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Analysis of Particle Swarm Optimization Algorithm

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Abstract

Particle swarm optimization is a heuristic global optimization method and also an optimization algorithm, which is based on swarm intelligence. It comes from the research on the bird and fish flock movement behavior. The algorithm is widely used and rapidly developed for its easy implementation and few particles required to be tuned. The main idea of the principle of PSO is presented; the advantages and the shortcomings are summarized. At last this paper presents some kinds of improved versions of PSO and research situation, and the future research issues are also given.

Keywords: Particle swarm optimization Algorithm, Swarm intelligence, Heuristic

1. Introduction

Particle swarm optimization is a heuristic global optimization method put forward originally by Doctor Kennedy and E berhart in 1995(Kennedy J,Eberhart R,1995;Eberhart R,Kennedy J,1995) It is developed from swarm intelligence and is based on the research of bird and fish flock movement behavior. While searching for food, the birds are either scattered or go together before they locate the place where they can find the food. While the birds are searching for food from one place to another, there is always a bird that can smell the food very well, that is, the bird is perceptible of the place where the food can be found, having the better food resource information. Because they are transmitting the information, especially the good information at any time while searching the food from one place to another, conduced by the good information, the birds will eventually flock to the place where food can be found. As far as particle swam optimization algorithm is concerned, solution swam is compared to the bird swarm, the birds' moving from one place to another is equal to the development of the solution swarm, good information is equal to the most optimist solution, and the food resource is equal to the most optimist solution during the whole course. The most optimist solution can be worked out in particle swarm optimization algorithm by the cooperation of each individual. The particle without quality and volume serves as each individual, and the simple behavioral pattern is regulated for each particle to show the complexity of the whole particle swarm. This algorithm can be used to work out the complex optimist problems.

Due to its many advantages including its simplicity and easy implementation, the algorithm can be used widely in the fields such as function optimization, the model classification, machine study, neutral network training, the signal procession, vague system control, automatic adaptation control and etc(Zheng Jianchao,Jie Jing,Cui Zhihua,2004,(In Chinese)).

2. Basic Particle Swarm Optimization Algorithm

In the basic particle swarm optimization algorithm, particle swarm consists of "n" particles, and the position of each particle stands for the potential solution in D-dimensional space. The particles change its condition according to the following three principles:

(1) to keep its inertia (2) to change the condition according to its most optimist position (3) to change the condition according to the swarm's most optimist position.

The position of each particle in the swarm is affected both by the most optimist position during its movement (individual experience) and the position of the most optimist particle in its surrounding (near experience). When the whole particle swarm is surrounding the particle, the most optimist position of the surrounding is equal to the one of the whole most optimist particle; this algorithm is called the whole PSO. If the narrow surrounding is used in the algorithm, this algorithm is called the partial PSO.

Each particle can be shown by its current speed and position, the most optimist position of each individual and the most optimist position of the surrounding. In the partial PSO, the speed and position of each particle change according the following equality (Shi Y,Eberhart R C,1998):

$$v_{id}^{k+1} = v_{id}^{k} + c_1 r_1^k \ (pbest_{id}^k - x_{id}^k) + c_2 r_2^k \ (gbest_d^k - x_{id}^k) \quad (1)$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \quad (2)$$

In this equality, v_{id}^{k} and x_{id}^{k} stand for separately the speed of the particle "i" at its "k" times and the d-dimension quantity of its position; $pbest_{id}^{k}$ represents the d-dimension quantity of the individual "i" at its most optimist position at its "k" times. $gbest_{d}^{k}$ is the d-dimension quantity of the swarm at its most optimist position. In order to avoid particle being far away from the searching space, the speed of the particle created at its each direction is confined between $-v_{dmax}$, and v_{dmax}. If the number of v_{dmax} is too big, the solution is far from the best, if the number of v_{dmax} is too small, the solution will be the local optimism; c1 and c2 represent the speeding figure, regulating the length when flying to the most particle of the whole swarm and to the most optimist individual particle. If the figure is too small, the particle is probably far away from the target field, if the figure is too big, the particle will maybe fly to the target field suddenly or fly beyond the target field. The proper figures for c1 and c2 can control the speed of the particle's flying and the solution will not be the partial optimism. Usually, c1 is equal to c2 and they are equal to 2; r1 and r2 represent random fiction, and 0-1 is a random number.

In local PSO, instead of persuading the optimist particle of the swarm, each particle will pursuit the optimist particle in its surrounding to regulate its speed and position. Formally, the formula for the speed and the position of the particle is completely identical to the one in the whole PSO.

