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Review Article

A Review of the Metaheuristic Algorithms and their Capabilities (Particle Swarm Optimization, Firefly and Genetic Algorithms)

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Abstract

This study is conducted with the aim of introducing metaheuristic algorithms with emphasis on particle swarm optimization, firefly, and genetic algorithms. Metaheuristic algorithms have today are widely usable in different fields of optimization science. The foundation of these algorithms is mainly the order or rules in natural organisms or derived from other branches of science. In this study, among different metaheuristic algorithms, particle swarm optimization, firefly, and genetic algorithms is investigated. Firefly algorithm is a type of metaheuristic algorithm derived from nature and based on Collective Intelligence algorithms on basis of flashing light of fireflies. The algorithm is able to solve problem with all branches of science. The results obtained from this study show that firefly algorithm is simple in terms of concept and implementation and can solve all applied problems. Moreover, it could be mentioned that the algorithm can typically determine achievement to result. Firefly algorithm is one of the best metaheuristic algorithms than two other metaheuristic algorithms because of including features such as high speed convergence, non-sensitive to initial values, flexibility and a high error tolerance.

Keywords*: metaheuristic algorithm, particle swarm optimization algorithm, firefly algorithm, genetic algorithm*

1. Introduction

Nowadays, metaheuristic algorithms are widely usable in different fields of optimization sciences. The basis of such algorithms is mainly the order or rules in natural organisms or derived from other branches of science. Metaheuristic algorithm can be a method in fields of Evolutionary Computations, which seek to find optimal solution for different problems of optimization. Metaheuristic algorithm provides appropriate algorithm to solve mathematical optimization problems through mathematical modeling of social-political evolution. In terms of function, the algorithm is in group of evolutionary optimization algorithms like genetic algorithm and Particle Swarm Optimization Method.

The abovementioned approaches, despite to other careful optimization methods, seek points as much as close to global optimization, so that it can meet the idea of the decision maker to an acceptable level. In other words, metaheuristic algorithms are methods that find solutions close to optimum level with an acceptable calculative cost; although they can give no guarantee to achieve optimal solution. Metaheursitic methods are also known as imprecise methods, since random mechanisms play key role in creating their structure. Many evolutionary algorithms are derived from the nature. Metaheuristic algorithm moves from an initial population of random solutions toward finding better solution in each cycle (3).

Metaheurstic algorithms are such algorithms that present high quality solutions in short time for complicated optimization problems. Although there is no guarantee to achieve optimal solution using these algorithms, their high ability in achievement to solutions close to optimal level in short time for these problems has caused their fame. Today, metaheuristic algorithms are being used as powerful tools to solve many optimization problems in a variety of fields of science. The algorithms could be observed in research projects and MA and PhD theses of many fields of science like industrial engineering, electricity, mechanics, civil engineering, computer, mathematics, physics, chemistry, agriculture and management and so on. Wide use of metaheuristic algorithms in a lot of fields of science and MA and PhD theses can indicate importance of codification of books in Persian in this field (1).

2. Firefly Algorithm

Firefly algorithm is an evolutionary model derived from the nature and based on collective intelligence algorithms that is on basis of flashing light of fireflies.

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The algorithm was for the first time presented by Yang in Cambridge University on 2008 (4).

Fireflies produce lights that optical pattern of each light is different from another one. They use this light to attract mates and for hunting. The amount of this light is in direct relation with attractiveness of firefly. Through considering amount of light of each firefly as target function, the behavior of fireflies could be modeled as an optimization algorithm. To ease simulation of life of fireflies, 3 main assumptions are considered in modeling process:

1) Fireflies are all from one gender and hence, gender plays no role in attracting them towards each other.
2) The amount of attraction between two fireflies is in reverse correlation with their brightness and with the space between them. Hence, the brighter firefly can attract adjacent fireflies and if no one of them is brighter than others, their movement would be randomly.
3) Brightness of fireflies is determined based on target function related to them (4).

