A Review of Recent Advancements of Firefly Algorithm; A Modern Nature Inspired Algorithm

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Abstract— Nature inspired algorithms are modern AI related algorithms which embrace natural optimization techniques to build optimization algorithms. This new field has attracted many researches and one can now see a rapid development of the algorithms as well as frequent application of the algorithms on complicated problems. Firefly Algorithm is one such algorithm that mimics the flashing behaviour of fireflies. The algorithm which was initially proposed for continuous domain optimization problems has been adopted for many types of real world continuous optimization problems. Further, many research has been done on adjusting the algorithm for various discrete optimization problems. This paper aims to provide a review of the recent advancements in the firefly algorithm and the type of problems addressed by the research on continuous and discrete domains. Applications of firefly algorithm were selected from both domains and several important factors like the problem of interest; comparisons with other algorithms and new modifications to the original algorithm were taken into account when doing the study. The most important factor is how the researchers have used exploration and exploitation properties in Firefly algorithm for the problems they have solved. A brief analysis has also been carried out to compare the implementation of the same problem by different nature inspired algorithms, including the firefly algorithm. The results of the review reveal that in many applications, firefly algorithm's performance is remarkable compared to other nature inspired algorithms like Genetic algorithms. Firefly algorithm's behaviour is similar to genetic algorithms but the algorithms like Bat, cuckoo search are more likely to behave as particle swarm optimization, where always the globally best solution is concerned. The study concludes that firefly algorithm's performance over many applications is admirable and is worth modifying to solve many real world complex optimization problems.

Keywords— *Firefly Algorithm, Optimization, Nature Inspired Algorithms*

I. INTRODUCTION

Nature inspired algorithms are algorithms which mimics different optimization procedures in nature. Ants' root optimization techniques, evolution process of living beings, use of echolocation to identify preys by bats are some inspirations to such algorithms. In the recent optimization literature there can be seen a remarkable success of using such algorithms to solve many difficult problems where other methods are irrelevant or less performable. The immediate reason for these algorithms' continuous success can be mentioned as their resemblance of the optimization processes in natural world that proves the success through the long term existence. Evolutionary algorithms and swarm intelligence are two main areas of nature inspired algorithms. Evolutionary algorithms are meta-heuristic optimization algorithms inspired by biological evolution; reproduction, mutation, recombination, and selection (E.g. genetic algorithms (Golberg, 1989), differential evolution (Storn and Price, 1997)). Swarm intelligence, by its name, defined as an optimizing technique developed due to the grouping behaviour of individuals (e.g. bacteria, ants, termites, bees, spiders, fish, and birds).

Firefly algorithm which imitates the attraction strategy of the natural fireflies via their charmed light; is a recent nature-inspired meta-heuristic algorithm belongs to swarm intelligence, developed by Xing-She Yang (Yang, 2010), (Yang, 2009). The algorithm is originally designed to solve continues optimization problems although it can be and it has been discretised effectively to solve permutation problems (Sayadi et al., 2010), (Karthikeyan et al., 2015), (Sayadi et al., 2013). As a new nature inspired algorithm, FA's performance is admirable when compared with other such algorithms. Exploration and exploitation; the main two strengths of problem solving by search (Črepinšek et al., 2013) are implemented in the firefly algorithm to maximize the performance. Because of the special behaviour of the algorithm, within its short history, it has been adopted to solve many optimization problems where most of them are successful. The aim of this paper is to do a review on such recent advancements of Firefly Algorithm including both continuous and discrete domains and evaluate the operators introduced in the algorithm to explore and exploit solutions. Several

important studies are selected and the difficulty of the problem, how FA has adopted and parameter settings were done and the performance of the firefly algorithm over other nature inspired algorithms are discussed.

This paper aims to provide a review on firefly algorithm and its recent advancements. The sections are outlined as follows. In the next section, we will introduce the algorithm. Section three provides some new advancements/ solutions provided by the algorithm. Section four is about variations people have added /suggested to the original algorithm in order to adjust the algorithm with different problem domains. In the fifth section we discuss the special features of the algorithm which make it superior. Section six summarizes the paper.

II. FIREFLY ALGORITHM

The original algorithm proposed by Yang is inspired by the flashing behaviour of fireflies. It relies on the following three idealized rules.

a. Fireflies are unisex so their attraction to each other is gender independent.
b. Attractiveness is proportional to the brightness, and for any two fireflies, the less brighter one is attracted by (and thus moves toward) the brighter one; however, the brightness can decrease as their distance increases; If there is no brighter one than a particular firefly, it moves randomly.
c. The brightness of a firefly is determined by the value of the objective function.