3. An Analysis on the Advantages and Disadvantages of the Basic Particle Swarm Optimization Algorithm.

Advantages of the basic particle swarm optimization algorithm:

(1)PSO is based on the intelligence. It can be applied into both scientific research and engineering use.

(2)PSO have no overlapping and mutation calculation. The search can be carried out by the speed of the particle. During the development of several generations, only the most optimist particle can transmit information onto the other particles, and the speed of the researching is very fast.

(3)The calculation in PSO is very simple. Compared with the other developing calculations, it occupies the bigger optimization ability and it can be completed easily.

(4) PSO adopts the real number code, and it is decided directly by the solution. The number of the dimension is equal to the constant of the solution.

Disadvantages of the basic particle swarm optimization algorithm:

(1)The method easily suffers from the partial optimism, which causes the less exact at the regulation of its speed and the direction.

(2)The method can not work out the problems of scattering and optimization(Chen Yonggang,Yang Fengjie,Sun Jigui ,2006,(In Chinese)).

(3)The method can not work out the problems of non-coordinate system, such as the solution to the energy field and the moving rules of the particles in the energy field

4. The Present Research Situation of the Particle Swarm Optimization Algorithm

The PSO method is based on swarm intelligence. The research on it is just at the beginning. Far from the Genetic algorithm (GA) and the simulated annealing (SA) approach, the POS has no systematical calculation method and it has no definite mathematic foundation. At present, the method can only be used successfully in the aspect of Evolutionary neural network, and its other applications are still being explored. By the national documents on it, the research on PSO concerns mainly the mathematic foundation and application research. The mathematic foundation includes the mechanical principle of PSO itself, the prove of its convergence and Robustness and etc. In the publicly published documents, there are fewer documents about the study on its mathematic foundation, the prove on the convergence and the estimate of the speed of the convergence has not been found., which demands the research on the PSO should be perfected; The application research involves continuing its advantages, overcoming its shortcomings and developing its application ranges. The study on PSO should be concentrated on the following :some modern technologies should be applied to PSO to design the improved PSO; PSO can be combined with the other intelligent optimization methods to design several compound optimization methods; PSO can be also led into scattering system, compound optimist system, non-coordinate system to develop PSO's application ranges.

5. The Improvement of Particle Swarm Optimization Algorithm

5.1 Inertia weights

Inertia weights is put forward by Shi and others (Eberhart R C,Shi Y,1998; Eberhart R C,Shi Y,2000). An Inertia weight ω is a proportional agent that is related with the speed of last time, and the formula for the change of the speed is the following:

$$v_{id}^{k+1} = \omega v_{id}^{k} + c_1 r_1^{k} (pbest_{id}^{k} - x_{id}^{k}) + c_2 r_2^{k} (gbest_{d}^{k} - x_{id}^{k})$$

The influence that the last speed has on the current speed can be controlled by inertia weights. The bigger ω is, the bigger the PSO's searching ability for the whole is, and the smaller ω is, the bigger the PSO's searching ability for the partial. Generally, ω is equal to 1, so at the later period of the several generations, there is a lack of the searching ability for the partial. Experimental results show that PSO has the biggest speed of convergence when ω is between 0.8 and 1.2. While experimenting, ω is confined from 0.9 to 0.4 according to the linear decrease, which makes PSO search for the bigger space at the beginning and locate the position quickly where there is the most optimist solution. As ω is decreasing, the speed of the particle will also slow down to search for the delicate partial. The method quickens the speed of the convergence, and the function of the PSO is improved. When the problem that is to be solved is very complex, this method makes PSO's searching ability for the whole at the later period after several generation is not adequate, the most optimist solution can not be found, so the inertia weights can be used to work out the problem.

5.2 Increase Convergence Factor

A particle swarm optimization algorithm with convergence agents is introduced in paper (Clerc M,1999), and the following is the formula for its position and speed changing:

$$v_{id} = \chi \{v_{id} + c_1 \text{ rand}( )(p_{id}-x_{id})+c_2\text{rand}( )(p_{gd}-x_{id})\}$$

$$\chi = \frac{2}{|2-\varphi-\sqrt{\varphi^2-4\varphi}|}$$

is called the convergence factor, $\varphi = c_1+c_2 > 4$. Generally, φ is equal to 4.1, so χ is equal to 0.729. The experimental result shows compared with the particle swarm optimization algorithm with inertia weights, the convergence speed in the particle swarm optimization algorithm with the convergence agent is much quicker. In fact, when the proper ω, c_1 and c_2 is decided, the two calculation methods are identical. So, the particle swarm optimization algorithm with convergence agent can be regarded as a special example of the particle swarm optimization algorithm with inertia weights. Meanwhile, the properly selected parameters in the algorithms can improve the function of the methods.