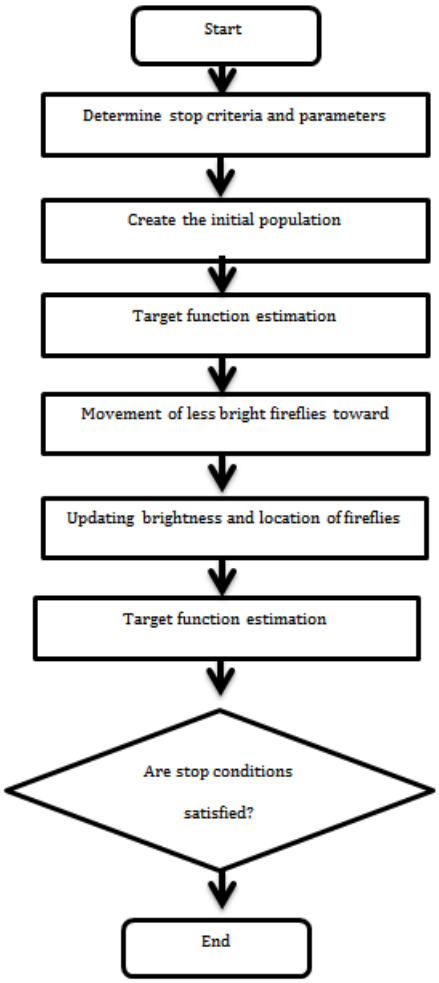

Figure 1: Firefly algorithm

Figure 2 has illustrated the steps of firefly algorithm in pseudocode form.

Firefly algorithm
Initialize algorithm Parameters:
MaxGen: the maximum number of generations
Objective function of f(x), where $\mathbf{x}=(x1,\ldots,xd)T$
Generate initial population of firefly or $xi=(i=1,2,\ldots,n)$
Define light intensity of $\mathbf{Ii}$ *at* $\mathbf{xi}$ *via f(xi)*
While *(t<MaxGen)*
For *i= 1 to n (all n fireflies);*
For *j=1 to n (all n fireflies)*
If *(Ij >Ii), move firefly i towords j;* ***end if***
Attractiveness varies with distance r via Exp $[-\gamma r^2]$*;*
Evaluate new solutions and update light intensity;
End for j;
End for i;
Rank the firefly and find the current best;
End while;
Post process results and visualization;
End procedure;

Figure 2: Pseudocode of firefly algorithm (4)

3. Behavior of firefly

Fireflies produce rhythmic and short lights. Each firefly has different optical pattern. Fireflies use these lights for two purposes: one the process of attracting mates and another one to attract hunts. Moreover, the lights can be a protective mechanism for the fireflies. Rhythmic lights, lighting rate and the time intervals of light signals can make two genders be attracted to each other. Each particle is a firefly and it is updated in multidimensional search environment through dynamic attraction based on a science of firefly and its neighbors. Firstly, the initial coordinates and light intensity and the space between firefly particles are determined in search point. The searching process in firefly algorithm is in this way that each firefly is compared with technique of other fireflies. If the firefly is less bright than the compared firefly, it moves toward brighter firefly. Such action can make particles concentrate on surrounding area of the particle with more brightness and if there is a particle with higher brightness in next iteration of algorithm, the particles move toward it. Searching steps are equal to maximum iterations (2).

4. Light intensity and adsorption

In firefly algorithm, there are two important issues including variety of light intensity and formulation of light adsorption. Simply, it could be imagined that light adsorption in fireflies is determined by brightness that is related to coding target function. In simplest mode for maximum optimization problem, brightness of I firefly in certain point x is selected as $I(x) \times f(x)$. At the same time, brightness of β is partial. Therefore, the rij space is different between I firefly and j firefly.

Moreover, light intensity is reduced with the distance from the origin and the light is also adsorbed with the object and here, the brightness differs from degree of adsorption.

In simplest form, light intensity I(r) varies based on inverse square law.

$$I(r)=\frac{I_S}{R^2} \quad (1)$$

Where; I_s refers to light intensity in the origin. For the average with a ɣ coefficient of light adsorption, I light intensity is different from R distance; it means that:

$$I=I_{0e}^{-\gamma r} \quad (2)$$

In order to determine optimal parameters of firefly algorithm, α and β values usually vary in range (0, 1) and ɣ value varies in range (0, ∞) (Yang, 2008).

