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Solving of Travelling Salesman Problem using Firefly Algorithm with Greedy Approach

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Abstract. Travelling salesman problem is one of the most important problems in graphs theory which is considered as NP-hard problems. The important of this problem is due to the fact that it is used in many fields such as transportation, logistics, semiconductor industry, problem of routing, scan chain optimization and drilling problem in integrated orbit test, production and many others scientific and industrial fields. Till now various methods that have been used to solve this problem have their own advantage and disadvantage and problems, become clearer when the problem become harder. Therefore, travelling salesman problem remain as an open problem in research field of computer science. This paper tried to solve the above problem with an optimization algorithm with less complexity in order to solve this problem with firefly algorithm with greedy approach and it was compare and examined with other standard algorithm. The results show the superiority of proposed algorithm compared to the other used algorithm.

Keywords: Travelling salesman problem, firefly algorithm, greedy mutation, NP-hard

1. INTRODUCTION

Travelling salesman problem was a NP-hard problem and is one of the most important problems in combinatorial optimization. In this problem we have the salesman who wants to travel to some city and return to the first city so that all the cities are visited and each city is met only once. The main purpose is to find a permutation of cities that minimizes the coast and reduces the complexity of the existing state thus the optimal solution result provide to travelling salesman problem. In this problem if the distance between A and B city is equal to distance between B and A, travelling salesman problem is the type of symmetric, otherwise the problem is asymmetric.

The mathematical model is as follows:

$$\min \sum_{i=0}^{N} \sum_{j\neq i, j=0}^{N} c_{ij}$$

c_{ij} *is distance between* i *and* j *cities*

$i, j = 0, 1, \dots, N$

In travelling salesman problem with increasing the number of cities the existing solutions don't provide optimal solution at the appropriate time; for this reason meta-heuristic algorithms for finding optimization is used. Many meta-heuristic algorithms which have been inspired by nature are used

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[1-5]. That we will obtain better results in each of this algorithm by changing parameters and using techniques. In order to obtain almost accurate answer, this algorithm have many usages for solving this problem. Each of this meta-heuristic algorithms have different strength and weakness but what is important is method or algorithm to find the best tour in the shortest possible time. Ryzakallah et.al. [6], in 2013 presented a hybrid algorithm called ACO-FA that ant colony optimization (ACO) merge with firefly algorithm (FA) for unlimited problems solving. Karabuga and Gourakmali [7] in 2011 offered hybrid algorithm of bee colony (BC) to TCP problem and they compared result with traditional methods to solve this problem. Chen et.al. [8], in 2011 have offered parallel system of ant colony genetic (PGACS) to solve problem of traveling salesman. This method consists of genetic algorithm, including crossover new operations and hybrid mutation operations, and ants colony systems with communication strategies. Janio and Remond [9] in 2013 have examined travelling salesman problem on the type of ABC algorithm such as improved (I-ABC) and ABC selection forecast (PS-ABC). Floris and Maverotas [10], in 2014 using multi-objective mathematical programming that is capable of producing of accurate Pareto set in right programming multi-objective problems (MOMP) that produced all Pareto optimal solution in two popular problem, multi-objective travelling salesman problem (MOTSP) and multi-objective coverage problem (MOSCP). In [11] multi-objective travelling salesman problem is solved with improved genetic algorithm.

2. FIREFLY ALGORITHM

The first time, this algorithm was created in 2009 by Xin-She-Yang. Firefly algorithm, is inspired from fireflies that are using short lights and rhythmic for attracting hunt, protection system or attract mates. In firefly algorithm, there are two important issues, light intensity changes and formulating charm. For simplicity we can always assume that firefly charm is determined by its light that in turn is associated with function objective. Attraction is proportional to shine and dimmer firefly is absorbed to the lighter firefly and firefly is moving randomly if there is no light [12].

