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A Study on Flower Pollination Algorithm and Its Applications

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ABSTRACT

This paper presents a study on Flower Pollination Algorithm and its applications. Flower Pollination Algorithm is the most recently developed nature inspired algorithm based on pollination process of plants. Flower Pollination Algorithm is principally used to solve constrained and unconstrained optimization problems. Researchers are attracted towards this algorithm for its processing speed, ease to modify based on the requirement and robustness.

Keywords:- Flower Pollination, nature inspired algorithm, constrained, optimization

1. INTRODUCTION

1.1. Optimization

Optimization is basically used to enhance the performance and efficiency and to reduce the cost. The scarce resources like time and money are to be deployed properly and effectively in real-world applications such as manufacturing, engineering design, business planning and software development. Hence it is essential to devise solutions to optimally use these valuable resources under various constraints. Mathematically, Optimization is the study of effective planning and solving design problems using mathematical tools. Traditional optimization techniques set many limitations while developing the mathematical and operational research models. Model solutions in traditional optimization algorithms are mostly dependent on the type of objective and constraint functions. The effectiveness of traditional algorithms depends on the size of the solution, number of variables and constraints used for solving the problems. Further the traditional algorithms do not suggest general solution strategies which will be useful for solving the problem having different variables and constraints.

1.2 Nature Inspired Algorithms

Researchers have been exploring new ways of solving optimization problems due to inefficiency of traditional optimization algorithms especially to solve large and complicated problems. The popularity of the Nature-Inspired Algorithms is primarily influenced by the ability of biological systems to effectively adjust to frequently changeable environment**.** Swarm intelligence has been of great interest for many research scientists in the last decade. onabeau [5] has defined the swarm intelligence as designing algorithms or distributed problem solving devices based on the collective behavior of animal societies and social insect colonies. The core of this study is to develop meta-heuristics by adopting the insect problem solving abilities. Many studies were conducted on social insects like termites, bees, wasps and ant species. Good example of a swarm is bees swarming around their hives; however the logic can easily be extended to other systems with a similar behavior. An ant colony and flock of birds can be called as a swarm whose individual agents are ants and birds respectively. An immune system is also swarm of cells and molecules. Particle Swarm Optimization (PSO) Algorithm has been developed based on the social behavior of bird flocking or fish schooling. Some of other algorithms developed are Ant Colony, Wasp nets, Firefly Algorithms. Artificial Bee Colony algorithm is a population based swarm intelligence optimization technique developed by Karaboga in 2005 [6]. Artificial Bee Colony algorithm is based on the behavior of honey bees in food foraging. The honey bees use different methods like waggle dance to locate optimal food sources and reaching new ones. This unique character of sourcing the food in efficient way inspired many computational researchers to develop a new intelligent search algorithm [7]. The latest nature inspired algorithm is Flower Pollination Algorithm which was proposed by Xin-She Yang in 2012 [4]. This is based on the pollination of flowers.

2. FLOWER POLLINATION

2.1 Pollination

The reproduction in plants happens by union of the gametes. The pollen grains produced by male gametes and ovules borne by female gametes are produced by different parts and it is essential that the pollen has to be transferred to the stigma for the union. This process of transfer and deposition of pollen grains from anther to the stigma of flower is pollination. The process of pollination is mostly facilitated by an agent. The pollination is a result of fertilization and it is must in agriculture to produce fruits and seeds [2].
There are two types of pollination:

1. Self-Pollination.
2. Cross Pollination.

2.1.1 Self Pollination

When the pollen from a flower pollinates the same flower or flowers of the same plant, the process is called self-pollination. It occurs when a flower contains both the male and the female gametes.

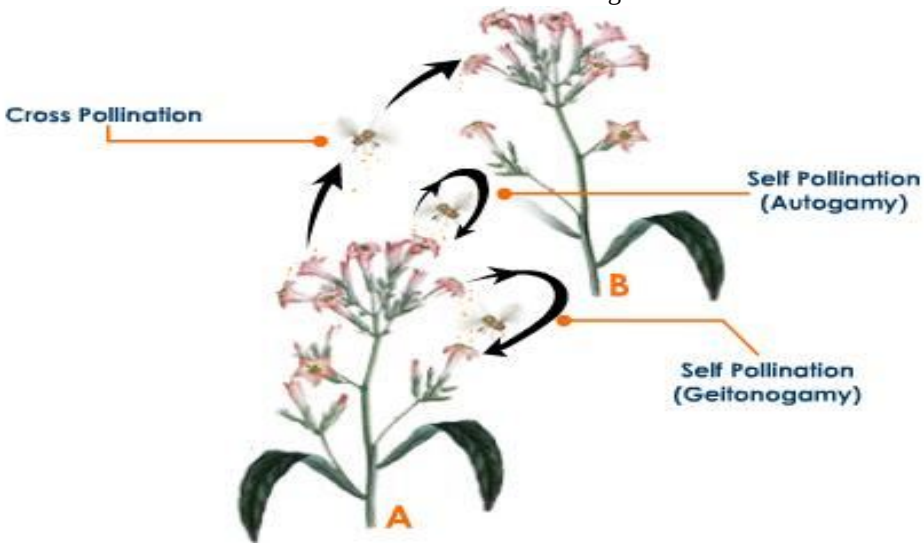

Figure 1: Pollination [2]