Where; I_0 refers to original light. To avoid sameness in r=0 in mode I_0/I_s, combinational effect of inverse square law and approximate adsorption is in following Gaussian mode:

$$I(r)=I_{0e}^{-\gamma r} \quad (3)$$

As it was mentioned, attraction of fireflies and (β) is partial and is depended on the distance between two fireflies (r) and the following equation has estimated light adsorption coefficient (ɣ):

$$\beta=\beta_{0e}^{-\gamma r} \quad (4)$$

Where; β0 refers to brightness in r=0. Mostly to calculate $1/(1+r^2)$ compared to exponential function, the above function can be a proportion of eq.5 if required.

$$\beta=\frac{\beta 0}{1+\gamma r2} \quad (5)$$

In both equations 4 and 5, distance $=1/\sqrt{\gamma}$ while brightness changes is defined significantly from β0 to β_{0e}^{-r} for eq.4 or β0/2 for eq.5.

In real operations, brightness function β(r) can reduce following generalized functions:

$$\beta(r)=\beta_{0e}^{-\gamma rm}, (m\geq 1) \quad (6)$$

The distance between two i and j fireflies in xi and xj can be in form of following Cartesian distance:

$$r_{ij}=\|\boldsymbol{x}_i-\boldsymbol{x}_j\|=\sqrt{\sum_{k=1}^{d}(x_{i,k}-x_{j,k})^2}, \quad (7)$$

Where; xi, k of k component is spatial coordinate of xi for i firefly.

$$r_{ij}=\sqrt{(x_i-x_j)^2+(y_i-y_j)^2} \quad (8)$$

Where; xj and xi respectively refer to location of fireflies i and j; d refers to total independent input duties. Movement of firefly i toward bright firefly j could be calculated as follows:

$$x_i^n=x_i^{n-1}+\beta_0^{-\gamma r2}\left(x_j^{n-1}-x_i^{n-1}\right)+\alpha e_i^{n-1} \quad (9)$$

Where; xi refers to less bright firefly; xj refers to location of brighter firefly; n is the number of iteration; αis random value and e_i^{n-1} is random number and a vector of random numbers that can have Gaussian distribution. Third part of eq.9 is regarded as random term that can cause more comprehensive search of decision of the problem by the algorithm. Adsorption of fireflies continues to the time that they are adsorbed by the brightest firefly. In fact, the firefly can create the best value for target function.

In this equation, the second part shows adsorption of firefly i toward firefly j and third part is related to random movement in adsorption process. β and α are two constant parameters that can respectively determine amount of mutation and adsorption of each firefly. Effect of two said terms is that they can regulate mode of movement of firefly i. η (gamma) value is the coefficient of light adsorption in each firefly. The parameter is significantly effective in determining convergence speed and behavior of firefly algorithm and is usually determined in range of zero to infinity (0, n) (4).

5. Performance of firefly algorithm

This algorithm has abundant similarities with other swarm-based algorithms such as particle swarm optimization algorithm (5); bee colony optimization algorithm (6) and ant optimization algorithm (7). In this field, it has been proved that firefly algorithm is very simpler than them in terms of concept and implementation. Scholars have used firefly algorithm to solve non-linear complicated functions. The results obtained from this study show that firefly algorithm is efficient enough in convergence toward optimized solution and to find solution in short time (8). Moreover, in firefly metaheuristic algorithm, first a random initial population would be created and then, it covers fireflies for optimization using adsorption equation and through creating new coordinate between two fireflies and making they move toward each other (9).

6. Advantages of firefly algorithm

Firefly algorithm has two main advantages compared to other algorithms: 1) Automatic segmentation and capable of dealing with multi-quality issues and 2) firefly algorithm takes action based on adsorption and

light and is based on swarm intelligence. It could be mentioned that accordingly, such issue can cause automatic segmentation of total population in subgroups with certain average distance and each group can be collected around a local optimum. Moreover, among all of the optimums, the best general optimum could be found. Secondly, the segmentation allows finding all optimums and can be specifically used for nonlinear multi-quality optimization problems. For firefly algorithm, random control is regulated due to iterations, so that convergence can also be accelerated through regulating these parameters. The advantages of being in deal with connectivity, clustering and segmentation and also optimization problems can create an appropriate composition.

Firefly algorithm can generally have 3 different advantages compared to other algorithms: automatic segmentation of the population in subgroups and the capability of dealing with multi-quality optimization having various solutions. is one of the best metaheuristic algorithms because of including features such as high speed convergence, non-sensitive to initial values, flexibility and a high error tolerance.

