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A REVIEW OF FIREFLY ALGORITHM

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ABSTRACT

Firefly algorithm is one of the swarm intelligence that evolve fast for almost area of optimization and engineering problems. Stand alone firefly algorithm already has managed to solve problems. For problems that have multi dimensional and nonlinear problem, some modification or even hybridization with the other metaheuristic is advisable. This modification and hybridization is to aim for help for the computational constrain and it will become more flexible and more efficient.

Keywords: firefly algorithm, hybridization, modification.

INTRODUCTION

The algorithm can be categorized into many classifications, one of its deterministic or stochastic. Deterministic algorithm is algorithms that produce on the given input, and it will produce same result by following the same computational steps. Deterministic algorithm is quite efficient in finding local optima because of it will do local search.

Stochastic can be defined in two group, heuristic and metaheuristic. Heuristic means 'to find' or 'to discover by trial and error. The quality solutions for a tough optimization problem can be found but, there is no guarantee that solution is the optimal solution. Metaheuristic is generally better than heuristic algorithm since the search process is randomization and local search (Yang, 2010). Even though metaheuristic only able to provide "acceptable" solution, but it leaves to tackle tough and complex problem in engineering and science field in a fair time (Talbi, 2009). There are two main components in metaheuristic, diversification or exploration and intensification or exploitation (Yang, 2010), (Blum and Roli, 2003).

Diversification or exploration is to explore the global search space thoroughly and able to generate diverse solutions. Intensification or exploitation is to exploit the local information for the search process and generate current good solutions (Yang, 2010), (Yang and Karamanoglu, 2013). Since diversification is about global search, the advantage is it will increase the chance to gain the optimality globally. The disadvantages are the process will be slower and less convergence rate. While the intensification is about local search, the optimization will be converging quickly. The disadvantages are, it will may lead to premature convergence and it will reduce the chance to find global optimum (Yang and Karamanoglu, 2013). Seeing that diversion is better in global search with diverse solutions, while intensification is fast in search space thus will use less time. Balancing between these two components with the selection of best solutions will be a great help to find higher chance of diversity solutions, in less time taken and global optimality is achievable (Yang and Press 2010), (Blum and Roli, 2003), (Yang and Karamanoglu, 2013).

Swarm intelligence in a system of collective agent that interact with the surrounding environment that perform global pattern. This intelligence compose base for the evaluation, comparing and imitation. Swarm intelligence system is act as in their coordinated without external disturbance. In years, the numbers of swarm base optimization is increased such as Particle Swarm Optimization (PSO), Artificial Bee Colony optimization (ABC) and Firefly Algorithm (FA) for robot path planning (Pal and Sharma, 2013).

FIREFLY ALGORITHM

Introduction of Firefly Algorithm

In the book of Yang (Yang, 2010), there is an explanation of how the algorithm that follows the firefly characteristic. Firefly is an insect that mostly produces short and rhythmic flashes that produced by a process of bioluminescence. The function of the flashing light is to attract partners (communication) or attract potential prey and as a protective warning toward the predator. Thus, this intensity of light is the factor of the other fireflies to move toward the other firefly.

The light intensity is varied at the distance from the eyes of the beholder. It is safe to say that the light intensity is decreased as the distance increase. The light intensity also the influence of the air absorb by the surroundings, thus the intensity becomes less appealing as the distance increase (Yang, 2010). Firefly algorithm was followed three idealize rules, 1) Fireflies are attracted toward each others regardless of gender. 2) The attractiveness of the fireflies is correlative with the brightness of the fireflies, thus the less attractive firefly will move forward to the more attractive firefly. 3) The brightness of fireflies is depend on the objective function (Yang, 2010).

Structure of firefly algorithm

In firefly algorithm, there are two important variables, which is the light intensity and attractiveness. Firefly is attracted toward the other firefly that has brighter flash than itself. The attractiveness is depended with the light intensity.