Light distance and analysis by air; makes firefly visible only for limited distance. A firefly can be considered as a point light source. It is known that light intensity at a certain distance **r** from light source follows inverse square law. This law stated that light intensity **I** decreased by increasing **r** distance.

$$I \propto 1/r \qquad (1)$$

As mentioned, the air undermines light that is weaker and weaker with increasing distance. In the simplest case, light intensity can be considered as a point sourer by coefficient analysis γ, in distance of r as a equation 2 (I_0 is light intensity in r=0).

$$I = I_0 e^{-\gamma r^2} \qquad (2)$$

Since the firefly attraction is proportional to the light intensity seen by nearby firefly, attraction firefly is defined as equation (3) (β_0 attraction is r=0)

$$\beta(r) = \beta_0 \, e^{-\gamma r^2} \qquad (3)$$

Distance of both firefly I and j is equal to Cartesian distance between them.

$$r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad (4)$$

Also light is proportional to objective function. Therefore location update for each pair of firefly x_i وx_j is as equation (5):

$$X_i^{t+1} = X_i^t + \beta_0 e^{-\gamma r_{ij}^2}\left(X_j^t - X_i^t\right) + \alpha_t \epsilon_t \qquad (5)$$

Firefly algorithm is formulated with the following three assumptions:

1. All fireflies are single sex; so that a firefly is attract all other fireflies.
2. The attraction is proportional to the light, and for both firefly, dimmer firefly is attracted to lighter one.
3. If the firefly isn't lighter than the other firefly then firefly will randomly move.

Firefly algorithm pseudo-code is as follows:

Firefly Algorithm

$Objective\ function\ f(x), x = (x_1, \ldots, x_d)^T$
$Generate\ initial\ population\ of\ fireflies\ x_i\ (i = 1, 2, \ldots, n)$
$Light\ intensity\ I_i\ at\ x_i\ is\ determined\ by\ f(x_i)$
$Define\ light\ absorption\ coefficient\ \gamma$
$while\ (t < MaxGeneration)$
$for\ i = 1 : n\ all\ n\ fireflies$
$for\ j = 1 : i\ all\ n\ fireflies$
$if\ (Ij > Ii), Move\ firefly\ i\ towards\ j\ in\ d - dimension;\ end\ if$
$Attractiveness\ varies\ with\ distance\ r\ via\ exp[-r]$
$Evaluate\ new\ solutions\ and\ update\ light\ intensity$
$end\ for\ j$
$end\ for\ i$
$Rank\ the\ fireflies\ and\ find\ the\ current\ best$
$end\ while$
$Postprocess\ results\ and\ visualization\ Rank\ the\ fireflies\ and\ find\ the\ current\ best;$
$End\ while;$
$Post\ process\ results\ and\ visualization;$
$End\ procedure$

3. GREEDY ALGORITHM

A wide range of issues are solvable by greedy algorithms. Greedy algorithms are a special groups of problem solving method that performs in present time based on benefit increase. These algorithms, regardless of the operations and choices that has been done in the past or will be accepted in the future trying to make the best choice in the present. In other words, regardless of the efficiency of the current selection, it chooses an option in the future that now seems better. However, these methods have no integrity and usually does not lead to overall optimal, but since the decision-making process is simple are still used. Using this technique with an innovative optimization algorithms provide a suitable methodology for convergence of optimum solution. It is clear that implementation of this procedure, imposes additional actions on the algorithm. These techniques is one of conscious methods. Because by Problem Solving Knowledge disregards inappropriate response, as possible. And by doing so fitness increase.In the greedy method, reaching the purpose in each step is independent of the previous and next steps. This means that at any stage to achieve the ultimate goal,

independent of the choices made in the previous steps, and what choices are possible in the current selection, the best choice may be done.

4. GREEDY MUTATION

As mentioned, approaches greedily, in order to increase profits are designed in the present, without past and future review process. Using greedy approach as greedy mutation and its use in firefly algorithm brings optimal results for this problem.