7. Particle swarm optimization algorithm

Particle Swarm algorithm was first proposed in 1995 by Eberhart and Kennedy. In the development of this method of mass flight of birds and fish and swim and their social life inspired which is formulated using a simple formula. Like all other evolutionary algorithms, algorithm particles by generating a random population of individuals begin here as a group of particles called. View all speck in the group, based on a set of parameters to determine the optimum amount of which must be determined. In this way, each particle shows a part of the solution space. Each particle has a memory, the best position in the search space to which they are to die for. The motion of the particles takes place in two directions:

1) To have the best position so far and
2) In the best position ever, have chosen to remove all traces

In this way, the position of each particle in the search space influenced by his experience and knowledge and its neighbors suppose at a particular problem, and i th bit of the group may have space next D with a velocity vector and a position vector is displayed. The position of each particle by changing the structure of the position and speed previously is possible. Every bit of information, including the best value ever reached (personal optimal) and position Xt offers. The information obtained by comparing efforts that will do every bit to find the best answer. In addition, every bit the best results ever achieved in the whole group, from different particles known than optimal values (optimal inclusive). Each particle to achieve the best answer tries to change its position by using the following information:

- The current position (Xt)
- Current speed (Vt)
- The optimum distance between the current situation and personal
- The distance between the current position and the optimum surround

Thus, the speed of each particle and consequently the new situation with the relations (2-14) and (2-15) will change:

$$V_i^{t+1} = wV_i^t + c_1 rand(0,1)(pbest_i - x_i^t) + c_2 rand(0,1)(gbest_t - x_i^t) \quad (14\text{-}2)$$

$$x_i^{t+1} = x_i^t + v_i^{t+1} \quad (15\text{-}2)$$

Where, Vit + 1 speed particle i in the new iteration, Vit slower in the current iteration i, Xit current position of the particle, Xit + 1 position of the particle in the new iteration, pbesti best position of particle i have ever and Gbestt best location and the best bit (the best position so far adopted that all particles). Rand (0,1) is a random number between zero and one to keep the diversity of the group is used. Cognitive and social parameters are c1 and C2 respectively. Select the appropriate value for this parameter to accelerate the convergence of the algorithm and prevent premature convergence at the local optimum. Recent research shows that the greater the amount of cognitive parameters C1 to C2 social parameters is more appropriate, but the condition C1 + C2 4 must always be observed and the inertia weight parameter is to ensure convergence of particles is used. Inertia weight, to control the impact of previous speed records on the current speed is used. Based on current research, the amount is between 0.4 and 0.7 and suitable for w [1, 27, 31 and 32].

8 Genetic algorithms

Genetic algorithms are inspired by Darwin's theory of evolution and genetics and natural selection is based on the survival or superior. A common application of genetic algorithm optimization is to use it as a function. Genetic algorithm tool in pattern recognition is feature selection, image understanding machine learning [39 and 40]. In genetic algorithms simulated to genetic evolution of living beings. So by a biologist named Fraser in the field of evolution in biological systems modeling in the late 60s was genetic algorithms for engineering applications and for the first time today by the University of Michigan computer scientist John Holland was proposed in 1975. His work started all efforts to use genetic algorithms in engineering. After those things Dejong in 1975 investigate and compare several genetic algorithms to provide a theoretical basis. This algorithm is inspired by nature based on the principle of sustainable best. The evolutionary

strategy algorithm genetic algorithm was proposed the most famous of evolutionary algorithms. In a genetic algorithm, a population of individuals survives in the environment according to their desirability. Those with superior functionality, greater will be the chances of marriage and reproduction. So after a few generations, children with better performance are produced. Each individual of the population as a chromosome in the genetic algorithm is introduced. Chromosomes during several generations are more complete. Chromosomes in each generation are evaluated and adapted to survive and reproduce realize its value. In terms of next generation genetic algorithm with mutation w is the contact operators. Top parents are selected based on a fitness function.

At each stage of the implementation of the genetic algorithm, a bunch of random parts of the search space are processed. That is, a sequence of characters assigned to each point on these sequences, genetic operators apply. The sequence obtained is then decoding the new points obtained in the search space. Finally, on the basis of the objective function at each of the points how much the likelihood of their participation shall be determined at a later stage [26]. Genetic algorithms can be considered a method of stochastic optimization arrow that moves gradually towards the optimum. Compared to other properties on genetic algorithm optimization methods can be said is that the algorithm without having any knowledge of the problem and any limitation on the type of variable it is applicable to any issue and have established efficiency in finding a global optimum. The ability of these methods to solve complex optimization problems, the classical methods are inapplicable or receivable and optimal generally is not confidence.