Firefly Algorithm

Objective function $f(\boldsymbol{x})$, $\boldsymbol{x} = (x_1, ..., x_d)^T$
Generate initial population of fireflies $\boldsymbol{x}_i$ $(i = 1, 2, ..., n)$
Light intensity I_i at $\boldsymbol{x}_i$ is determined by $f(\boldsymbol{x}_i)$
Define light absorption coefficient γ
while $(t < MaxGeneration)$
for $i = 1 : n$ all n fireflies
   for $j = 1 : n$ all n fireflies (inner loop)
   if $(I_i < I_j)$, Move firefly i towards j; **end if**
     Vary attractiveness with distance r via $\exp[-\gamma r]$
     Evaluate new solutions and update light intensity
   end for j
end for i
Rank the fireflies and find the current global best $\boldsymbol{g}_*$
end while
Postprocess results and visualization

Figure-1. Pseudo code for Firefly Algorithm
(Yang, 2010).

The light intensity thus attractiveness is inversely proportional with the particular distance r from the light source. Thus the light and attractiveness is decrease as the distance increase.

$$I(r) = I_0 e^{-\gamma r^2} \tag{1}$$

I	=	light intensity,
I_0	=	light intensity at initial or original light intensity,
γ	=	the light absorption coefficient
r	=	distance between firefly i and j

Attractiveness is proportionally to the light intensity seen by the another fireflies, thus attractiveness is β

$$\beta = \beta_0 e^{-\gamma r^2} \tag{2}$$

β_0	=	Attractiveness at r is 0

The distance between two fireflies can define using Cartesian distance

$$r_{ij} = |x_i - x_j| = \sqrt{\sum_{k=1}^{d}(x_{i,k} - x_{j,k})^2} \tag{3}$$

Firefly i is attracted toward the more attractive firefly j, the movemeunt is defined as

$$\Delta x_i = \beta_0 e^{-\gamma r_{ij}^2}\left(x_j^t - x_i^t\right) + \alpha \varepsilon_i, \qquad x_i^{t+1} + \Delta x_i \tag{4}$$

In equation (4), the first term is for attraction, γ is the limitation when the value is tend to zero or too large. If γ approaching zero ($\gamma \to 0$), the attractiveness and brightness become constant, $\beta = \beta_0$. In another word, a firefly can be seen in any position, easy to complete global search. If the γ is nearing infinity or too large ($\gamma \to \infty$), the attractiveness and brightness become decrease. The firefly

movements become random. The implementation of firefly algorithm can be done in these two asymptotic behaviors. While the second term is for randomization, as α is the randomize parameter. The ε_i can be replace by ran -1/2 which is ran is random number generated from 0 to 1.

Variation of firefly algorithm

Firefly algorithm is widely use to solve many problems, such as solving the economic emissions load dispatch problem (Apostolopoulos and Vlachos, 2011), multilevel image thresholding selection (Horng and Jiang 2010), finding optimal test sequence generation (Srivatsava, Mallikarjun and Yang, 2013), solving travelling salesman problem (Kumbharana and Pandey, 2013), vector quantization for image compression (Horng, 2012) and object tracking (Gao *et al.*, 2013).

Despite that firefly algorithm is widely used for solving problem, standart firefly algorithm also have some coming in term of trapping into several local optima when solving complex problem (Farook and Raju, 2013), (Yu, Yang and Su, 2013). There are disadvantages of using of single method only; this is because it will be overly restrictive for high dimensional and nonlinear problem. Thus, some modification and hybridization is suggested to overcome the shortcoming of single method (Abdullah *et al.*, 2012).

Modified firefly algorithm

In standart firefly algorithm, global best is the current best solution of firefly or known as the firefly that hold the highest light intensity or attractiveness. This firefly will move randomly to find the next best firefly for the next iteration. Since the firefly is move randomly, the attractiveness will be lose in certain distance from the others fireflies. Thus this will lead to the loose of performance in that particular iteration (Yang, 2010), (Tilahun and Ong, 2012), (Hassanzadeh and Meybodi, 2012).

