A RADICLE STUDY OF FIRE-FLY ALGORITHM

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Abstract - Firefly algorithm (FA) is a metaheuristic algorithm which was proposed by Dr. Xin-She Yang in 2008 at Cambridge University [1-2], inspired by the flashing behaviour of firefly insects. In this paper, we will see how firefly algorithm is being used in different engineering process applications and also how it is more efficient than others. Firefly algorithm is better than many other methods as it gives optimal solution with minimum time complexity. Our paper show how firefly algorithm is modified and used with other methods to implement and obtain solution for different problems. Firefly algorithm has advantages over other algorithm such as automatical subdivision and the ability of dealing with multimodality. Also the parameters in firefly algorithm can be tuned to control the randomness as iterations proceed, so that convergence can also be sped up by tuning these parameters. These above advantages makes it flexible to deal with continuous problems, clustering and classifications, and combinational as well.

Keywords: Firefly algorithm, metaheuristic, hybridization, particle swarn optimization, image segmentation, thresholding, knapsack problem, travelling salesman problem, vector quantization, improved differential evolution, optimization.

I. INTRODUCTION

Firefly algorithm is a metaheuristic algorithm inspired by firefly insects [1-2]. FA is a population based algorithm. The fireflies insect use their flashing behaviour to attract other fireflies , usually of opposite sex but firefly objects used in mathematical models are unisexual and can attract any other firefly. For any two firefly objects, the attractiveness is proportional to their brightness, the brighter one attracts the lesser one and their intensity is inversely proportional to their distance. Modified firefly algorithm [4] gives best performance as compared to firefly algorithm and genetic algorithm. Firefly algorithm struct in local optimization. Firefly algorithm uses for classification, clustering, optimization and several engineering application. Firefly algorithm mainly categories in two type: improved firefly algorithm and hybrid firefly algorithm.

ALGORITHM

In pseudocode[3] the algorithm can be stated as:

Begin
1) Objective function: f(X), X=(x1, x2, . . . . . ,xd);
2) Generate an initial population of fireflies Xi (i=1, 2 . . . n)
3) Formulate light intensity I so that it is associated with f(X)
   (for example, for maximization problems, I=αf(X) or simply I=f(X) ;)
4) Define absorption coefficient γ
   While (t < MaxGeneration)
      for i = 1: n (all n fireflies)
         for j= 1 : n (n fireflies)
            if I > I i
               Vary attractiveness with distance r via (- γ r)
               move firefly i towards j;
               Evaluate new solutions and update light intensity;
            end if
         end for j
      end for i
While (t < MaxGeneration)

Rank fireflies and find the current best;

end while

Post-processing the results and visualization;

end

Note that the number of objective function evaluations per loop is one evaluation per firefly, even though the above pseudocode suggests it is n*n. (Based on Yang's matlab code.) Thus the total number of objective function evaluations is (number of generations) * (number of fireflies).

The main update formula for any pair of two fireflies \( X_i \) and \( X_j \) is

\[
x_{i}^{t+1} = x_{i}^{t} + \beta \exp \left( - \frac{d_{ij}^2}{\alpha_{t}} \right) (x_{j}^{t} - x_{i}^{t}) + \alpha_{t} \epsilon_{t}
\]

Where \( \alpha_{t} \) is a parameter controlling the step size, while \( \epsilon_{t} \) is a vector drawn from a Gaussian or other distribution.

It can be shown that the limiting case \( \lim_{t \to \infty} \) corresponds to the standard Particle Swarm Optimisation (PSO) [5]. In fact, if the inner loop (for \( j \)) is removed and the brightness \( I_j \) is replaced by the current global best \( I_{gb} \), then FA essentially becomes the standard PSO.

II. RADICLE STUDY OF FF ALGORITHM


Electricity generation must meet the increasing demand with time. The power plant generating electricity must be efficient and reliable and at the same time the cost of generation of per unit electricity must be minimum to maintain the profit. The amount of emission produced by the burning fossil fuel must be minimized. The firefly algorithm is used to solve this economic emission load dispatch problem to maintain both the quality and quantity with minimum pollution.

Firefly algorithm used to reduce a single pollutant nitrogen oxide, NOx while maintaining the quality. The results obtained are comparably better than the results obtained by other stochastic alternative optimization algorithms such as the goal attainment SQP method, the particle swarm optimization, and the Genetic algorithms, in terms of efficiency and success rates. The execution time was less than 3 seconds and the optimal solution very quickly (probably from 10th iteration).

