ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 4, April 2015

Understanding the Aging Leader and Challengers Concept in PSO and its Applications

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Abstract: Aging is the process of getting older with the passage of time. It brings the physical, psychological and societal changes in every organism. Concept of aging leader and challengers is implanted in the particle swarm optimization i.e. ALC-PSO to prevent premature convergence in swarm by generating challenger particles when existing leader particle get trapped in local optima. Leader in ALC-PSO is the particle with the best position so far in the swarm and challengers are the set of candidates claiming to give the best optimal solution (i.e. better than the solution provided by the existing leader) in PSO to achieve leadership. In this paper, we have made an effort to understand the concept of ALC-PSO and its applications. It also presents a brief study about how ALC-PSO overcame shortcomings in standard PSO and lists further scope required in ALC-PSO.

Keywords: Aging, leader, particle swarm optimization, convergence, population.

I. INTRODUCTION

Particle swarm optimization is a population based stochastic optimization technique developed by Kennedy and Ebehart [1] which mimics social behavior like movement of organisms in a flock of bird or fish school. It is based on the concept of social influence and social learning.PSO utilizes a population of optimal solutions to explore the search space. Information exchange takes place between the individuals called particle of population called swarm [2]. Simplicity and ease of implementation has made PSO a popular area of research .It has wide range of applications such as fuzzy networks, power control, computer graphics, distribution, sensor and communication networks etc. PSO provides best solution for the hard problems and also used to solve real valued, binary and discrete problems. [3]

This paper is organized as following. Next section covers the brief description of particle swarm optimization and the concept of aging . This section is followed by the brief overview of the PSO with Aging leader and Challengers ie. ALC-PSO. Next section list various applications of ALC_PSO discovered so far . This section is followed by the various open issues in the field of ALC-PSO which gives direction for future research.

A. Particle swarm optimization

This heuristic population based method consists of a problem having a swarm of probable particles, and moving these particles around in the search-space as per velocity and position update rule. A population of particles randomly positioned in an n-dimensional search space is initialized in PSO. Every particle in the swarm maintains two vectors i.e. velocity vector and a position vector. During each generation, each particle adhere update rules to update its velocity and position by knowing from the particle's previous best position and the best position found by the entire swarm so far. Let v_i and x_i be the velocity and position vector respectively and M be no of particle in the search space or swarm. The update rules in the standard PSO are defined as

$$v_i^j \leftarrow v_i^j + c_1 .r_1^j .(pbest_i^j - x_i^j) + c_2 .r_2^j .(gbest_i^j - x_i^j) \quad (1)$$

$$x_i^j \leftarrow x_i^j + v_i^j \quad (2)$$

In eqn.1, pbest is the best position of a particle whereas gbest is the best position of the whole swarm.c_1 and c_2 are the two constants to measure relative performance of pbest and gbest. r_1^j and r_2^j are random numbers distributed in[0,1], and j(1<j<n) represents the j^{th} dimension of the search space.[4]

Comparison among particles is required for finding best position in the swarm. Convergence speed and global searching ability are the two dynamics for evaluating the functioning of PSO algorithms. Original PSO algorithm exhibits fast-converging behavior as gbest updates velocities and distance. But In multimodal problems, a best position confined to a local optima may take in the entire swarm leading to premature convergence .Many PSO variants developed to improve the performance of PSO achieve the preservation of swarm diversity at the cost of slow convergence . It is difficult to avoid premature convergence without worsening the speed of convergence and the simplicity of the structure of PSO.