4-1 Swapping Mutation:

These mutations can be implemented as a couple of points two elements are selected from the selected range in this method, (that in this problem is the place of two cities from the tour) and then values are change with each other. This is one of the easiest and most used mutations. In the following pseudo-code, these mutations are mentioned:

Procedure Swapping Mutation

$n\ is\ number\ of\ cities$
$tour, new\_tour\ is\ permutation\ of\ cities$
$i = randsample(n, 2)$
$i1 = i(1)$
$i2 = i(2)$
$new\_tour = tour$
$new\_tour([i1\ i2]) = tour([i2\ i1]))$

4-2 Use a Mutation with Greedy Approach

In mutation, by using greedy approach mutation process can be continued until the fireflies change lead to increase elegance as far as the algorithm to achieve good fitness elegance. Greedy mutation is not a standalone operator but combined with other methods of mutations applies mutation until elegance increase to a suitable value.

In this study, Swapping mutation is used for combining with the greedy mutation. Greedy pseudo-code mutation and its combination with the Swapping mutation are in the following:

The combination of mutation method with greedy approach should also be taken with a certain elegance because with this approach to choose the right path the speed decreases. Therefore, an internal mutation should be used that has high speed. Therefore using mutations like Inversion Mutation or Swapping Mutation is efficient. The table 1 shows the results of run the algorithms for 500 iteration and the size of the population of 10 for a different number of cities. The results indicates that the proposed algorithm presents a better tour compared to other algorithm and besides increasing number of cities, efficiency of the proposed method is declared.

Procedure greedy

$C\ is\ maximum\ of\ desired\ fitness$
$tour\ is\ permutation\ of\ cities$
$new\_tour\ =\ tour;$
do
$tour\ =\ new\_tour;$
$P\ =\ fitness\ (tour);$
$Mutation\ swap\ (new\_tour)\ \%\ or\ any\ type\ mutation$
$While\ (fitness\ (new\_tour)\ >\ P\ or\ fitness\ (new\_tour)\ >\ c);$

5.SIMULATION

In this paper, the improved firefly algorithm has been run to solve the standard traveling salesman problem using MATLAB 2013 on a platform with the specifications of Intel CORE i3 and RAM memory, 4GB and operating system windows 7, 32bit, is running. Cities coordinates used in order to test the proposed algorithm and algorithms to compare including Genetic algorithms, Particle Swarm Optimization, and standard firefly algorithm, are as follows:

X:	44 38 77 80 18 49 45 65 71 76 27 68 66 16 12 50 96 34 59 22 75 25 51 70 89 96 55 14 15 26 84 25 82 24 93 35 19 25 62 47 35 83 59 55 92 28 76 76 38 57 7 5 53 78 94 13 57 47 1 34 16 80 31 53 16 60 26 66 69 75 45 8 23 92 15 83 54 100 7 44 10 97 0 78 82 87 8 40 26 80 43 91 18 26 14 13 87 58 55 14
Y:	86 62 35 51 40 7 24 12 18 24 42 5 91 95 49 49 34 90 37 11 78 39 24 40 9 13 95 96 58 6 23 35 82 1 4 17 65 73 65 45 55 29 75 19 69 18 37 63 78 8 93 78 49 44 45 30 51 51 82 80 65 38 81 53 35 94 88 55 62 59 20 30 47 23 85 19 22 17 22 44 31 93 43 18 91 98 44 11 26 41 60 26 60 71 22 11 29 32 42 51

The results are provided for the 20, 40, 70 and 100 towns as for 100 cities, coordination of 100 primary cases of this collection is considered and similarly, for 70 cities, coordinates of 70 primary cases in the set of x and y have been provided. Traveling salesman problem (TSP) for standard population-based algorithms, genetic, particle swarm optimization and firefly is executed. And the results have been compared with the results of the proposed method in this study. Table 1 shows the results for a population of 10, and 500 iteration for 10 times. The results are shown in Figure 1 to 4 as graphical output.

