Evaluating the performance of Particle Swarm Optimization Algorithm with Aging Leader and Challengers (ALC-PSO) using Benchmark Functions

Abstract

Particle Swarm Optimization with Aging Leader and Challengers(ALC-PSO) is an optimization technique which uses the concept of aging. Aging is a vital process that comes to all. This mechanism is applied to the Particle Swarm Optimization Algorithm, to find the optimal solution to a difficult problem. The ALC-PSO algorithm uses the concept of a leader, leading the swarm and another particle challenging the position of the leader, based on its efficiency, performance, lifespan and leading power. When Aging mechanism is applied to PSO, the premature convergence is overcome and the efficiency of the algorithm is increased. This paper transplants a few of the benchmark functions which can be used to evaluate the performance of Particle Swarm Optimization (ALC-PSO) algorithm, that may give the greater comparison of results. The benchmark functions that have now been probably the most commonly adopted to assess performance of ALC-PSO-based algorithms and information on all of them are given, like the search range, the position of their known optima, and other relevant properties.

Keywords- *Aging, Benchmark functions, Best Position, Challengers, Leader, Optimization, Particle, Premature Convergence, optimal point, optimization, optimization algorithms, optimization problems, Particle swarm optimization, performance, search space*

1. Introduction

PSO is a heuristic global optimization method[1]. It has its roots from the Swarm Intelligence[2]. It is an optimization technique based on stochastic behavior of population[6]. It can be an Artificial Intelligence technique, which could find approximate solution with a difficult problems. PSO is a biologically inspired optimization method[4]. PSO uses swarming behaviors observed in bird flocking, fish schooling, bee swarming and socially interactive behavior of humans.

Aging is a progressive process[5], which is inevitable in nature. In reality, aging is a universal process[5], which maintains the balance among species and makes the population grow at an ordinary pace, bringing diversity in species[3]. Organisms grow older i.e. they age with time. Aging is an essential and intrinsic process. There is a leader of the population who is best on the list of population in certain qualities. It leads the members of the population. This leader also ages as time passes and becomes weaker. It cannot lead the population efficiently. Then arises the requirement of a new leader, who can actively lead its population. This deleterious process of aging leads to challenge the positioning of the leader leading several organisms and makes one other and young organisms become new leader.

The election of the leader from among various available challengers is done based on its leadership performance and lifespan. Based on the leading power of the leader, its lifespan is adjusted. If it's good leading power, it lives longer leading the swarm, and brings all of the members of the swarm towards best position so found but when isn't capable of leading the swarm, new challengers emerge as new leader , claiming the leading position in swarm.

Whenever the leader of population becomes aged, new challengers come up to lead the population[12]. The new challengers are generated using two parameters i.e. performance and lifespan. The lifespan of the leader is tuned by the lifespan controller according to its leading power and new challengers are generated. Using some function evaluations, the generator continues generating the challengers till the most evaluations are reached. The best challenger becomes the new leader of the swarm [3].

2. Designing and Working of ALC-PSO

The designing of ALC-PSO can be done in three steps:

1. Design lifespan controller- adjusting the lifespan of the leader.
2. Generating challengers- generation of challengers for challenging the position of the current leader.
3. Accepting challenger- deciding whether generated challenger can be accepted as new leader.

ALC-PSO is different from original PSO as in simple PSO there is no limit on lifespan of leader of the swarm but in ALC-PSO, the leader ages within a limited lifespan. This lifespan depends on the leading power of leader of swarm which can be adjusted accordingly. When lifespan of leader gets exhausted, the leader is replaced by a new particle, which challenges the position of the leader and makes itself becomes the leader. The velocity update rule is changed to:

$$v_i^j = w.* v_i^j + c_1.r_1^j.(pBest_i^j - x_i^j) + c_2.r_2^j.(Leader^j - x_i^j)$$

Here leader is a particle with adequate leading power generated by aging mechanism.

