m = 0.08 (Note this must be minimal)

5. Set the chromosome length to obtain an optimized solution

6. Initialize the population size and the chromosome length

For the size of the chosen population

Apply the operators

i. Selection

ii. Crossover

iii. Mutation

7. Calculate the fitness values for the operators

8. Update the initial generation with the new chromosomes

9. Find the best fit solution

The operators of GA are modified as functions and are as shown in the Table 2 and Table 3.

Table 2 Mutation Workflow

1. *New population is updated with mutation*
2. *The initial generation of chromosomes are assumed to be fit by set it to all ones*
3. *The mutants are generated randomly as suggested for reproduction*
4. *The new population is updated with new chromosomes*
5. *Else the population is updated with the ones, as taken with the previous population*

Table 3 Crossover Workflow

1. *For the size of the image bounded by its resolution, set the population values initially as ones.*
2. *The random length combination of the chromosomes are performed*
3. *If the randomly selected value is less than the probability of the crossover p_c, then the new population is obtained by crossover*
4. *Else it remains as the old population size*
5. *The crossover across on randomly selected chromosomes among the population*

5 Analysis and Results

The proposed algorithm is applied for the DICOM image, a CT scan image of the human brain. The image is processed with generic Ant Colony Optimization and Hybrid ACO-CPM algorithms. The processed image files are subjected to GA for finding the best fit solutions and fitness values obtained from number of iterations as outputs. The fitness values are compared among the images obtained with the application of the methods such as Sine, Gaussian, Fourier and Wave in the ACO and the Hybrid ACO-CPM. But in Hybrid ACO-CPM the ant population is segregated into two categories as real and virtual ants. The image edge processed by real ants is considered as input by the virtual ants and the image edge is linearly covered for the uncovered regions. A figure-of-merit is constructed based on the image analysis, fitness values and the best fit values are plotted for comparison.

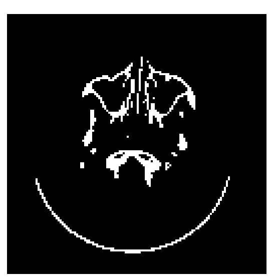

Figure 1 Original Bitmap Brain Image

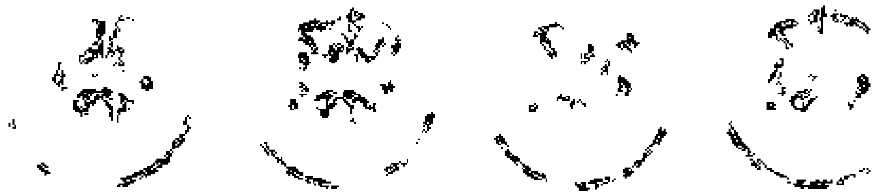

Figure 2 Hybrid ACO-CPM processed Images by Real Ants

Figure 3 Hybrid ACO-CPM processed Images by Virtual Ants

The GA is run for accessing and evaluating the fitness values and best fit value. With the fitness values compared for the edge processed DICOM images and the Best fit value to be considered being minimal suits the best possible solution. The images below represent the Fitness Values and Best fit value plots for original image processed by generic ACO and Hybrid ACO-CPM. This helps in evaluating the need for image enhancement and its inherent characteristics via figure-of-merit.

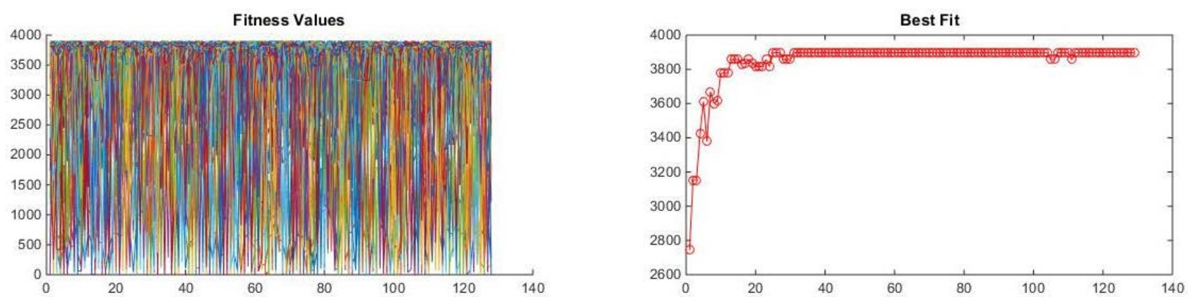

Figure 4 Fitness Values and Best Fit Value for the image processed with ACO algorithm

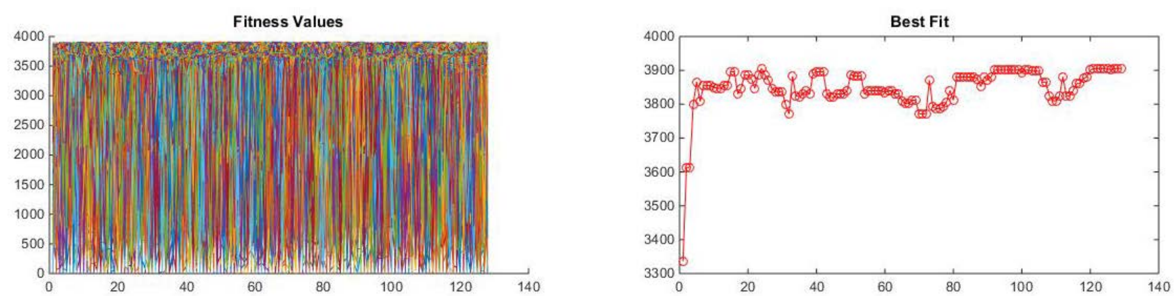

Figure 5 Fitness Values and Best Fit Value for the image processed with Hybrid ACO-CPM algorithm for Real Ants