2.1.2 Cross Pollination

Cross Pollination occurs when pollen grains are moved to a flower from another plant. The process of cross pollination happens with the help of abiotic or biotic agents such as insects, birds, snails, bats and other animals as pollinators. Abiotic pollination is a process where the pollination happens without involvement of external agents. Only about 10% of plants fall in this category. The process of pollination which requires external pollinators is known as Biotic Pollination [2] to move the pollen from the anther to the stigma. Insects play most important role as the pollinators. Insect Pollination occurs in plants with coloured petals and strong odour which attract Honey bees, moths, beetles, wasps, ants and butterflies [1]. The insects are attracted to flowers due to availability of nectar, edible pollen and when insect sits on the flower, the pollen grains stick to the body. When the insect visits another flower, the pollen is transferred to stigma facilitating pollination. The pollination is also facilitated by vertebrates like birds and bats. Flowers pollinated by bats mostly have white coloured petals and strong odour. The birds usually pollinate flowers with red petals and without odour.

3. FLOWER POLLINATION ALGORITHM

Flowering plants flow pollination process inspired Xin-She Yang to develop Flower Pollination Algorithm (FPA) in 2012. For ease, the four rules given below are used [4].

1. Biotic and cross-pollination can be considered processes of global pollination, and pollinators carrying pollen move in a way that confirms to Lévy flights.

2. For local pollination, abiotic pollination and self-pollination are used.

3. Pollinators, like insects develop flower loyalty, which is comparable to the reproduction possibility proportional to the matching of two flowers involved.

4. Switching or the interaction of global pollination and local pollination can be controlled by a switch probability p □ [0, 1], slightly biased towards local pollination.

To formulate the updating formulas, these rules have to be changed into correct updating equations. The main steps of FPA, or simply the flower algorithm [4] are illustrated below:

min or max objective $f(x)$, $x = (x_1, x_2, \ldots, x_d)$
Initialize n flowers or pollen gametes population with random solutions
Identify the best solution (g_*) in the initial population
Express a switch probability p □ [0, 1]
While (t < Max Generation)
for i = 1 : n (all n flowers in the population)
if rand < p,
Draw a (d-dimensional) step vector L *from a* Levy distribution
Global pollination via $x_i^{t+1} = x_i^t + \gamma L(g_* - x_i^t)$
else
Draw □ from a uniform distribution in [0,1]
Do local pollination via $x_i^{t+1} = x_i^t + \square (x_j^t - x_k^t)$
end if
Evaluate new solutions
If new solutions are better, update them in population
end for
Find current best solution
end while
Output the best solution obtained

In principle, flower pollination process can happen at both local and global levels. But in reality, flowers in the neighbourhood have higher chances of getting pollinated by pollen from local flowers than those which are far away. To simulate this feature, a proximity probability p (Rule 4) can be commendably used to switch between intensive local pollination to common global pollination. To start with, a raw value of p = 0.5 may be used as an initial value. A preliminary parametric study indicated that p = 0.8 may work better for most applications.

3.1 Multi-Objective Flower Pollination Algorithms

FPA has been applied to multi objective optimization. A multi-objective optimization problem with m objectives can be written in general as [4]

$$\text{Minimize } f_1(x), f_1(x), \ldots, f_m(x),$$

subject to the nonlinear equality and inequality constraints

$$h_j(x) = 0, \quad (j = 1,2, \ldots, j),$$

$$g_k(x) = 0, \quad (k = 1,2, \ldots, j).$$

To use the techniques for single-objective optimization or to extend the existing methods for solving multi-objective problems, there are different approaches to achieve this task. One of the simplest ways is to use a weighted sum to combine multiple objectives into a composite single objective

$$f = \sum_{i=1}^{m} w_i f_i$$

With

$$\sum_{i=1}^{m} w_i = 1, \quad w_i > 0,$$

where $w_i (i = 1, \ldots, m)$ are no negative weights

The central idea of this weighted sum approach is that these weighting coefficients act as the preferences for these multi-objectives. For a given set of $(w_1, w_2, \ldots, w_m)$, the optimization process will produce a single point of the Pareto front of the problem. For a different set of w_i, another point on the Pareto front can be generated. With a sufficiently large number of combinations of weights, a good estimation to the true Pareto front can be obtained. It has been proved that the solutions to the problem with the collective objective are Pareto-optimal if the weights are positive for all the objectives, and these are also Pareto-optimal to the original problem. In practice, a set of random numbers u_i are first drawn for a uniform distribution $U(0, 1)$. Then, the weights w_i can be calculated by normalization.

