ABC+ES: A Novel Hybrid Artificial Bee Colony Algorithm with Evolution Strategies

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ABSTRACT

This paper has the purpose of presenting a new hybridization of the Artificial Bee Colony Algorithm (ABC) based on the evolutionary strategies (ES) found on the Evolutionary Particle Swarm Optimization (EPSO). The main motivation of this approach is to augment the original ABC in a way that combines the effectiveness and simplicity of the ABC with the robustness and increased exploitation of the Evolution Strategies.

The algorithm is intended to be tested on two large-scale engineering design problem and its results compared to other optimization techniques.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search – Heuristic methods

General Terms

Algorithms, Theory

Keywords

Swarm Intelligence; Artificial Bee Colony; Evolution Strategies; Hybrid Metaheuristic; Constrained Optimization

1. INTRODUCTION

In the last years, a vast number of modifications of the Artificial Bee Algorithm were made by researchers involving many kinds of approaches [4].

In order to create a new hybridization of the algorithm that has never been made, a hybrid version of the ABC involving Evolution Strategies (ES) found on the work of [5] concerning the Evolutionary Particle Swarm Optimization(EPSO) has been created.

The Artificial Bee Colony algorithm (ABC) is a metaheuristic that simulates the foraging behaviour of honey bees, created from the work of [3]. The ABC is well-known for being a simple and effective algorithm for both constrained and unconstrained problems, being used on both constrained and unconstrained optimization problems [1]. Although this popular algorithm is effective, it has been empirically indicated that the ABC when applied to constrained optimization problems produces solutions that are not entirely robust, displaying high variance and mean values.

One of the optimization techniques that are most well-known for its large use in the field of engineering is the Particle Swarm Optimization (PSO). One of its variations that is noteworthy is the Evolutionary Particle Swarm Optimization (EPSO) [5] where it consists of a variant of the PSO in which employs operations from evolutionary strategies such as replication, mutation and selection. The EPSO through the evolutionary strategies achieves a very high convergence rate albeit maintaining a good quality for its solution.

The new Algorithm has the same Bees cycles as of the ABC, however the position update formula for the onlooker and employed bees are expanded according to the movement formula of the EPSO and replicas are made of the original bee as part of the ES. Also, new behavioural mechanisms for the selection of onlooker bees and abandonment of scout bees were made in order to further optimize the algorithm.

2. A BRIEF OVERVIEW OF THE ABC+ES

After observing that even though the original ABC is able to produce very good results for continuous unconstrained optimization problems, for the constrained counterparts, it has been empirically proven that for such problems, the ABC often displays a high standard deviation and variance values in comparison to others optimization techniques like the Particle Swarm Optimization (PSO) and the Differential Evolution (DE). Following such observations, a hybridization of the ABC has been devised with the intention of increasing the algorithm robustness as well as to produce even better solutions, thus resulting in an new algorithm that has either ES and ABC.

The ABC+ES follows the Evolution Strategies present in the EPSO where the solution is replicated n times and then mutated with various goals, such as to provide an increased exploration in the solution space because of the high variability rate, raise the convergence rate due to the fact that the clones will be trying to further improve a solution that has already been improved, and lastly to increase the quality of the solutions in the same cycle.

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The Evolution Strategies is also responsible for a feature present on constrained optimization problems that is, an infeasible solution might as well become a viable solution with a small push from one of the parameters values. Such possibility is much present in this case since the mutation operation is likely to perform a minor modification on one random chosen parameter, thus making a solution transform from infeasible to feasible, although on some cases it may further improve an already optimum value. Equation 1 shows the mutation for the replicas of the solution ($\gamma_m^{*\,*}$).

$$\gamma_m^* = \gamma_m + (1 + \sigma N(0,1)) \tag{1}$$

The new position update formula for the ABC+ES as seen on 2 is the same as the ABC with the addition of a portion of the EPSO movement formula. Given the absence of an individual component like the one found on PSO, the new position update equation tends to guide the source towards the global best only having in reference the global component P_g via a social weight that undergoes mutation γ_m^* which forces the solution to converge to the global best (P_g).

$$X_m^{(t+1)} = X_m^{(t)} + \varphi * (X_m^{(t)} - X_k^{(t)}) + \gamma_m^*(P_g^* - X_m^{(t)}) \tag{2}$$

Aside from the new position update formula, other modifications were: a new selection mechanism has been created where it replaces the simple tournament selection with an elitism favoured variation where it consists of creating a pool where it contains the winner solutions — that can be present multiple times in the pool— of n tournaments of two or four participants; and a new policy for the scout bees cycle where if multiples solutions reach the limit value at the same time, only one will have its values rerolled. However, if a solution reach a threshold value, which is 1.5 times the limit value, all of the solutions that are abandoned will have new values generated.

3. RESULTS

The ABC+ES has been tested on two constrained optimization problems, that also are engineering problems that is widely used in scientific literature, the Design of a Pressure Vessel (DPV) and Minimization of the Weight of a Tension/Compression Spring (MWTCS). The results obtained for each problem are shown below on Table 1 and on Table 2.

Table 1: Comparison of Results for the DPV

Variables	ABC+ES	[7]	[2]
$X_1(T_s)$	0.785258	0.812500	0.812500
$X_2(T_h)$	0.390208	0.437500	0.437500
$X_3(R)$	40.686332	42.092732	42.097398
$X_4(L)$	196.341524	195.678619	176.654050
G_1	-0.000012	-0.000110	-0.000020
G_2	-0.002061	-0.035935	-0.035891
G_3	-7198.483555	-1337.994634	-27.886075
G_4	-201.981720	-63.052220	-63.345953
Violations	0	0	0
Fitness	5933.919333	6066.029360	6059.946300

Table 2: Comparison of results for the MWTCS

Variables	ABC+ES	[6]	[7]
$X_1(d)$	0.050000	0.050000	0.500250
$X_2(D)$	0.282023	0.282023	0.280748
$X_3(P)$	2.000000	2.000000	2.036163
G_1	-0.000000	-0.000000	-0.002840
G_2	-0.235327	-0.235327	-0.249450
G_3	-43.146137	-43.146145	-42.176000
G_4	-0.778651	-0.778651	-0.780140
Violations	0	0	0
Fitness	0.002820	0.002820	0.002836

4. CONCLUSION

The ABC+ES was able to produce better results compared to the others, indicating that it presents: a higher convergence rate due to the replications of the bees, allowing a further exploration of the search space; an improved quality of solutions because of the mutation factor of the replicas that may improve an already optimum solution; lastly, a fix of the issue brought by the ES that causes the algorithm to have many solutions trapped at local optima on later iterations, since the ABC+ES overcomes the problem by utilizing the classical position update formula for the original bee.

The next step for this algorithm is to: execute more tests with engineering design functions as well as other kinds of problems such as Real Valued Parameter Function Problems, Knapsack Problem and Real-World Problems; design a multi-swarm model to be run under CUDA architecture; and further study of the behaviour of the onlooker bees based on social aspects of the Game Theory from the work of [7] .

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