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Hybrid swarm intelligent parallel algorithm research based on multi-core clusters

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ABSTRACT

In order to solve poor fine searching capacity of artificial fish swarm algorithm and artificial bee colony swarm algorithm in late state to result in insufficient local optimization, hybrid swarm intelligent parallel algorithm research based on multi-core clusters is proposed; Then, reverse learning mechanism is introduced in early stage of algorithm, initialized swarms are evenly distributed, and swarms are randomly divided into two groups to make interactive learning strategy accelerates rate of convergence, and basic artificial fish swarm algorithm and artificial bee colony swarm algorithm are used to make global searching. In late stage of algorithm, niches artificial fish swarm algorithm and Random Perturbation Artificial Bee Colony are used to make local fine searching to the solution obtained in early stage; On this basis, MPI+OpenMP+STM parallel programming model based on multi-core clusters is established for parallel design and analysis. Finally, stimulation experiment indicates optimizing efficiency of this algorithm is higher than single artificial fish swarm algorithm and artificial bee colony swarm algorithm.

1. Introduction

Artificial Fish Swarm Algorithm (AFSA) [1,2,3,4] and Artificial Bee Colony Swarm Algorithm (ABC) [5,6,7,8], proposed in recent years, are two intelligent optimization algorithms based on animal commune swarm. Characterized by simple parameter settings and easy implementation, both algorithms have become the hot spot of research to date. LIU Ling-zi [9] proposes a hybrid optimization algorithm between the artificial fish swarm algorithm and the cultural algorithm that inserts artificial fish swarm algorithm into the framework of cultural algorithm to result in increment in artificial fish swarm diversity and improvement in calculation accuracy and rate of convergence; Y. Huang [10] and H. Ma [11] proposes artificial fish swarm algorithm for chaos searching, effectively compensating for existing shortcomings of artificial fish swarm algorithm to achieve better convergence and stability. DAI Dian-xin [12] applies the chaos searching idea into artificial bee colony swarm algorithm, at the same time, introduces evolutionary algorithm idea, and puts forward the hybrid artificial bee colony swarm algorithm. Although these improved algorithms promote optimizing efficacy to some extent, long running time, inaccurate searching later and other problems exist in algorithm for dealing with high-dimensional complicated function optimization. On this basis, we propose the hybrid swarm intelligent parallel algorithm based on multi-core clusters, giving full play to efficacy of clusters to realize optimizing rapidity and accuracy.

2. Related working

2.1. Research status of artificial fish swarm

The artificial fish swarm algorithm (AFSA) was firstly proposed by China's Dr. LI Xiaolei in 2003 in his doctoral thesis [1], this algorithm has fast convergence speed and strong robustness, able to quickly find the viable solution, and thus it is suitable for optimization problem with lower accuracy requirements. Since then, many researchers have conducted the studies mainly from the following five aspects: the first is the theoretical research on AFSA convergence, for example, the literature [13,14] used Markov Chain Theory and Stochastic Functional Theory to conduct the theoretical demonstration on AFSA convergence; the second is the improvement study on the parameters of this algorithm. The literature [15,16] improved the step size and congestion factor of this algorithm, while the literature [17,18] used the dynamic parameter adjustment improvement method to improve the solving ability and accuracy of this algorithm. The third is the intelligence

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algorithm fusion improvement study. The literature [19] generated new hybrid algorithm through the fusion of AFSA and other optimization algorithm. The fourth is the application of AFSA to solve the complex and practical problem. The literature [19] used AFSA to solve the combinatorial optimization problem and multiple knapsack problem. The fifth is the parallel solving for algorithm and its application, and the literature [20] accelerated the solving speed of complex problems.

2.2. Research status of artificial bee colony

In 1946, German biologist Frisch firstly deciphered the information contained in the dancing of bees after collecting the honey and coming back to the hive, thereof USA Seeley firstly proposed the self-organizing simulation model of bee colony. Subsequently, USA TEODOROVIC further proposed the bee colony optimization algorithm. In 2005 Turkey Karaboga proposed the more perfect artificial bee colony algorithm [5], and this algorithm has strong global convergence. Thereafter, the artificial bee colony algorithm has become a hot topic of research; the research content is mainly divided into five categories: The first category is the comparison with other optimization algorithms. For example: Karaboga and Basturk compared and evaluated the operating results of artificial bee colony algorithm, genetic algorithm, and particle swarm algorithm [21]. The second category is the improvement research on the modification of algorithm parameters. For example: the literature [22,23,24,25] improved the solving accuracy and convergence rate of artificial bee colony algorithm through the experimental study on the optimal settings of parameters, discrete of food source location, candidate food source generation by neighborhood moving method, adaptive changes of parameters, new location update formula defined by extrapolation techniques, perturbation factors and other methods. The third category is the fusion of artificial bee colony algorithm and other optimization algorithms, and the literature [26,27] respectively introduced the fusion of differential evolution algorithm and artificial bee colony algorithm, fusion of simulated annealing algorithm and artificial bee colony algorithm, and fusion of chaos operator and reverse learning operator and artificial bee colony algorithm, and designed new hybrid intelligence algorithm. The fourth category is the applied research. Karaboga *et al.* applied this algorithm to the study of optimization of multivariable function, integer programming and traveling salesman problems, and the literature [28,29] respectively applied this algorithm to robot path planning and UAV route planning, power system fuel costs, power loss and voltage stability optimization problems, aero engine PID controller parameter optimization, vehicle routing problem and location allocation problem of supply chain logistics network, which all achieved good application results. The fifth category is to establish the parallel algorithms of artificial bee colony on parallel platforms, and the literature [27,29] etc. conducted the parallelization of artificial bee colony based on the serial algorithm, so as to improve problem-solving speed.