Algorithm 1: Original Firefly Algorithm

Begin;
Initialize algorithm parameters:
MaxGen: the maximum number of generations
γ: *the light absorption coefficient*
β_0: *initial brightness of a given firefly*
D: the domain space
Define the objective function $f(X)$, *where* $X = (x_1, \ldots\ldots, x_d)^T$
Generate the initial population of fireflies, X_i
$(i = 1,2, \ldots\ldots, n)$
Determine the light intensity I_i *of* i^{th} *firefly* X_i
via $f(X_i)$

while $t <$ *MaxGen do*
  for $i = 1 : n$ (*all n fireflies*) *do*
    for $j = 1 : n$ (*all n fireflies*) *do*
      if $I_j > I_i$ *then*
        Move firefly i towards j by using eq (1);
      end if
      Attractiveness varies with distance r
        via $e^{-\gamma r^2}$ *using eq* (2);
      Evaluate new solutions and
        update light intensity;
    end for
  end for
  Rank the fireflies and find the current best;
end while
Post process results and visualization;
end

The initial population can be defined randomly with a set of feasible solutions for the problem. Then each firefly's light intensity is calculated using the problem specific objective function. Each firefly in the population starts moving towards brighter fireflies according to the following equation.

$$Assume\ x(i)\ and\ x(j)\ are\ two\ fireflies$$

$$x(i) = x(i) + \beta(x(j) - x(i)) + \alpha(rand - 0.5); \rightarrow (1)$$

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

$$Here\ \gamma\ denote\ the\ light\ absorption\ coefficient,$$
$$r\ is\ the\ distance\ between\ two\ fireflies\ \&$$
$$\beta_0 is\ the\ attraction\ at\ r = 0;$$

The Eqn (1) has terms including the attraction of the fireflies and the randomness. The second term of the Eqn (1) is for the attraction between two fireflies and the third term is a randomization parameter where α is the randomization factor.

Comparisons done in Yang's original paper outline its high performances comparative to Genetic Algorithms and Particle swarm Optimization algorithms (Yang, 2009) . Popular two dimensional mathematical functions were used in his original implementation to prove the idea. Because of its success many researches followed his foot prints to test the algorithm over difficult optimization problems in the fields of Mathematics, engineering and physics.

III. RECENT ADVANCEMENTS

Applications of firefly algorithm can be seen in many areas like digital image processing, circuit and system design, feature detection, scheduling and TSP, parameter optimization and so on.

In the research "The Codebook Design of Image Vector Quantization Based on the Firefly Algorithm", (Horng and Jiang, 2010) the traditional vector quantization methods were replaced using the firefly algorithm. They have used a powerful traditional vector quantization method to initiate the firefly population. The same approach has been used in another research (Chen et al., 2005), with Particle Swarm Optimization algorithm (PSO-LGB). The results clearly revealed that use of firefly algorithm for vector quantization has improved the quality of the reconstructive images with respect to other methods. This is significant that FA can be usefully contributed to the field of digital image processing.

Feature selection is one of the important areas in Data mining. Noisy and high dimensional data, containing large number of features, degrades the performance of data mining and machine learning tasks. For this, feature selection is used in data mining in order to reduce the dimensionality of the data. A Feature selection method can be used to select a subset of features representing original features in problem domain with high accuracy. The problem is to find a proper way to select the most appropriate subset. Since most available methods consume time or compromise with the optimality, FA has been adopted to find a solution and was successful. The method out-performed other such methods developed using Genetic algorithms, Ant colony systems and particle swarm optimization algorithms in terms of time and optimality (Banati and Bajaj, 2011). This is an evidence to prove how Firefly algorithm was benefitted for the field of data mining.

Clustering is another important area where the problem is to group data based on some similarity. It is widely used in the fields like statistics and image processing for data analysis and image analysis. For this task, firefly algorithm is effectively adopted in a recent research (Senthilnath et al., 2011). There they have used some bench mark problems and applied the clustering involved with firefly algorithm. The results were compared with other two nature inspired algorithms, artificial bees colony and particle swarm optimization and some other known methods. The conclusion is that firefly algorithm can be successfully adopted for clustering problems.

In the fields of chemistry and biology, Protein structure prediction is the prediction of the three-dimensional structure of a protein from its amino acid sequence. Protein structure prediction is one of the most important goals pursued by bioinformatics and theoretical chemistry; it is highly important in medicine and biotechnology. Because of that, research on protein structure prediction is a continuous process, seeking for better approaches. A research has been carried out to find the feasibility of firefly algorithm in predicting protein structure (Maher et al., 2014). Bench mark protein sequences were used to test the suggested approach and the research concludes FA's success implementation for the situation.

Scheduling problems (Yamada and Nakano, 1997) and travelling salesman problem (Lawler, 1985)are important areas in optimization. These problems are also known as NP Hard (Papadimitriou, 2003) because of their complexity growth over number of cases. For these problems with large number of inputs, there is no guaranteed solution as optimal. But the nature inspired algorithms are found in the literature as algorithms which are capable of providing good approximations for optimal solutions. Firefly algorithm is also discretised for these tasks of job shop secluding and TSP (Khadwilard et al., 2011) (Jati and others, 2011), and are successful than other algorithms in providing good solutions efficiently. For the developed discrete TSP, a comparison is carried out with the Memetic algorithm (Knowles and Corne, 2000) in the original research and in another research a comparative study has carried out with Ant Colony Systems, Particle Swarm Optimization and Genetic Algorithms (Ariyaratne and Fernando, 2014). Both studies indicate that discrete firefly algorithm is capable of giving the most optimal solution efficiently.