That is,

$$w_i = \frac{u_i}{\sum_{i=1}^{m} u_i},$$

so that $\sum_i w_i = 1$ can be satisfied. For example, for three objectives f_1, f_2, and f_3, three random numbers or weights can be drawn from a uniform distribution $[0, 1]$, and they may be $u_1 = 0.2915, u_2 = 0.9147$ and $u_3 = 0.6821$ in one instance of sampling runs. Then we have $\sum_i = 1.8883$, and $w_1 = 0.1544, w_2 = 0.4844, w_3 = 0.3612$. Indeed, $\sum_i w_i = 1.000$ is satisfied.

To get accurate Pareto front with solutions reasonably uniformly distributed on the front, random weights w_i should be used and should be as different as possible. According to Xin She Yang [4], experiments conducted on test functions and design examples, FPA is very efficient for both single and multi-objective optimization. Table 1 shows the comparison of FPA with GA and PSO for single objective functions

Table 1: Comparison of FPA with GA and PSO for benchmarks Spring Design Optimization, Welded Beam Design, Speed Reducer Design, and Pressure Vessel Design [4].

Cases	GA	PSO	FPA
Spring	2.6681	2.659	2.6586
Beam	2.4331	2.3810	1.72485
Reducer	2985.2	2996.348	2993.7496
Vessel	5850.383	5850.383	5850.383

4. APPLICATIONS OF FLOWER POLLINATION ALGORITHM

FPA is recently proposed algorithm and it is applied only to some problems. Xin-She Yang [13], developed flower pollination algorithm and applied to optimization problems. It was used on test function for validation and results were compared with Genetic Algorithm (GA) and Particle Swarm Optimization(PSO). Simulated results were found to be better than GA and PSO. Further FPA was used to solve a nonlinear design benchmark and convergence rate was

nearly exponential. Osama Abdel-Raouf, et. al. [8] proposed a new optimization hybrid method called FPCHS (Flower Pollination Algorithm with Chaotic Harmony Search) to improve the accuracy of search. This algorithm was used to solve Sudoku puzzles. The results indicated that the FPCHS is accurate and efficient when compared to standard Harmony Search (HS) algorithm. Authors have indicated that the better result is due to superior search capability of FPA. Gaganpreet Kaur et.al, [9] presented a new technique to improve the fractal image compression through pollination based optimization. The visual quality of image is much better with Pollination Based Optimization [PBO] as compared to Fractal Image Compression [FIC]. Image compressed using PBO is much close to original one, eliminating distortion of the image in FIC. It is easy to modify to purposed method and results show that the use of PBO, reduces the encoding time and improves the visual quality of image. Also overall performance of purposed technique is better than other optimization techniques. Further this paper concludes that the proposed technique is better suited for applications requiring fast access to high- quality images. Xin-She Yang et.al, [4] stretched the single objective optimization flower algorithm for solving the multi objective optimization problems. The multi objective flower algorithm was applied to solve a bi-objective disc brake design problem. Tests and design benchmarks indicated that multi-objective FPA is very efficient with rapid convergence rate. This conclusion was drawn by comparing the output of Flower Pollination Algorithm with the output of other algorithms while solving multi-objective optimization problems. A new optimization technique based on pollination to segment colour images was proposed by Gaganpreet Kaur, et.al.,[10]. The algorithm has been implemented for extracting the optimal clusters from the coloured images. The proposed algorithm worked better on the coloured images and the time required to segment the images was reduced considerably as compared to most optimization algorithms. E.Emry et.al, [11] proposed a new retinal vessel segmentation that was carried out using the flower pollination search algorithm (FPSA) to localize the retinal vessel map that uses the possiblistic fuzzy c-means (PFCM) fitness function. The result obtained proves the quick convergence of the FPSA and the robustness of the obtained results even with image with abnormalities. O.Abdel-Raouf et.al, [12] presented a hybrid Flower Pollination with Particle Optimization Swarm(FPPOS) algorithm to solve constrained optimization problems. The new algorithm has been validated using several benchmark mathematical and engineering design problems. The results obtained by the proposed algorithm were compared with other algorithms and the same were superior, more accurate, reliable and efficient at finding global optimal solution than are other algorithms. Rui Wang et al [14], proposed a dimension by dimension improvement using FPA. In this modified algorithm, local search approach was used to enhance the local search ability. The simulated investigations indicated that the proposed approach can improve the convergence speed and the quality of solutions. Prathiba R et al [15], proposed FPA for optimizing Economic Load Dispatch (ELD) in power system operation. The objective was to minimizing the fuel cost by effectively setting the real power outputs from generators. The new algorithm was tested on the standard IEEE-30 bus system and the results are compared with other algorithms and the results were found to be better.

5. CONCLUSION

In this paper, need for optimization techniques, limitations of traditional optimization techniques and the benefits of nature inspired algorithms are discussed. Study indicates that Flower Pollination algorithm is simple, flexible and exponentially better to solve optimization problems. FPA can be used for solving both single objective and multi-objective optimization problems. The paper presents works carried out by researchers in various fields using FPA, and also study indicated that FPA reduces time, improves the results and the performance is better compared to other optimization techniques. FPA looks very promising and is still in nascent stage and can be applied for medical image Analysis.

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