B. Concept of aging

Aging is an inevitable process in nature which cannot be overlooked. Aging process is a necessity as it maintains equilibrium and diversity among species. It has been argued that aging is an important characteristic for evolution because it provides a mechanism to promote favorable properties of organisms and to increase the diversity of species. In a social animal gathering, Aging in organisms causes gradually increasing weakness, loss of mobility, and increased exposure to diseases and

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environmental conditions which may affect its competency in finding best solutions in swarm, providing opportunities for the other individuals claiming the leadership position. The one who provides the best solution in swarm is assigned leadership. This natural phenomenon associated with Aging provides the basis for particle swarm optimization with aging leader and challengers which was developed to address issues in particle swarm optimization like Premature aging, fast convergence, global search ability. The idea that aging is closely related to evolution has brought this concept into notice. [5]This selection is done using some parameters. There are two main parameters which are checked to select the new leader. These are: lifespan and performance.

a. Lifespan: Lifespan can be defined as the life time of the leader of a population that means for how long a leader can live actively in swarm. The lifespan of the leader can be elongated or shortened, according to its activity.
b. Performance: The performance of a leader is defined as its capability to lead a population. If a new particle tries to enter the population, its performance is compared with the performance of the leader. The one with better leading power capability is assigned as the new leader.

Different aging theories have been proposed from time to time which come under two classifications:
Classification 1: The two categories are: programmed theories and error theories.

- Programmed Theories state that the human body is intended to age and there is a certain biological timeline that our bodies follow.
- Error Theories state that aging is caused by environmental damage to our body's systems, which accumulates over time.
- Classification 2 : Two major theories explain the psychosocial aspects of aging in older adults
- Disengagement theory observe aging as a process of mutual retraction in which older ones voluntarily slow down by retiring and provide opportunity to young and active candidates.
- Activity theory sees a relationship between keeping active and aging well. It states that the aging does not implies that a person is inactive. .Individuals who led active lives as young adults will probably remain active as older adults, while those who were less active may become more disengaged as they age. Level of activity should not be completely related to aging process [5][6]

C. PSO with aging leader and challengers algorithm

ALC-PSO algorithm is introduced for solving problem of premature convergence in PSO and maintains fast converging features of PSO. ALC-PSO differentiates itself from the original PSO in such a way that the leader of the swarm ages within a limited lifespan. The lifespan of leader is adjusted according to the leader's leading power. When the lifespan is expired, the leader is challenged and replaced by newly generated particles with better leading power. In ALC-PSO velocity update formaula, gbest is replaced by particle with the best leading power i.e leader .The velocity and position update rules for ALC-PSO are given as follows:

$$v_i^j \leftarrow w.v_i^j + c_1 .r_1^j .(pbest_i^j - x_i^j) + c_2 .r_2^j .(Leader^j - x_i^j) \quad (3)$$

$$x_i^j \leftarrow x_i^j + v_i^j \quad (4)$$

w in the equation (3) is inertia weight whose large value leads to global search and smaller value leads to local search. value of inertia weight affect convergence. In ALC-PSO, as soon as the leader traps into local optima, new challengers are generated to claim leadership of swarm and lead the swarm towards best solution. On straightforward unimodal functions, it is normally simple for the leader to enhance the nature of the swarm and consequently the leader has solid driving force. For this situation, the leader has a longer lifespan to lead the swarm and the pursuit conduct of ALC-PSO is fundamentally the same to that of the original PSO. Subsequently, the fast converging feature of the PSO can be protected. whereas on complex multimodal functions, once the leader confines to local optima, it neglects to enhance the nature of the swarm and gets matured rapidly. For this situation, new challengers rise to supplant the old leader and bring in differences.

In terms of search speed , ALC –PSO is the quickest algorithm of all other PSO algorithms. ALC-PSO figures out how to get results with high precision on these multimodal functions regarding function evaluations and execution time. ALC-PSO performs better than the other enhanced PSO variations on unimodal functions.

The Steps involved in ALC-PSO is given as follows:
Step 1: Initialization: The initial positions of all particles are generated randomly within the n-dimensional search space. Velocities of particles are initialized to 0. The best particle among the swarm is chosen to be the Leader. The age of the leader is initialized to zero and the lifespan of the leader is set to an initial value 0.

