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Differential Evolution Algorithm and Its Variants

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Abstract— Differential evolution (DE) is a popular population-based stochastic meta-heuristic method. There are many meta-heuristic methods with different names such as League Championship Algorithm, Artificial Bee Algorithm, Bee Swarm Optimization, Cat Swarm Optimization, Differential Search, Goose Optimization Algorithm. In this paper, the similarities of all these methods were discussed.

Keywords :*Differential Evolution, League Championship Algorithm, Artificial Bee Algorithm.*

1.Introduction

Meta-heuristic methods are nature-inspired methods such as Sapling Growing-up Algorithm [1,2], Fire-Fly Algorithm [3], Cricket Algorithm [4], etc. There are over 150 such algorithms in literature.

The aim of this paper is to reveal the similarities of some meta-heuristic methods to differential evolution.

Differential evolution (DE) is a stochastic, population-based heuristic search strategy for continuous domains which is a branch of evolutionary programming, developed by Storn and Price [5] in 1997. DE is a simple, easy to use, robust and speed heuristic method. There are many meta-heuristic algorithms derived from DE such as bee food searching based methods, league championship, political competition, cat swarm optimization algorithm.

The league championship algorithm (LCA) [6] is stochastic population-based algorithm for continuous domain. Its aim is to mimic a championship environment wherein artificial teams play in an artificial league for solving optimization problems.

There many algorithms based on bee food searching strategy have main idea derived from DE. These are Artificial Bee Colony [7], Bee Swarm Optimization [8].

There are some other meta-heuristic algorithms derived from DE. Cat swarm optimization is another heuristic algorithm based on the behaviours of cats [9]. Differential Search Algorithm (DSA) was proposed for solving continuous optimization problems [10] and it is a population-based meta-heuristic method. Goose Optimization Algorithm (GOA) is heuristic algorithm based on population and behaviours of geese in nature. Each candidate solution is considered as a goose and they are sorted with respect to their fitness values and the best one is considered as a leader goose [11].

2. Differential Evolution

DE should fulfil the following requirements [5]:

a) It is able to handle multi-modal, nonlinear and non-differentiable functions.
b) It is able to cope with computation intensive cost by parallelizing.
c) It is simple to handle.
d) It is able to converge to optimal or near-optimal solution.

The aim of the DE is to generate new offsprings by using the following process:

A trial vector is generated from the current candidate solutions by applying mutation operator to current candidate solutions. After that crossover operator is applied to trial vector.

First of all, each candidate solution is a candidate to compete versus to a target vector. In order to obtain target vector, mutation operator is used and the obtained target vector and current candidate solution are subject to crossover operator. For example, X_a is a candidate solution and X_{aT} is a target vector for X_a from X_b, X_c, X_d (Eq.1)

$$X_{aT}=X_b+F(X_c-X_d) \quad (1)$$

where F is a $F\in[0,2]$ and it is called as scaling factor which controls the amplification of differential variation. X_a and X_{aT} are subject to crossover operator such as (Eq.2)

$$X_{aU,i}=\begin{cases} X_{aT,i} & if \quad rand \le CR \\ X_{a,i} & otherwise \end{cases} \quad (2)$$

where CR is crossover rate and $CR\in[0,1]$. After that selection operator is applied (Eq,3).

$$X_{a\,next}=\begin{cases} X_{aU} & if \ f(X_{aU}) \le f(X_a) \\ X_a & otherwise. \end{cases} \quad (3)$$

There are some types of DE based on the mutation operator application type:

DE/rand/1: $X_{aT}=X_b+F(X_c-X_d)$

DE/rand/2: $X_{aT}=X_b+F(X_c-X_d)+F(X_e-X_f)$

DE/best/1: $X_{aT}=X_{best}+F(X_c-X_d)$

DE/best/2: $X_{aT}=X_{best}+F(X_c-X_d)+F(X_e-X_f)$

DE/rand_to_best/1: $X_{aT}=X_b+F(X_{best}-X_d)+F(X_e-X_f)$

3.League Championship Algorithm

LCA is a framework based on population for global optimization and the aim of LCA is to move a population of candidate solutions to promising areas of the search space. LCA consists of a set of candidate solutions called as population. In order to move candidate solutions to valley of better candidate solutions, information modification operator (mutation as in DE) can be applied to each candidate solution. In order to apply mutation operator, SWOT (strong, weak, opportunity, threat) idea is used in this algorithm. The formation of a team at week t+1 can be set up by one of the following equations.

a) If both teams won the matches, then
$X_U=X_b+Y(F_1r_1(X_c-X_d))+F_1r_2(X_e-X_f)$

b) If first team won and second lost
$X_U=X_b+Y(F_2r_1(X_c-X_d))+F_1r_2(X_e-X_f)$

c) If first team lost and second won
$X_U=X_b+Y(F_1r_1(X_c-X_d))+F_2r_2(X_e-X_f)$

d) If both teams lost
$X_U=X_b+Y(F_2r_1(X_c-X_d))+F_2r_2(X_e-X_f)$

where F_1 and F_2 are scaling factors and r_1 and r_2 are random numbers. Y is a binary number.