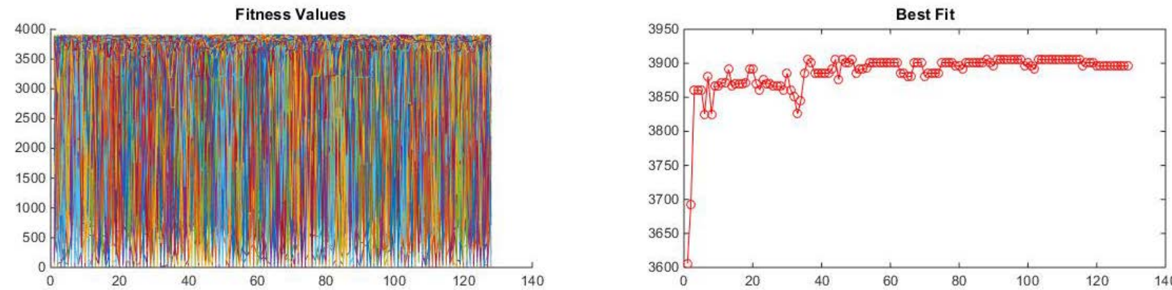

Figure 6 Fitness Values and Best Fit Value for the image processed with Hybrid ACO-CPM algorithm for Virtual Ants

Figure-of-Merit

The figure-of-merit helps us in finding the deviations between the algorithms used in detecting the edge of DICOM image and its application. It also helps in evaluating the efficiency of the algorithm. The fitness values computed using the GA and the image enhancements factors helps in differentiating and analyze the productivity of the algorithm as proposed in Hybrid ACO-CPM, with the generic ACO algorithm. This also shows the deviations among various algorithms, wherein the image solutions being optimized across at different fitness value rates versus the population size. In this case and for the considered DICOM image, it's the pixel count.

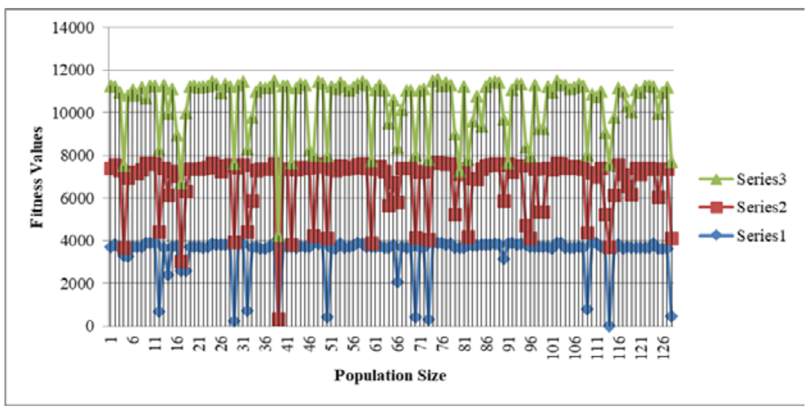

Figure 7 Figure-of-Merit with the Fitness Values vs Population Size

In the above figure the Series 1 corresponds to the fitness values obtained from the DICOM image processed by Hybrid ACO-CPM with virtual ants. While Series 2 corresponds to the fitness values obtained by processing the DICOM image using Hybrid ACO-CPM with real ants. Series 3 corresponds to the fitness values obtained from the DICOM image processed by generic ACO algorithm. The optimization is inferred from the plot wherein the more linear values are intended to be most optimized with the application of GA.

6 Conclusion

The solutions to the combinatorial problems like the edge detection within a DICOM image using the Hybrid ACO-CPM algorithmic approach are dynamic and they evolve with the dynamics of the image. The reliability of these algorithms rendering an optimized solution from a set of solutions is much desirable from the optimization algorithm. Also the need for a better visual quality image after the processing by the edge detection optimization algorithms enhance the diagnosis capabilities with the

DICOM standard medical image. This purpose of image enhancement with the provision of an optimized solution from a collection of solutions is successfully taken care by the application of Genetic Algorithms. The evolution also plays an important role in obtaining new population as well as much better optimized results from the search space of the solutions to the problem.

In this paper, we could successfully implement the GA for the DICOM images processed by generic ACO and as well as for Hybrid ACO-CPM. The figure-of-merit is plotted and analyzed to evaluate between the different implementation features and characteristics of these edge detection algorithms. Also the impact of these algorithms is analyzed with the application of GA on the images obtained from these algorithms. The evaluation resulted in proving that the Hybrid ACO-CPM is more suitable with an optimized solution within the entire search space of solutions. This also shows that the convergence rate of the solutions is much faster and more adaptable with the increase in the population count.

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