In paper of (Tilahun and Ong, 2012) propose that, instead of the firefly move in random behavior, but in the proper manner. The firefly is only move to the direction if only there is improvement of brightness. The author (Tilahun and Ong, 2012) propose modification is by generate unit vector, then to determine the movement of firefly is by direction that leads toward the increases of brightness firefly. If there is none; the current brightest firefly will stay in the current position. As for (Wang *et al.*, 2012), in the paper also done some modification toward firefly algorithm for improvement. First is to add Lévy flight for improvement in term of localized searching for closer solution. In paper written by (Yu *et al.*, 2013), Olamaei, Moradi and Kaboodi, 2013), (Farahani *et al.*, 2011) is to proposed to use adaptive formulation for randomization value α. This is because when the value of α is large it is better for firefly to explore unknown place while small value of α will make firefly for local search. In (Farahani *et al.*, 2011) the author also propose the movement of firefly that is change from random

movement to direct movement. This is happen when there is no brighter firefly from the particular firefly, then firefly will move randomly. To avaoid this, the author propose that the random movement is change to direct movement and the firefly will move toward the best solution in that iteration. This will make firefly in the better position for next iteration and help to achive to near global best.

Hybrid firefly algorithm

Solving problem with only one metaheuristic is rather restrictive. This is because the single metaheuristic is hard to reach the optimal solution within reasonable time. Thus by combining with other metaheuristic or called hybridization will help with the high dimentional and nonlinear problems. Hybridize metaheuristic also can provide a more efficient behavior and a higher flexibility when dealing with real-world and large scale problems (Abdullah *et al*., 2012), (El-Sawy, Zaki and Rizk-Allah, 2012), (Rizk-Allah, Zaki and El-Sawy, 2013).

In this paper, the author (Farahani *et al*., 2012) propose of using Genetic Algorithm hybridize with Firefly Algorthim. This is because of the basic firefly algorithm weakness is in global optima. Thus, by using genetic algorithm which is more suitable for search globally, it will find better solution. By completing this, firefly algorithm will be used the solution for local search.

There is hybridization done after completing between two or more algorithms paralleled. In the paper by (El-Sawy, Zaki and Rizk-Allah, 2012), the Ant Colony Optimization and Firefly algorithm is done parallel and the result is sorted base on the constrain violation by descending order of the feasibility rule. The rules are grouped based on, the feasible solution preferable compare to others infeasible solution, or if there are two feasible solution, which is have better objective function is preferable, and last is if there is none feasible solution, which is have small constrain of violation is preferable.

In the hybrid firefly algorithm introduce by (Abdullah *et al*., 2012) is combination between firefly algorithm and differential evolution. The population of firefly will be produce into two group, one is in the with the potential fitness values, and will proceed to calculate the distance between solution using Euclidean distance and attractiveness. The others sub population which is contains of less significant fitness value will used evolutionary operation of differential evolution. This will produce offspring solution, if these offspring solutions have better fitness values, it will be replace the original solution. If not, the original solution will be remains till next iteration.

Application of firefly algorithm

Firefly algorithm is vastly used for solving engineering problem and optimization. Even only standart firefly apply for solving problem can produce superior result, but some modification or hybridization is done for convenient of application to apply firefly algorithm to solving multi dimentional and nonlinear problem.

Routing problem

Firefly algorithm is adapt from the behavior of firefly that attracted to the more attractive firefly (Yang, 2010). Thus, by using the characteristic of firefly, researcher apply firefly algorithm to fint the shortest path or route for vehicle, bus or salesman. Below is example of application of firefly algorithm to find the shortest or optimum route for the problem. There are many variable and conditions that the researcher to deal in order to solve the problems.

Travelling salesman problem is to find the shortest distance in tour city that visited once. The salesman have to find the shortest distant that can cover all the stops, visited once and return to the starting point. In paper by (Jati, Manurung and Suyanto, 2013), the author use evolutionary discrete firefly algorithm (EDFA) with some modification from the original. In the original EDFA, the firefly did not have direction of movement. Thus, movement in new EDFA is adapt from the evolution strategies (ES), which is used the inversion mutation. In the paper, tha author also discuss about discrete firefly algorithm (DFA). The movement of firefly in DFA is different from EDFA. The total number of firefly in EDFA is constant per generation. While the total number of firefly in DFA is changing base on total number of firefly with best objective function.