As the discretization of the original algorithm, there can be seen many variants of the original algorithm adopted to solve different problems. The most nearest reason can be the algorithm's great performance over continuous domains in its original version. Following section discuss some admirable variants of the Firefly Algorithm.

IV. VARIENTS OF FIREFLY ALGORITHM

A hybrid nature inspired algorithm developed using firefly algorithm and ant colony optimization has been successful in portfolio optimization (Giannakouris et al., 2010). The research is to find the optimal combinations of assets to satisfy investment goals with constraints. Several other algorithms and heuristics that has been used for the same task was highlighted from the literature. One of the main disadvantages pointed there is the lack of efficient computational time. In this research the hybrid approach has been used mainly the two algorithms for two tasks; ACS for discrete optimization (assets), while FA is used for continuous optimization (weights). Conclusions were made that the proposed hybrid's capability of providing better optimal solutions that the previous methods.

In another research, a modified firefly algorithm was developed by modifying the random movement of the brighter firefly in the current population. The attractiveness which is responsible for a firefly's brightness is also modified. The study generates several random directions for the best firefly and check for the paths which maximizes the performance of it. If such path exists, the firefly moves on or else it will remain as it is. Results were generated with several popular maximization problems and conclusions reveals that the modified firefly algorithm performs better in achieving the near optimal solutions for the 7 bench mark problems tested (Tilahun and Ong, 2012).

A combination of firefly algorithm with memetic algorithm is used in a research (Hu et al., 2013) to predict electricity load. Support Vector regression (SVR) is the existing better approach for the prediction and its performance highly depends on its parameters. The research is about seeking better parameters for the SVR with the use of firefly and memetic algorithms. In this FA-MA algorithm, the FA is applied to explore the solution space, and the pattern search is used to conduct individual learning and enhance the exploitation of FA. The results confirm that the proposed FA-MA based SVR model yield more accurate forecasting results than the other four evolutionary algorithms based SVR models and also outperform the hybrid algorithms in the related existing literature.

V. WHY FIREFLY ALGORITHM IS SO SPECIAL?

The first response that can be made regarding this question is the moment strategy of the fireflies. Eqn (1) is the moment equation and is consist of 2 main parts. We can mention them as *information based movement* and *random moment*. These two parts are responsible for providing proper exploitation and the exploration over the search space for finding optimal solutions.

Information Based Movement

$$x(i) + \beta(x(j) - x(i))$$

Random Movement

$$\alpha(rand - 0.5)$$

The information based moment exploit the current firefly to build a new firefly. The given firefly's brightness and its distance with another brighter firefly are taken into the account when modifying its solution. Random part will create some random solution which can lead the solution to a good or bad situation. It is like mutation operator in genetic algorithms. In this random process the distribution of the random number generator ($rand$) and the value of the randomization parameter (α) play a very important role in maximizing performance. The (α)

controls the randomness. The randomness should control properly otherwise it may lead to poor performance. The best practice is to reduce the randomness gradually. The assigning of parameter values highly depends on the problem at hand at the moment and so there is no such predefined set of parameter values. Initial way of scaling the parameter α is, using the ($Ub - Lb$) where Ub and Lb are the upper bounds and lower bounds, respectively.

In a searching process, exploitation handles the local search part and exploration shows random or the global search. Importance of firefly algorithm is keeping balance between exploration and exploitation in each step of solving a problem. For the local search part, the value of (β) is also important. Brightness of a firefly is associated with the Eqn (2) which is influenced by the distance (r) and the light absorption coefficient (γ). The value of (γ) is important for the convergence of the solution. As in the Eqn (2), if the value of gamma (γ) is increasing, the value of beta (β) is going near zero (0), which will remove the exploiting ability from the algorithm and making it a simple random walk. On the other hand if gamma (γ) is becoming zero, the brightness beta (β) is moving towards its initial value. This means the distance between the fireflies is no longer in use and they identify each other clearly. In this case, exploitation does more work than the random moment. That leads to solutions to be trapped in a local optimum solution. Therefore balancing the value of gamma (γ) is very important. Proper balance of these parameters leads and is the cause of the success of the firefly algorithm in many optimization tasks.

VI. CONCLUSIONS

In this paper we have done a brief review on a young meta-heuristic optimization algorithm; Firefly algorithm. Although the field of nature inspired algorithm has a short history, its contribution towards the optimization in many fields is remarkable. Genetic algorithms (Golberg, 1989), Particle swarm optimization (Kennedy, 2010) and Ant colony systems (Dorigo and Gambardella, 1997)have kept their unique mark in solving difficult problems including NPhard problems. Firefly algorithm, as a new comer, has shown its superiority over other such algorithms because of its parameters and the appropriate use of exploitation and exploration techniques for problem solving. Many fields including engineering, physics, mathematics, chemistry, and computer science have benefited by using the algorithm with appropriate modifications to solve difficult problems. With the results we have obtained via the review, it can be concluded that the firefly algorithm as a modern nature inspired algorithm is worthwhile in trying to solve optimization problems where other optimization techniques are failed, less performable or not suitable.

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