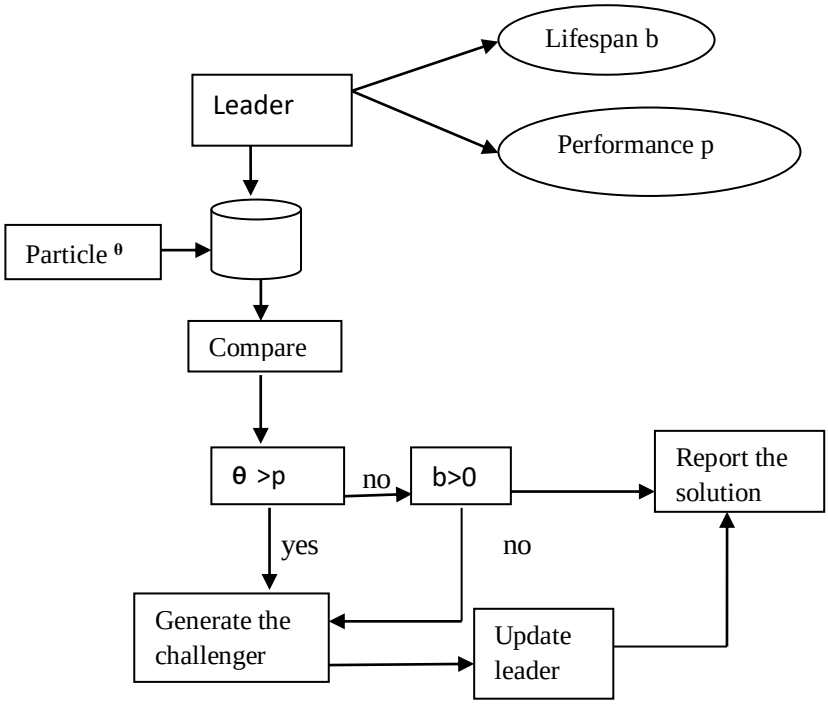


Figure: Aging Leader Algorithm with challenger

1. Lifespan Controller

After updating the positions of the particles, the leading power of leader to improve the entire swarm is evaluated. Lifespan b is adjusted by the lifespan controller. The generated leader checks the gBest and has three cases:

1. gBest<0: In this case, the leader can efficiently lead the population, so its lifespan is increased by 2.
2. gBest =0: In this case, the leader can satisfactorily lead the population and its performance can be enhanced to some extent, so its lifespan is increased by 1.
3. gBest>0: In this case, there is no hope for improvement in performance, so the leader's lifespan is decreased by 1.

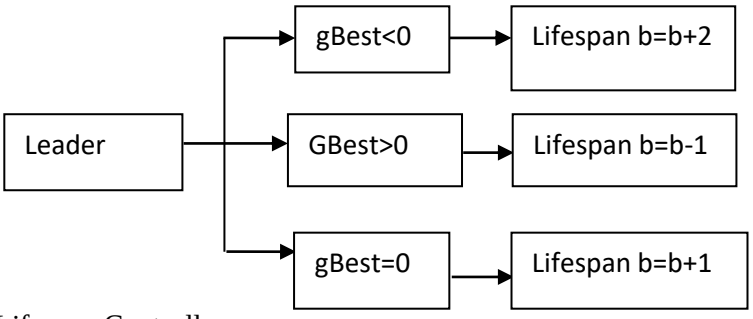


Figure: Lifespan Controller

2. **Generation of the Challenger:** New challenger is generated when the lifespan of the old leader gets exhausted. When the performance of particle is greater than the previous leader, the leader is updated and when the best solution of the population is found, it is reported.