Some modification done by (Kumbharana and Pandey, 2013) in his paper to adapt TSP with FFA which are initial solution, distance function and movement. In initial solution, the pseudo code by Yang describe that the fireflies is scattered over the search space. But with good solution among random solutions, it will make immediate advance toward better solution. By using this method, it will make faster to find local optima. As for distance function, instead of using Cartesian distance, the author uses Hamming's distance and numbers of swapping required being same with the next solution. For the movement, the firefly is represented in form of permutation matrices, and then inverse it to preserve the previous path formed.

Firefly algorithm also has been use in the research of vehicle routing problem. Vehicle routing is a problem to find the set of route for the fleet of vehicles to serve the number of stops. The number of stops is deterministic, when there is no demand exceed the capacity of the vehicle, it is the standards vehicle routing problem. The VRP can be extend into many constrains such as time window, mix pick up (backhauls) and deliveries (linehauls) (Breedam, 2001).

There are many variation of vehicle routing problems, one of it is Vehicle routing problem with time windows (VRPTW). VRPTW is aim for to find route to the all vehicle to such that all the customer will be serve within the respective time windows. In practice, the customers and the carrier companies have difference concerns. For the customers, is to receive the deliveries on time, while the carries company is to delivers the goods to the different customers efficiently while be able to cut cost and save the time (Tas *et al*., 2013). This paper of (Pan *et*

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al., 2013), the authors adopt the VRPTW coding from CVRP. The modification of infeasible solution is done, so that only the effective solution that has the requirement of value will be kept.

Finding path by using firefly algorithm also is not restricted for road vehicle; firefly algorithm also had applied for finding route of uninhabited combat air vehicle (UCAV). There are constrain of UCAV that should not be over looked. The route planning for UCAV should include the terrain, data, threat information, fuel and time (Wang et al., 2012). Thus in the paper, the author (Wang et al., 2012) do improvement of FA algorithm, so that it able to search the most optimal route with multi constrains.

Image processing

Firefly algorithm in image processing wold also is not new, there are bunch of research base on image processing using firefly algorithm such as multilevel image thresholding selection (Horng and Jiang, 2010), active contour model for medical image segmentation (Sahoo and Chandra, 2013) and vector quantization using the firefly algorithm for image compression (Horng, 2012).

In paper of (Horng, 2012), had used firefly algorithm to solve vector quantization by hybridize the firefly algorithm with Linde-Buzo-Gray, (FFA-LBG). LBG is a scalar quantization that used for input vectors for determining the codebook. In FFA-LBG, LBG is put at the first part of the initial solutions. The author conclude that FFA-LBG method is achievable same par with the PSO-LBG and QPSO-LBG with the less the computation time.

In image processing, there is one segment for image tracking using video sequence. Object tracking is one of the research that is vastly studied into real world application such as surveillance, vision based control and robotics. On the other hand, video sequencing for object tracking still a challenging topic for researches due to large amount of data used and high specification for real time computation (Gao et al., 2013). The authors state that, to overcome problems in the object tracking the researcher used the varieties of methods and algorithms. One of the optimization algorithms that is doing well is meanshift. From this research, the authors conclude that the firefly algorithm is indeed superior compare to particle filter, particle swarm optimization and meanshift in tracking object. The result is compare in four different method and shows that firefly algorithm out perform in term of speed and accuracy.

CONCLUSIONS

Firefly algorithm is considering new algorithm in the swarm intelligence family. Despite that, the usage of the firefly algorithm in the various types of problem shows that the anticipation from the researcher to use this algorithm. This algorithm already proves that it is superior compared to the previous introduce swarm intelligence from the research done before. Even though the firefly algorithm has proven to be superior compared to the previous swarm intelligence, some modification can be done to improve the local search a well as global search to ensure the solution obtains is the optimum and not premature solution.

Firefly algorithm also suitable is used for the high dimensional and nonlinear problems. The downside of it is the single that the single metaheuristic is hard to reach the optimal solution within a reasonable time. Thus, by combining the metaheuristic will help to overcome the shortcoming of the single metaheuristic algorithm.

In the future work, the researcher should tackle firefly in more various types of problem such as find optimum route for new build trains rails route which is have multiple constrains such as to preserve the nature maximum as possible and multi tracking for object tracking

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