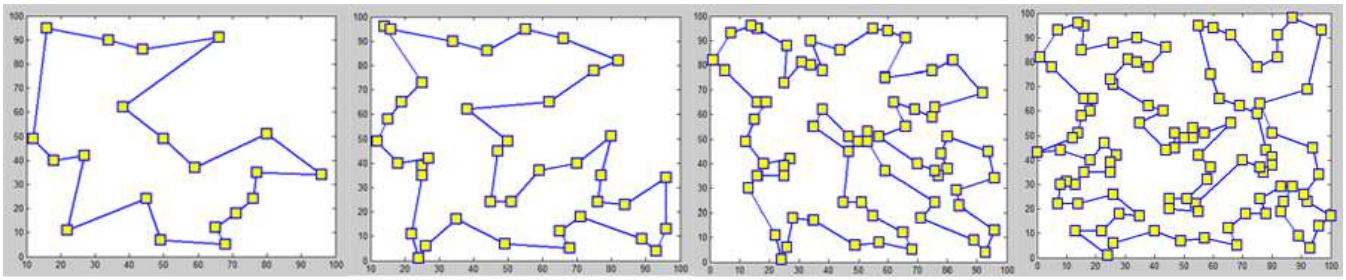

figure1:result for 20 cities — Best Tour:30

Figure2:result for 40 cities — Best Tour:504.965

Figure3:result for 70 cities — Best Tour:664.0505

Figure4:result for 100 cities — Best Tour:827.0897

Table 1. Comparison of results between GA, PSO, FA and Greedy FA Algorithms for Solving TSP with 500 iteration & 10 population.

No.City	time Algorithm	No. Iteration	No. Population	The obtained tour length in the first performance	Obtained time in the first performance (in seconds)	Average tour length in 10 times performance (in seconds)	Average time in 10 times performance (in seconds)	Best Tour
20	GA	500	10	425.2955	19.0752	480.2134	20.8576	425.2955
	PSO	500	10	672.148	15.9945	619.8129	16.7086	516.6587
	FA	500	10	672.3872	17.145	641.9084	17.5824	610.9944
	Greedy FA	500	10	**411.3089**	**57.4288**	**396.6761**	**63.3322**	**388.1824**
40	GA	500	10	901.9653	20.0615	902.7675	21.466	787.7045
	PSO	500	10	1466.6003	15.3071	1430.1118	16.8825	1358.4269
	FA	500	10	1558.2614	16.4119	1412.4715	17.1059	1166.4222
	Greedy FA	500	10	**527.4605**	**53.349**	**526.7147**	**56.6014**	**504.965**
70	GA	500	10	1469.4523	21.7492	1468.6275	23.0545	1455.7181
	PSO	500	10	2773.8009	16.2577	2671.5446	17.8001	2525.8305
	FA	500	10	2735.376	15.6931	2504.4124	16.9246	2274.5052
	Greedy FA	500	10	**717.906**	**61.0176**	**689.9423**	**75.1911**	**664.0505**
100	GA	500	10	2173.1146	23.3613	2335.1172	26.0838	2092.9098
	PSO	500	10	4192.6016	17.1997	4030.8799	21.7723	3709.4103
	FA	500	10	3604.4661	18.8523	3636.8554	18.1751	3556.4732
	Greedy FA	500	10	**840.8797**	**61.2274**	**856.2856**	**77.8947**	**827.0897**

6. DISCUSSION AND CONCLUSION

According to the results, it can be seen that firefly algorithm with greedy approach offers a better tour length compared to standard firefly algorithm, genetics and particle swarm optimization. In firefly algorithm with increase of the number of cities algorithm performance intensively drops in finding optimal intensity; but in algorithm with greedy approach according to analysis of some tours, in each algorithm repetition, a good result is offered but this improvement accompanied with huge time increase of obtaining the optimal tour. This is due to the repeated cycle of greedy mutation jump and the time increase is inevitable but for a number of different cities to some extend by resetting the parameters you can control this time increase and take advantage of obtained optimal tour.

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