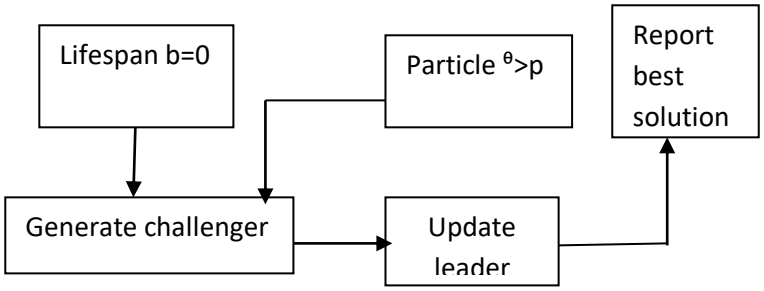
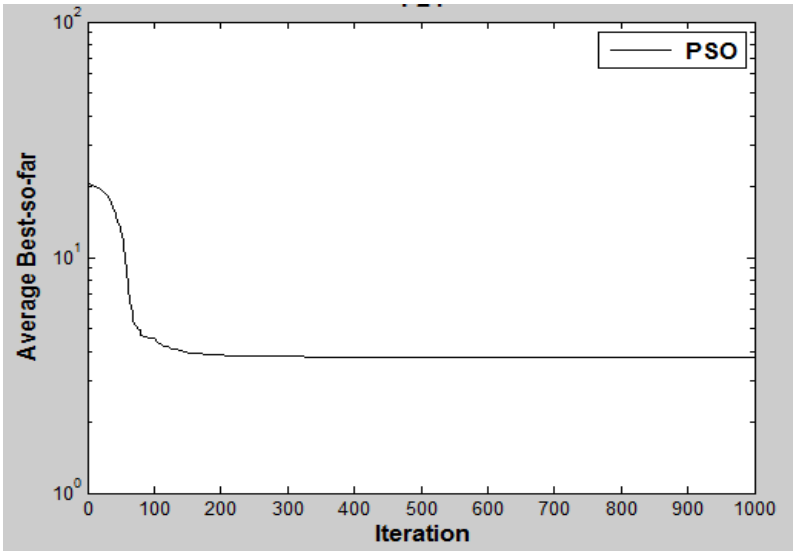


Figure: Generation of Challenger

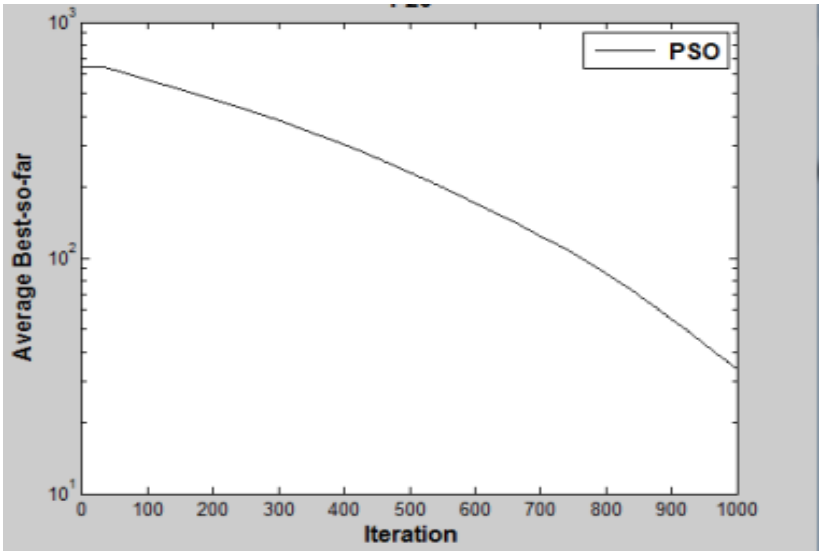
3. **Accepting the challenger-** The leading power of newly generated challenger is evaluated, if this challenger has enough leading power, it replaces the old leader and itself becomes the new leader [11].