4.Artificial Bee Algorithm and Bee Swarm Algorithm

There are more than one artificial bee colony algorithms. In this paper, we gave the mutation operator for each algorithm, since crossover and selection operators are similar to crossover and selection operators of DE.

a) Artificial Bee Colony: In order to create new candidate solution from existents candidate solutions, the following equation is used (Eq.4).

$$v_{ij}=x_{ij}+\varphi_{ij}(x_{ij}-x_{kj}) \quad (4)$$

where x_{ij} is an old candidate food position and also x_{kj} is also an old candidate food position selected randomly. v_{ij} is the new dandidate food position obtained from current food positions.

b) Bee Swarm Optimization: BSO algorithm is based on the behaviours of bees while searching for food. Assume that w_b and w_e are the best food position and elite food position, respectively. r_b and r_e are random numbers. The forager bee position updating is handled by using the following equation.

$$x_{new}(f,i)= x_{old}(f,i)+w_b r_b(b(f,i)+x_{old}(f,i))+w_e r_e(e(f,i)-x_{old}(f,i)) \quad (5)$$

where e(f,i) is the elitist bee for forager bee at iteration i, and b(f,i) is the best bee for forager bee at i^{th} iteration. The onlooker bee changes its position with respect to the following equation (Eq.6).

$$x_{new}(k,i)= x_{old}(k,i)+w_e r_e(e(k,i)-x_{old}(k,i)) \quad (6)$$

The scout bee updates its position with respect to the following equation (Eq.7).

$$x_{new}(v,i)= x_{old}(v,i)+Rw(r-x_{old}(v,i)) \quad (7)$$

whereRw is a random walk function of radius r.

5.Cat Swarm Optimization

CSO is a population based optimization algorithm derived from the behaviours of cats such as “seeking mode” and “tracking mode” (Eq.8).

$$v(k,d)=v(k,d)+r_1c_1(x(best,d)-x(k,d)) \quad (8)$$

where v(k,d) is the velocity of cat k at iteration d and x(k,d) is the position of cat k at iteration d. x(best,d) is the position of cat whose fitness value is the best value at iteration d. c_1 is a constant and r_1 is a random number in [0,1]. The position update process is performed by using obtained velocity.

6. Differential Search Algorithm

DSA consists of artificial organisms making up a super-organism. The candidate solution of the best fitness value is regarded as a super-organism. The following equation is used for update process (Eq.9)

$$StopoverSite=Superorganism+S(Donor-Superorganism) \quad (9)$$

where S is a random number in [0,1] by using gamma-random number based on uniform random number.

7.Goose Optimization Algorithm

GOA is heuristic algorithm based on population and behaviours of geese in nature. Each candidate solution is considered as a goose and they are sorted with respect to their fitness values and the best one is considered as a leader goose [11]. In order to obtain the solution, each goose changes its position with respect to the position of leader goose. This process is done by using the following equations (Eq.10 and Eq.11).

$$v(k+1,i)=wv(k,i)+\alpha(spop(k,i)-x(k,i))+\beta(pbest(k,i-1)-x(k,i)) \quad (10)$$

$$x(k+1,i)=x(k,i)+v(k+1,i) \quad (11)$$

8. DE and Its Derivatives

DE is an important and effective meta-heuristic algorithm. Due to this case, there are many variants of DE known with different names. Table 1 depicts this case. It is ease to see that all these methods have similar/same logic in reproduction methods.

Table 1. DE and its derivatives

	Reproduction Methods		
League Championship Algorithm	$X_U=X_b+Y(F_1r_1(X_c-X_d))+F_1r_2(X_e-X_f)$ $X_U=X_b+Y(F_2r_1(X_c-X_d))+F_1r_2(X_e-X_f)$ $X_U=X_b+Y(F_1r_1(X_c-X_d))+F_2r_2(X_e-X_f)$ $X_U=X_b+Y(F_2r_1(X_c-X_d))+F_2r_2(X_e-X_f)$	*DE/rand/1:* $X_{aT}=X_b+F(X_c-X_d)$ *DE/rand/2:* $X_{aT}=X_b+F(X_c-X_d)+F(X_e-X_f)$ *DE/best/1:* $X_{aT}=X_{best}+F(X_c-X_d)$ *DE/best/2:* $X_{aT}=X_{best}+F(X_c-X_d)+F(X_e-X_f)$ *DE/rand_to_best/1:* $X_{aT}=X_b+F(X_{best}-X_d)+F(X_e-X_f)$	*Differential Evolution*
Artificial Bee Algorithm	$v_{ij}=x_{ij}+\varphi_{ij}(x_{ij}-x_{kj})$		
Bee Swarm Algorithm	$x_{new}(f,i)= x_{old}(f,i)+w_b r_b(b(f,i)+x_{old}(f,i))+w_e r_e(e(f,i)-x_{old}(f,i))$ $x_{new}(k,i)= x_{old}(k,i)+w_e r_e(e(k,i)-x_{old}(k,i))$ $x_{new}(v,i)= x_{old}(v,i)+Rw(r-x_{old}(v,i))$		
Cat Swarm Optimization	$v(k,d)=v(k,d)+r_1c_1(x(best,d)-x(k,d))$		
Differential Search Algorithm	*StopoverSite=Superorganism+S(Donor-Superorganism)*		
Goose Optimization Algorithm	$v(k+1,i)=wv(k,i)+\alpha(spop(k,i)-x(k,i))+\beta(pbest(k,i-1)-x(k,i))$ $x(k+1,i)=x(k,i)+v(k+1,i)$		

As seen in Table 1, although all these algorithms known with different names, they are same to DE or variants of DE except there are different linguistic terms. If the reproduction equations for all algorithms are taken in consideration, it can be easily seen that all these methods are variants os DE.

There are some other heuristics methods derived from DE such as Dove Swarm Optimization, Particle Swarm Optimization, Honeybee Mating Optimization Algorithm, Firefly Algorithm, Teaching Learning Based Optimization, Flower Pollinating Algorithm, Roach Infestation Optimization, Swallow Swarm Optimization Algorithm etc.

9. Conclusions

The aim of this paper is to introduce DE and its variants in a compact way. Many meta-heuristic methods known with different names, although they have similar or same reproduction method. So, the performances of these methods will be similar. In future work, many of these methods will be compared based on application and reproduction rules.

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