5.3 Selection

The compound PSO put forward by Angeline is based on the basic mechanism and the selection mechanism created during the development of the computers (Angeline P J, 1999). Due to POS's depending on pbest and gbest during its searching, the area to be searched will be confined greatly. The introduction of the selection mechanism will solve the problem gradually. The test result shows although selection has better effect than basic PSO in the most tested functions, the result is less satisfying as far as the function "Griewank"is concerned. As a result, this method improve PSO's searching ability for the partial, meanwhile, it makes the searching for the whole area less powerful.

5.4 The Blending of the PSO Algorithm and the Other Intelligent Algorithms

The main process of the particle swarm optimization algorithm put forward by Gaoying based on depends on the main process of basic particle swarm optimization algorithm (Gao Ying,Xie Shengli ,2004). To introduce the simulated annealing (SA) approach, hybrid algorithm in the hybrid particle swarm optimization algorithm and mutation algorithm in the mutation particle swarm optimization algorithm are adapted to regulate further the optimized swarm. Angeline introduces the selection particle and the better particles selected after each generation is reproduced into the next generation to ensure the particle swarm has the better property. This algorithm has a better effect on the single peaks function. Higash(Higashi N,Iba H ,2003) and the other persons put forward their own mutation algorithms. By introducing the mutation particle, the algorithms escape the attraction of the optimized point in the partial area to improve the searching ability for the whole area. Inspired by the ants' behavioral pattern in their searching food, Italian Colorni and Dorigo(Colorni A,Dorigo M,Maniezzo V,et al,1991;Dorigo M,Maniezzo V,Colorni A,1996),ACO put forward originally Ant Colony Optimization, another kind of intelligent optimization algorithm. The algorithm is based on the research on the behavior of the ant colony's searching for food, and the algorithm simulates the virtual ant colony's cooperation. The behaviors of the several ants consist the routes of the solution together; the optimization can be achieved by leaving and exchanging information in the routes to find the more exact solution. Duan Haibin(Duan Haibin,2005, (In Chinese)) makes a further exploration into the ant colony's algorithm.

6. The Conclusion and the Future Research on PSO

Particle swam optimization is a new heuristic optimization method based on swarm intelligence. Compared with the other algorithms, the method is very simple, easily completed and it needs fewer parameters, which made it fully developed. However, the research on the PSO is still at the beginning, a lot of problems are to be resolved. The research on PSO will be mainly concentrated on the following:

(1)The math's basic theory of the Algorithm

Although PSO's application has been proved to be effective, its theoretical foundation is rather weak. Clerc and Kennedy(Clerc M,Kennedy J ,2002)make a analysis on the convergence of the method from the point of math's. By analyzing the stability of the condition transmitting matrix, they find the limited conditions where the particle can move stably. Based on this, Bergh makes the further analysis on it. Lebesgue and Borel explore the effect of casualty on the locus of the particle, and analyze the convergence from the point of measuring space.

Still, there is no mathematically proved about the convergence and the speed of the convergence. The most optimist solution of PSO can not be ensured in theory.

(2) Topology of the particle swarm

Research on the topology of the new pattern particle swarm which has a better function can be carried out. The neighboring topology of the different particle swarms are based on the imitation of the different societies. It is meaningful to the use and spread of the algorithm to select the proper topology to enable PSO have the best property and do the research on the suitable ranges of different topologies.

(3) The blending with the other intelligent optimization algorithm

Blending PSO with the other intelligent optimization algorithms means combining the advantages of the PSO with the advantages of the other intelligent optimization algorithms to create the compound algorithm that has practical value. For example, the particle swarm optimization algorithm can be improved by the simulated annealing(SA) approach ; It can be connected with the hereditary agents, the algorithm of a colony of ants, vague method and etc.

(4)Develop the application area of the Algorithm

The effect can be found out in the practical application. Although the PSO algorithm has been used widely, it will be very meaning to explore the developing area further. At present, the most research on PSO aim at the coordinate system. Although in practical usage, it is used in non-coordinate system, scattered system and compound optimization system, there is less research on the PSO algorithm application in these systems.

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