9. Discussion and conclusion

Current metaheuristic algorithms are widely being used in different fields of optimization science. The basis of these algorithms is mainly order or rules of natural organisms or derived from other branches of science.

Genetic algorithms can be considered a method of stochastic optimization arrow which gradually moves toward the optimal point. Compared to other properties on genetic algorithm optimization methods can be said is that the algorithm without having any knowledge of the problem and any limitation on the type of variable it is applicable to any issue and have established efficiency in finding a global optimum. The ability of these methods to solve complex optimization problems, the classical methods are inapplicable or not finding global optimum reliability. Particle swarm optimization algorithm of mass flight of birds and fish and swim and their social life inspired which is formulated using a simple formula. Like all other evolutionary algorithms, particle Swarm algorithm starts by creating a random population of people here as a group of particles called. View all speck in the group, based on a set of parameters to determine the optimum amount of which must be determined. In this way, each particle shows a part of the solution space. Each particle has a memory, the best position in the search space seem to remember it.

Firefly algorithm is a type of metaheuristic algorithm derived from nature and based on Collective Intelligence algorithms on basis of flashing light of fireflies. This algorithm has the capability of solving problems in all fields of science. This algorithm has abundant similarities with other swarm-based algorithms such as particle swarm optimization algorithm (5); bee colony optimization algorithm (6) and ant optimization algorithm (7). In this field, it has been proved that firefly algorithm is very simpler than them in terms of concept and implementation.

Scholars have used firefly algorithm to solve non-linear complicated functions. The results obtained from this study show that firefly algorithm is efficient enough in convergence toward optimized solution and to find solution in short time (8).

Firefly algorithm has two main advantages compared to both other algorithms: 1) Automatic segmentation and capable of dealing with multi-quality issues and 2) firefly algorithm takes action based on adsorption and light and is based on swarm intelligence. The results obtained from this study showed that firefly algorithm is very simpler than other algorithms in terms of concept and implementation and is able to solve all applied problems. Moreover, it could be mentioned that the algorithm guarantees achievement to result. Finally, it could be mentioned that firefly algorithm is one of the best metaheuristic algorithms than two other metaheuristic algorithms because of including features such as high speed convergence, non-sensitive to initial values, flexibility and a high error tolerance.

References

Fattahi, Parviz, 1976. Meta-heuristic algorithms, Bu-Ali Sina University Press/ 2009

Parwan, H., Behrooz. Yannezhad, Ebrahim Alawi, Seyed Enayat Allah (2014). Schedule tasks in grid computing using genetic algorithms and fireflies, Shoshtar Young Researchers Club March 2014

Hadidi, Kazemzade., Structural optimization using artificial bee colony algorithm 2nd International Conference on Engineering Optimization September 6 - 9 ,(2010) ,Lisbon, Portugal.

Yang. X.S, Firefly Algorithms for Multimodal Optimization, In: Watanabe, O., Zeugmann, T. (eds).SAGA 2009. LNCS, vol. 5792, pp. 169–178 .Springer, Heidelberg,2009

R. Poli, J. Kennedy, T. Blackwell, Particle swarm optimization: An overview (Springer Science and Business Media, LLC (2007)

Pei-Wei TSai, Jeng-Shyang Pan, Bin-Yih Liao, Shu -Chuan Chu, Enhanced Artificial Bee Colony Optimization , International Journal of Innovative Computing, Information and Control, Volume 5, Number 12, December (2009)

Yang, X. S. , Nature-Inspired Metaheuristic Algorithms, Luniver Press(2008

R. Khaze, I. maleki, S. Hojjatkhah and A.Bagherinia), , August 2013 (Evaluation the efficiency of artificial bee colony and the firefly algorithm in solving the continuous optimization problem, International Journal on Computational Sciences & Applications (IJCSA) Vol.3, No.4.

X-S. Yang (7 March 2010), Firefly Algorithm, L´evy Flights and Global Optimization arXiv:1003.1464v1 [math.OC]