Research on Parallel Optimization of Chaotic Ant Colony Algorithm

Chao-peng TAN
Guilin University of Technology Jiangan road No.12, Guilin, China

Keywords: Heterogeneous multicore, CAS, Parallel computing.

Abstract. According to the chaotic ant swarm algorithm (CAS) can improve the defects of the traditional ant colony algorithm (ACO) is easy to fall into local optimum, but extended the optimal time problem; parallel optimization of OpenMP/MPI hybrid parallel programming of heterogeneous CAS algorithm based on multi core platform, to ensure the effectiveness of the CAS algorithm at the same time, to improve the computational efficiency of CAS algorithm; CAS algorithm mixed parallel to shorten the running time, verify the rationality of the improvement.

Introduction

ACO algorithm is a hot group intelligence algorithm in recent years. It has positive feedback mechanism and heuristic search. It is easy to combine with other methods and has been applied in a wide range of fields. As a simulated evolutionary algorithm, the ACO algorithm has superior performance and great potential for development. However, the traditional ACO algorithm is based on probability theory. The evolution process takes a long time. Although there are certain mechanisms, it is still easy to fall into the local optimal. So far, the research on Optimization of ACO algorithm is mainly focused on the shortcomings of slow global convergence, easy to stagnation, and so on. M Mandloi combined with the ACO algorithm and particle swarm optimization algorithm, proposed a new search method to solve the premature convergence of ant colony algorithm. The optimization of the JA Lazz case s et al by use of chaos theory of swarm intelligence algorithm, verified the superiority of chaotic intelligent algorithm.

The CAS algorithm uses chaos theory to improve the ACO algorithm. It is a new swarm intelligence optimization algorithm, which can effectively avoid the prematurity of ACO algorithm. However, the characteristic of chaotic ergodicity is to extend the global convergence time of the algorithm. With the development of processors, multi-core processors begin to enter our field of vision. The trend of multicore is changing the face of computer industry. The stronger parallel processing power of multi-core processors has become a hot research topic. From the development trend of multi-core processors, heterogeneous multi-core systems have strong parallel development capabilities. With the progress of heterogeneous parallel technology, they are widely used in high-performance computing. In order to improve the search efficiency of CAS algorithm and give full play to the advantage of heterogeneous multicore processor, the research on parallel optimization of CAS algorithm suitable for heterogeneous multicore environment. The individual adjusts the structure with the path retained pheromone, and the group produces the optimal solution through mutual communication.

Optimization of CAS Algorithm

Basic ACO Algorithm Mechanism

First, The inspiration of ACO algorithm is from the observation of the complex social form of ant group organization. As a bionic algorithm, ACO algorithm has two parts: individual adjustment and group cooperation. The general ACO algorithm has the following basic assumptions.

(1) Each ant has a certain range of perception, and the way of communication is only through the pheromone and limited to the local environment.
The feeding rules of the internal model, the rules of movement, the rules of obstacle avoidance, etc. determine the response of each ant to the local environment.

The ant colony can form an orderly organization group as a whole.

**Introduction of CAS Algorithm**

Chaos is a universally existing phenomenon in nature. It has periodicity, but it is not a simple ordered disorder. It has its unique internal structure. It appears randomly, but contains a hidden ordered structure. It is an ordered mode hidden in disorder. Chaotic phenomena have rich spatiotemporal dynamics, between random and determination, and have the unique properties of periodicity, sensitivity and law. As a novel technology, chaos optimization is widely concerned. CAS algorithm based on chaos theory, the chaotic behavior of the individual ants intelligent organization behavior nature and the whole ant colony model, can avoid the search process into local optimum, solve all kinds of problems including adaptive; ergodicity of chaotic sequence in a certain range so that the search process from falling into local optimum, chaos is used to optimize the basic. The general chaotic search process is divided into two steps. One is based on the iterated traverse track, and the other is to find the optimal solution for the whole space. The two is based on the optimal solution of the first stage, adding disturbance factors to local search.

Every ant in nature is independent. The behavior of a single ant is chaotic. The traditional ACO optimization algorithm is based on probability theory, and its performance is lower than that of chaotic sequence. Therefore, the CAS algorithm, which combines the chaos theory with the ant colony algorithm, is proposed as a new intelligent optimization algorithm.

The study is limited to the real number space, and the optimal solution is searched in the $m$ dimensional real continuous space $\mathbb{R}^m$. Ant motion strategy:

$$z_{id}(t) = f(z_{id}(t), p_{id}(t), y_l)$$

$$z_{id}(t + 1)$$ said the ant, $d$ dimensional variable moment, $d \in \{1, 2, \ldots, m\}$.