Table 1: Minimum fuel cost and emission for various load demands using new particle swarm optimization [7].


Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images. The simplest thresholding methods replace each pixel in an image with either a black or white pixel depending on its image pixel \( I_{ij} \) whether it is less or greater than some fixed Constant \( T \).

In this paper, maximum entropy based firefly thresholding method algorithm which is a new multilevel MET (Multilevel Entropy Thresholding) algorithm is used which is based on firefly also for multilevel thresholds selection using the maximum entropy criterion.

The achieved segmentation results through this maximum entropy based firefly thresholding method algorithm is highly/significantly improved and has the shortest execution time. This maximum entropy based firefly thresholding method can be used further for real-time image analysis problem like target recognition, document analysis & much more.

For testing five images and corresponding histograms are: (a)LENA(\textit{girl}), (b)PEPPER, (c)BIRD, (d)CAMERA and (e)GOLDHILL.

Table 3. The computation times and the corresponding PSNR of the five different multilevel thresholding methods.
Table 4: The value of the objective function with regard with the corresponding thresholds listed in above table.

<table>
<thead>
<tr>
<th>Image (iter)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LENA</td>
<td>2</td>
</tr>
<tr>
<td>12.0970</td>
<td>12.0970</td>
</tr>
<tr>
<td>15.7658</td>
<td>15.7658</td>
</tr>
<tr>
<td>18.5979</td>
<td>18.5979</td>
</tr>
<tr>
<td>21.2690</td>
<td>21.2690</td>
</tr>
<tr>
<td>23.8549</td>
<td>23.8549</td>
</tr>
<tr>
<td>26.4405</td>
<td>26.4405</td>
</tr>
<tr>
<td>28.9018</td>
<td>28.9018</td>
</tr>
</tbody>
</table>

Finding Optimal Test Sequence Generation (Srivastava, Mallikarjun and Yang, 2013).[9]

In a software development life cycle [10], the most important but complex is the software testing [11]. To analyse the software testing and to optimize the process is a challenging task. In this paper, firefly algorithm is implemented to generate an optimal test paths. Modified firefly algorithm [3] is implemented to optimize the test cases by defining appropriate objective functions and introducing a guidance matrix in transversing the graph.

The obtained simulations through this paper show that the test path generated are critical and optimal paths. The implemented approach is the first of kind in software testing field, which minimizes the test cases by optimizing the test paths for the case. Since the simulations are optimal it will minimize the test efforts. The approaching method can be further used for other expensive testing procedure.

Table 5: Test cases for comparing FA and ACO.

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>No. of states</th>
<th>Cyclic complexity</th>
<th>% Reliability in path coverage ACO</th>
<th>% Reliability in path coverage FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>5</td>
<td>0.0</td>
<td>1.32</td>
</tr>
<tr>
<td>4</td>
<td>48</td>
<td>12</td>
<td>0.8</td>
<td>1.32</td>
</tr>
</tbody>
</table>

Solving Travelling Salesman Problem (Kumbhara and Pandey, 2013).[12]

We all are familiar with Knapsack Problem, vehicle routing, travelling salesman problem etc. which are some complex problems. Inspite of all the advanced technology still there are so many complex problems that elude scientists. In this paper, the firefly algorithm is used to solve the travelling salesman problem. Given a list of cities with their distances between each one, it gives the shortest possible route that visits each city and returns to its origin city.

A few modifications have been made to construct a proper/appropriate conversion of the continuous function as are attractiveness, distance and movement into a new discrete function. The results obtained are better than many other methods.

Table 6: Comparison between FA, ACO, GA and SA for Solving Standard TSP Instances [13].

Table 7. PSNR values of image compression for 5 different 512 x 512 images with 6 different Codebook sizes.

5. Vector Quantization for Image Compression (Horng, 2012).[14]

Vector Quantization (VQ)[15,16] is a classical quantization technique from signal processing that allows the modeling of probability density functions by the distribution of prototype vectors. It has a simple decoding architecture and high compression ratio. Codebook design is the most essential part in vector quantization. An appropriate codebook must be used as it affects the quantity of image compression like global codebook generation. Linde–Buzo–Gray (LBG) is a traditional method of generation of VQ Codebook which results in lower Peak signal to noise ratio (PSNR) value.

In this study, an Improved Differential Evolution (IDE) Algorithm based codebook training has been presented for Image Compression. The Peak signal to noise ratio (PSNR) of vector quantization is optimized by using IDE-LBG Algorithm where PSNR is considered as the fitness function for the optimization problem. The algorithm parameters have been tuned suitably for efficient codebook design. It is observed that using the proposed IDE-LBG Algorithm the PSNR values and the quality of reconstructed image obtained are much better than that obtained from the other algorithms in comparison for six different Codebook sizes.