3. Results of Testing ALC-PSO With Benchmark Functions

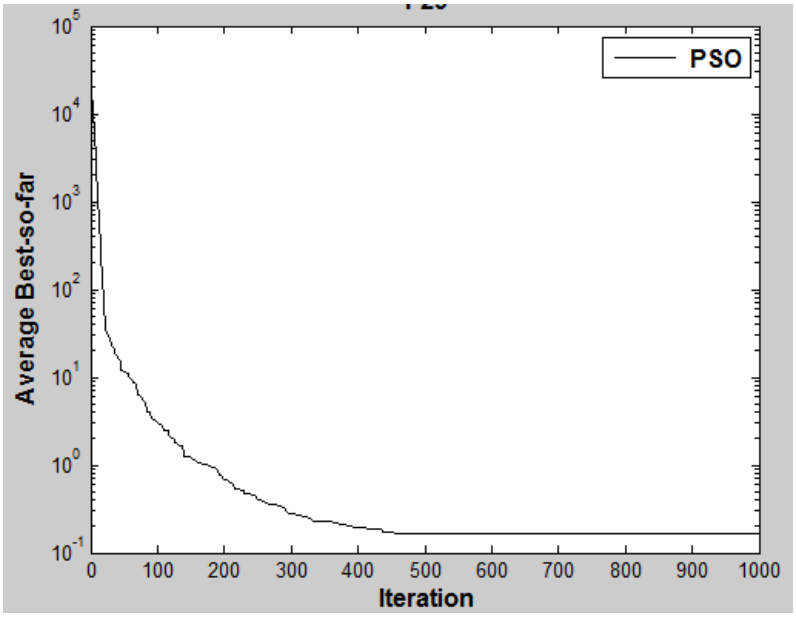
The ALC-PSO algorithm is implemented on MATLAB (R2011b). The algorithm gives the convergence point at which all the particles of the swarm get accumulated, means the optimal solution is found and the optimum point is achieved.



ACKLEY



GRIEWANGK



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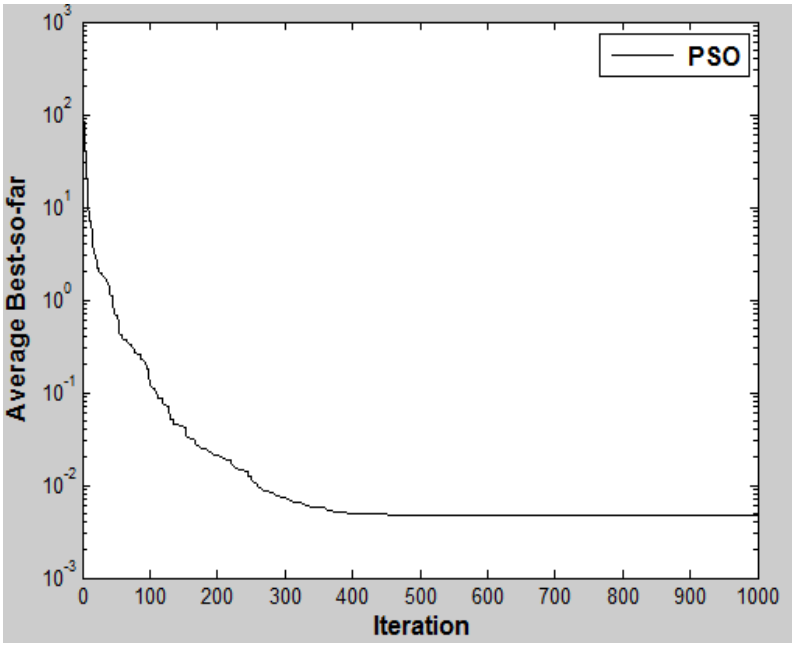