$f$ is a nonlinear function that reacts the chaotic mapping relation.

$p_{id}$ represents the best location for the $i$ ant and its adjacent ants at the time of $t$.

$y_l(t + 1)$ is the time state of the organization variable.

The mathematical model of the CAS algorithm is as follows:

$$
\begin{align*}
\psi_1 & = y_l(t - 1) (1 + r) \\
\psi_2 & = y_l(t - 2) d \cdot y_l(t - 1) (1 - 2 \psi_1 y_l(t - 1) + (\psi_1 y_l(t - 1) + 1) e^{-2\psi_1 y_l(t - 1) + b})
\end{align*}
$$

$\psi_1$ and $\psi_2$ for the two most important parameters in the model, and then affect the consumption time of the convergence speed of $\eta_t$ effect, $\psi_3$ effect of PSI search, and the search range is more negative. $\psi_2$ is larger, the search scope is small, should be selected according to the specific problems.

**Optimization Design of CAS Algorithm**

The CAS algorithm uses chaotic map to make chaotic disturbance, so that the basic ant colony algorithm can get out of the local optimum. Before designing the parallel CAS algorithm, we will optimize the corresponding algorithm to avoid disturbance. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar.

Optimizations of pheromone updating rules for learning strategy. The motion link of ant colony search is based on the information behind the ants. Under the positive feedback mechanism of ant colony, pheromone intensity greatly influences the path selection and convergence speed of ant colony. Therefore, the pheromone optimization of the CAS algorithm is carried out. Specific implementation is set up for learning strategy, each ant has a certain learning probability $p_l$. We will randomly select two ants to compare, and select better to update pheromone. The learning probability assignment is:
Optimization based on search bounds: The search scope of the basic CAS algorithm for positive and negative range, taking into account the optimal solution will not be fully concentrated to the same interval, you can set the search range of \([-\omega_d \cdot 1/2, 1/2 \omega_d]\), that can get a formula through calculation.

\[ p_{t+1} = 0.04 + 0.5 \times \left( \frac{e^{0.5 \times (1 - t)}}{e^{0.5} - 1} \right) \]  

Finally, a new CAS algorithm model is established.

\[
\omega_d = \frac{\theta}{q_d} 
\]

CAS parallel Optimization

Hybrid Parallel Programming Model

Using OpenMP/MPI hybrid parallel programming model, As shown in Figure1. OpenMP is a multi processor system suitable for shared memory in the hardware layer. It is a set of API in a multi - core processor architecture. It can realize parallelization between multithreading based on thread library. It is flexible and adaptable. It can efficiently utilize multi-core CPU for parallel computing, and provide high-level and abstract concurrent design. MPI messaging user interface standard is currently a widely distributed architecture system programming mode on parallel computers. All the parallel machines launched nowadays support messaging system. The message delivery system is universal, easy to expand, and the system's hardware and software requirements are not high, but the overhead is large. MPI provides an accessible call interface in a heterogeneous environment with good portability and scalability.

![Figure 1. OpenMP/MPI hybrid parallel programming model.](image)

The OpenMP/MPI hybrid parallel programming model is suitable for the current development trend of the processor, shared memory and distributed integration of heterogeneous multi-core architectures. Using shared memory model to save memory and improve programming efficiency. it combines the easy to use and extensible performance of distributed storage model. OpenMP/MPI hybrid programming, using the main process communication, circular parallel mode. Using large and medium granularity parallel in the MPI layer, transforming high level programs into multiple explicit MPI tasks. Using fine grained parallelism in the OpenMP layer, the sequence code contains the OpenMP instruction.
Parallel Optimization Process

Based on the optimization of CAS algorithm based on hybrid programming, the node uses the MPI, the multi core in the node uses OpenMP, and uses block synchronization programming. The MPI is used to improve the parallelization of the serial program in the CS algorithm, and the program is divided into each node, and the corresponding operation is carried out. The data parallel strategy of OpenMP is guided by for/parallel for, which can parallelize the most time-consuming cycle iteration, cyclic assignment and tabu list updating in CAS system. In order to improve the computing efficiency of the CAS algorithm, the information transfer link optimizes the MPI communication function, and the OpenMP mode is used in the node. Parallel implementation process description:

(1) Optimization program design of CAS algorithm.
(2) Using shared storage threads in nodes, block synchronization.
(3) Improved parallelization of cyclic statements such as program iteration and pheromone updating.
(4) Program partition outside the node and assigned to different nodes.
(5) Transfer the parallel library to modify the corresponding parallel parts in the serial program.
(6) A cycle program that optimizes the communication function and the time complexity is close.
(7) Parallel program error correction debugging and completion design.