Table 8: Comparison between FA, ACO, GA and SA for Solving Standard TSP Instances [13].

Table 8. PSNR values of image compression for 5 different 512 x 512 images with 6 different Codebook sizes.

6. Job Shop Scheduling Problem.[17]
Job shop scheduling problem is a non-deterministic polynomial (NP) hard problem. The objective of this paper is to show how recently developed FA is used to solve JSS and investigate the parameter setting of the proposed algorithm. The experiment was implemented using five benchmarking JSSP datasets from a classical OR – library. The analysis of the experiment results shows the best -so-far schedule better with appropriate parameter setting than without adapting parameter setting.

In this paper FA was implemented to final the lowest makespan for the five benchmark JSSP datasets adopted from the OR-Library. The results is obtained in one-third number of experimental run compared with the conventional designs. The obtained results through both with optimized parameter setting and without using one compared and found that the performance is better when the optimized parameter setting are being used.

Fig. 1. Comparison of Makespan with other Algorithm

7. A novel firefly algorithm based Ant colony optimization for solving combinatorial optimization problems.[17]

A new firefly optimization algorithm have been presented which is inspired by ant colony optimization algorithm which is called Firefly Colony Optimization algorithm (FCO). The implemented algorithm in this paper is a distributed and constructive greedy metaheuristic which produces greedily good solutions based on the positive feedback and avoid the low quality solutions. The performance of the proposed methodology have been assessed on the bin packing problem.

In this paper, a new constructive and distributed version of the firefly algorithm have been proposed which is called the Firefly Colony Optimization (FCO). FCO have the common properties of the bioluminescent communication of fireflies and foraging behavior of ants. FCO obtains near optimal results with significant faster convergence ability.

Fig. 2. Flowchart of the Firefly Colony Optimization

<table>
<thead>
<tr>
<th>Application</th>
<th>Methods used</th>
<th>Results obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solving the Economic Emissions Load Dispatch problem</td>
<td>Firefly algorithm, hybridization, SQP method</td>
<td>Minimum emission of nitrogen oxide</td>
</tr>
<tr>
<td>Multilevel Image Thresholding Selection</td>
<td>firefly algorithm, Image Segmentation, particle swarn optimization</td>
<td>Improved segmentation and shortest execution time</td>
</tr>
<tr>
<td>Finding Optimal Test Sequence Generation</td>
<td>Modified firefly algorithm</td>
<td>Optimal simulation and minimized number of test cases</td>
</tr>
<tr>
<td>Solving Travelling Salesman Problem</td>
<td>firefly algorithm, computational intelligence, optimization</td>
<td>Obtained results are better than ACO, GA and SA in most of the instances.</td>
</tr>
<tr>
<td>Vector Quantization for Image Compression</td>
<td>Linde-Buzo-Gray (LBG) Algorithm, Improved</td>
<td>PSNR values and the quality of reconstructed</td>
</tr>
</tbody>
</table>
Particle Swarm Optimization (IPSO) Algorithm, Bat Algorithm (BA), Firefly Algorithm (FA).

Firefly algorithm, job shop, scheduling

Firefly Algorithm, Firefly Colony Optimization, Greedy Algorithm, Bin packing problem.

FCO obtains near optimal results with significant faster convergence ability

<table>
<thead>
<tr>
<th>Job Shop Scheduling Problem</th>
<th>image obtained are much better</th>
</tr>
</thead>
</table>

| A novel firefly algorithm based Ant colony optimization for solving combinatorial optimization problems | lowest makespan and the number of experimental runs is reduced by 66.7% |

Table 8: list of applications with methods used and results obtained.

III. CONCLUSION

We have observed through this paper that how firefly algorithm is used to solve and obtain results for various problems. We have observed that for discrete problems and combinatorial optimisation, discrete versions of firefly algorithm have been developed with superior performance, which can be used for travelling-salesman problems, graph colouring and other applications. In addition, extension of firefly algorithm to multi-objective optimisation has also been investigated. There is no doubt that firefly algorithm will be applied in solving more challenging problems in the near future, and its literature will continue to expand.

IV. REFERENCES

2. Xin-She Yang, “Firefly Algorithm: Recent Advances and Application Solving the Economic Emissions Load Dispatch problem”, Apostolopoulos and Vlachos, 18th August 2013.