SPHERE

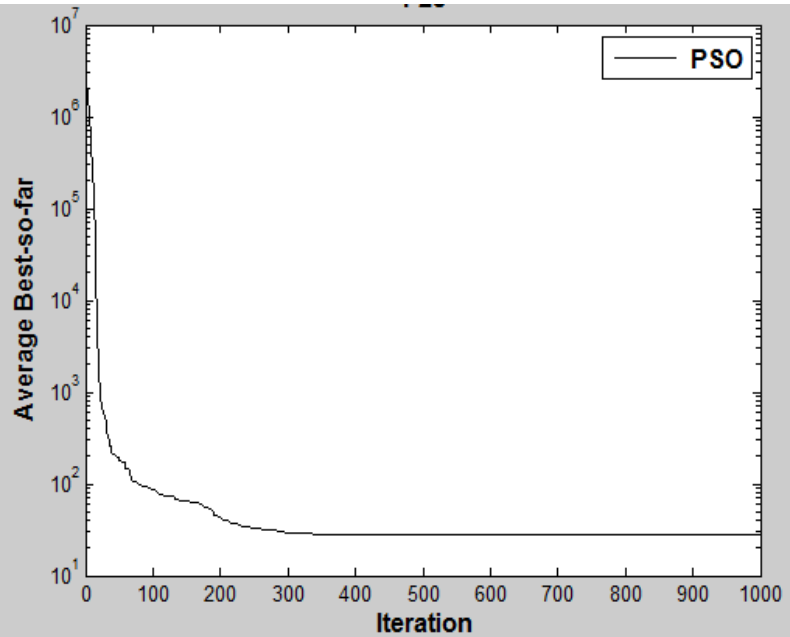

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Table 1- Optimal Value, Mean Best, Average Best Mean Values for ALC-PSO

Benchmark Function	Optimal Value	Mean Best	Average Mean Best
Ackley	3.7893	3.7893	3.7893
Griewangk	27.8034	27.8034	31.2050
Rosenbrock	27.9852	27.9852	27.9852
Schwefel	0.1658	0.1658	0.1658
Sphere	0.0048	0.0048	0.0048

3.1. Comparison of results using benchmark functions

In unimodal and multimodal functions:

1. It becomes easy for the leader to improve the swarm's quality and functionality. So , leading power of the leader can be easily adjusted.
2. The lifespan of leader can be easily adjusted according to the leading power of the leader.
3. Leader leads the swarm for a long time because it has got a large lifespan.
4. Searching in ALC-PSO is nearly same as for original PSO.
5. Fast converging is preserved in ALC-PSO as in the original PSO.

***On complex multimodal functions*:**

1. Once the situation of local optimum has been achieved, the further improvement in the swarm's quality cannot be done.
2. New particles challenge the old leader to replace them.
3. Diversity is achieved.
4. ALC-PSO can prevent the premature convergence and escape from the situation of local optima.
5. The fast converging factor of the original PSO is retained and it Prevents premature convergence .

On rotated and shifted functions- By rotating the functions, the dimensions of theses functions
become nonseparable, and thus the resulting problems become more difficult for a search algorithm to solve.

Results of implementing unimodal, multimodal and rotating benchmark functions in optimization problems can be compared as following:

	Unimodal functions	Multimodal functions	Shifting and rotating functions
Features	Easy to locate the global optimum	Difficult to locate the global optimum	- By rotating the functions, the dimensions of these functions become non-separable - the resulting problems become more difficult for a search algorithm to solve.

Table- Comparison of Benchmark functions

4. Conclusion and Future Scope

ALC-PSO (PSO with Aging Leader and Challengers) is a variant of PSO. Normally, PSO is applied on those behaviors, in which there's no leader to lead the population like: bird flocking and bee swarming, but in ALC-PSO, one of many members of the population is built to function as leader to lead the population and bring all of them to the best position in whole swarm. The aging mechanism is applied on the PSO, to ensure that some parameter be set to test the performance of the leader of swarm. In the event, the leader is insufficient to lead the swarm, a new leader is found which can efficiently bring the whole swarm toward a most useful position. The generation of challengers is done with a couple function evaluations. The challengers are evaluated and the best challenger is built to be the leader of the swarm, improving the best position in the swarm and thus, improving the performance of PSO algorithm. Benchmark functions are important in testing or evaluating any algorithm. These functions are well-suited to gauge a new algorithm, by comparing its efficiency with other algorithms and testing its validity using different parameters could be done. The facts in regards to the characteristics of these benchmark functions and some features like: search space, global optimum, optimal point, number of optimums etc are presented here. These properties are helpful in differentiating the benchmark functions from each other. The ALC-PSO algorithm could be tested for its performance by using several benchmark functions available. Here, five of the benchmark functions are used to provide the results. Many other available benchmark functions can be employed for testing the performance of the

ALC-PSO algorithm, to be able to have a lot more results for comparison and to have the improved and better ALC-PSO algorithm for solving the optimization problems.

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