2.3. Research status of parallel hybrid swarm intelligence algorithm

In the research of artificial bee colony and AFSA, a number of new hybrid swarm intelligence algorithms are established through the fusion of two swarm algorithms, or the parallel algorithm design is conducted in parallel environment to construct the parallel swarm intelligence algorithm. Study on fusion algorithm is mainly focused on the fusion of particle swarm algorithm and artificial bee colon algorithm, fusion of particle swarm algorithm and AFSA, fusion of simulated annealing and ant colony algorithm, and other serial algorithm studies [30,31,32]. The parallel algorithm design in parallel environment is mainly to study the parallel algorithms of a single cluster, such as: parallel artificial bee colony algorithm, artificial fish swarm parallel algorithm, and parallel particle swarm algorithm [33,34,35]. Through searching the SCI, EI, ISTP and other academic libraries and by Google, Yahoo, Baidu and other well-known search engines, we did not find any report on the fusion research results about the artificial bee colony and artificial fish swarm algorithms, nor the research results of parallel hybrid swarm intelligence algorithm based on multi-core cluster. Therefore, it is lack of research results on parallel hybrid swarm intelligence algorithm, thus our research on such subject has important practical significance.

2.4. Basic idea of artificial fish swarm algorithm

Individual state of artificial fish is expressed by $X=(x_1, x_2,\ldots, x_n)$. Where: x_i $(i=1, 2,\ldots,n)$ stands for pre-optimizing variable; $Y=f(x)$ shows food source concentration of current location of artificial fish, among which Y refers to objective function; distance between artificial fish individuals is expressed by $d_{ij}=\|x_i-x_j\|$; step length for each movement is expressed by *step*; visual range of artificial fish is denoted by *visual;* δ stands for congestion degree factor; the maximum repeated try number in foraging behavior is expressed by Try number. Take solving the maximum of multimodal function as an example to describe fish swarm behaviors as follows:

(1) Foraging Behavior
Current state of artificial fish is designed as x_i, and a state x_j is randomly selected within its field of view ($d_{ij} <$ visual). If food source concentration Y_j is more than Y_i (for the minimum, on the contrary), artificial fish moves one step towards x_i direction; If not, a state x_j is randomly re-selected. If repeated Try number does not satisfy forward conditions, randomly move one step.
(2) Swarm Behavior
Current state of artificial fish is set for x_i, partner quantity n_f and central position xc are searched within its field of view ($d_{ij} <$ visual). If $Y_c/n_f > \delta Y_i$,, it is demonstrated that many foods exist in the center of partners that are not too crowded, moving one step towards this position; If not, execute foraging behavior.
(3) Rear-end Behavior
Current state of artificial fish is designed as x_i, and food source concentration Y_j and the largest partner x_j are search within current neighboring field ($d_{ij} <$visual). If $Y_j/n_f > \delta Y_i$, it is shown that the state of artificial fish x_j is of higher food concentration δ and its adjacent fish is not too crowded, moving one step towards direction of x_j; If not, continuously implement foraging behavior.
(4) Behavior Selection
According to the nature of specific issues to be solved, artificial fish searches its current environmental conditions and makes evaluation. A proper behavior is selected from the above mentioned three behaviors to be implemented under a certain behavior selection strategy.

2.5. Basic idea of artificial bee colony swarm algorithm

Group of solutions is expressed by *SN* D-dimensional vectors, where the *i* solution is represented by x_i, $x_i = (x_{i1}, x_{i2},\ldots, x_{iD})$, $i=1,2,\ldots SN$. Food source pollen quantity corresponds to the mass of solution. Fitness is indicated by fit_1, fit_2,... fit_{SN}. If one food source is not updated after the maximum cycle number *limit* preset, guiding bee in this position abandons this food source, being a spy bee. Basic mechanism is described as follows:

(1) Initialized Food Source

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