Step 2: Velocity and Position Updating: Every particle follows the velocity update rule and the position update rule to adjust its velocity and position.

Step 3 : Updating leader: For particle i (i = 1, 2, . . ., M), if the newly generated position is better than Leader then the new generated particle becomes the new Leader of the particular population. If best position found in this iteration is better than the leader then leader is updated. In this way the Leader represents the best solution generated by particles during the leader's lifetime.

Step 4: Lifespan Control: After the positions of all particles are updated, the leading power of the Leader to improve the entire swarm is evaluated. The lifespan b is adjusted by a lifespan controller. When the leader has strong leading power the controller increases its lifespan

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ISSN (Print) 2319-5940

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.On the other hand if leading power of leader is poor, then controller decreases the lifespan of leader.

Step 5: Generating a Challenger: A newly generated particle with better position challenges the Leader whose lifespan is finished.

Step 6: Evaluating the Challenger: The leading power of the newly generated challenger is evaluated and compared with the leading power of existing leader . If the challenger has enough leading power, it replaces the old Leader and becomes the new Leader. Otherwise, the old Leader continues to be the leader of the swarm.

Step 7: Terminal Condition Check : Check whether the number of function evaluations exceed the maximum evaluations, if yes then terminate the algorithm else go to step 2 for another round of iteration.

II. APPLICATIONS OF ALC- PSO

ALC-PSO has reported better performance than standard PSO which encouraged the researchers to use this variant of PSO in different application .we have listed below the various applications of ALC-PSO developed so far :

1) ALC-PSO prevents premature convergence in single swarm as well as multi swarm while maintaining fast convergence behavior of PSO and results in swarm diversity .[7][8]
2) ALC-PSO executes the dual-task by effectively choosing the component values and also minimize the total design errors of low pass active filters.[9]
3) Harmony search based technique is applies to ALC-PSO to handle variable constraints which resulted in HALC-PSO that showed better convergence rate, lower computational cost and higher numerical stability.[10]
4) ALC-PSO set with flexible ac transmissions system finds its application in solving optimal power flow (OPF) problem. ALC-PSO performs way better as compared to other evolutionary computational algorithms[11]
5) Particle swarm optimization (PSO) with an aging leader and challengers (ALC-PSO) is applied to optimal reactive power dispatch (ORPD) problem which is a nonlinear constrained single-objective optimization problem where the power loss and the total voltage deviations needs to be done Independently.[12]

III. FUTURE SCOPE AND ISSUES IN ALC-PSO

Efforts have been made to overcome problem of premature convergence that occurred in PSO through ALC-PSO as discussed in previous section but still there is a lot of scope for further improvement leading to development of more efficient algorithm which has been discussed below :

1) ALC-PSO can be implemented in evolutionary computation techniques to analyze its effects on performance.
2) Additional Diversity is required in multi objective and dynamic optimization problems.
3) The effects of aging on the complex optimization problems can also be analyzed in future work.
4) In future, Efforts can be made to reduce the search time for selecting the leader of swarm.
5) Side constraints may get violated in ALC-PSO when a particle moves to a new position.
6) ALC-PSO may be applied in combinatorial problems where standard PSO has not been able to provide better result than other optimization algorithms.

IV. CONCLUSION

The motive of this paper is to give brief overview of the ALC-PSO and its applications so far which can be helpful for future research.PSO is stochastic system used to discover a best arrangement much quicker than the other improvement techniques. Straightforward idea and simple usage of PSO has made it mainstream among researchers. ALC-PSO was proposed to conquer the issue of premature convergence in standard PSO. ALC-PSO has gotten to be main stream among scientists of distinctive fields as it gives ideal execution over standard PSO. In future ALC-PSO can be used to replace standard PSO in certain applications to enhance the performance. This paper also envisages the work to be done and issues to be resolved in ALC-PSO in future.

ACKNOWLEDGMENT

I would like to thank my teachers, parents and my friends for all their support in this paper

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