Experimental Results and Analysis

In order to verify the effectiveness of the improved CAS algorithm, the comparison test of the ACO algorithm and the CAS algorithm is carried out. First, the number of ants is 20, the maximum number of iterations is 1000 times, and the number of set tests is 50 times, and the average value of the 50 times is calculated to reduce the random error. This experiment is based on a heterogeneous multi-core platform, in which the number of MPI nodes is 2, and the number of OpenMP threads is set to 4. Parameters: \( \beta_1 = 0.1 \), \( \alpha = 500 \), \( b = 0.5 \), \( (y(x) = 0.8, \theta = 0.00001, \gamma + 0.01 \) etc. The final result of the experiment is shown in Table 1. It needs to be explained that in OpenMP/MPI hybrid parallel programming belongs to thread level parallel design, its basic execution unit is still thread in every node, and the number of threads is not enough. When the number of threads is the same as the number of CPU, the highest efficiency is the highest. The thread settings of OpenMP will conflict with the process settings of MPI, resulting in thread competition. Here we set up multi thread execution in OpenMP, and reduce MPI multi process settings, so as to ensure the smooth operation of the program.

|             | Average running time(s) | average value | variance   |
|-------------|-------------------------|---------------|------------|
| iteration 200 |                         |               |            |
| ACO         | 1.41                    | 5.6079 × 10^-3 | 1.953 × 10^-3 |
| CAS         | 1.19                    | 4.7524 × 10^-2 | 1.776 × 10^-3 |
| iteration 500 |                         |               |            |
| ACO         | 2.66                    | 4.3414 × 10^-2 | 1.1236 × 10^-2 |
| CAS         | 2.14                    | 3.3815 × 10^-2 | 4.5337 × 10^-3 |
| iteration 1000 |                        |               |            |
| ACO         | 4.30                    | 4.3467 × 10^-3 | 6.0963 × 10^-4 |
| CAS         | 2.05                    | 3.2262 × 10^-2 | 7.9315 × 10^-3 |

Can be seen from the table, the CAS scheduling algorithm improved all search time is more less than the ACO algorithm, this is mainly because of the improved CAS algorithm to search neighbors, while using heterogeneous multi-core processing powerful parallel computing ability, thread library to achieve multi thread scheduling based on flexibility, adaptability, provides a task Abstract high
level scheduling, heterogeneous multi-core processor advantage play. In the test in the table, the improved CAS algorithm has a better average target function value and variance.

![Figure 2. Three algorithm execution time comparison.](image)

The improved CAS algorithm is compared with the general ACO algorithm and the widely used GA algorithm. In the experiment, the total number of iterations on the 4 core processor is 300 times, and the result of the test is shown in Figure 2. In order to not lose the general, the three algorithms have no special optimization, so the overall execution time is slightly higher. It can be seen that the GA algorithm is more stable than the ACO algorithm and the execution time is less. The improved CAS algorithm is more stable than GA algorithm and has less execution time. The improved CAS algorithm has more advantages.

Acknowledgement

According to the characteristics of heterogeneous multi-core, natural parallel ACO algorithm combined with chaos theory is adopted to improve the learning strategy of ant colony algorithm and search the boundary to carry out hybrid parallel programming under OpenMP/MPI model. It makes full use of the parallel execution of heterogeneous multi-core, accelerates the advantages of computing, and improves the CAS algorithm. The experiment shows that the improved CAS algorithm has better average value and variance and faster execution time than the ACO algorithm. Finally, the comparison and analysis of the task processing with the mature GA algorithm proves that the CAS algorithm has a better data processing efficiency.

References

[1] JA Lazzús, M Rivera, CH López-Caraballo. Parameter estimation of Lorenz chaotic system using a hybrid swarm intelligence algorithm [J]. Physics Letters A, 2016, 380(11-12):1164-1171.
[2] M Mandloi, V Bhatia. A low-complexity hybrid algorithm based on particle swarm and ant colony optimization for large-MIMO detection [J]. Physics Letters A, 2016, 50(C):66-74.
[3] M Mandloi, V Bhatia. Efficient parallel optimization of volume meshes on heterogeneous computing systems [J]. Engineering with Computers, 2017(33):717-726.
[4] JC Sprott, S Jafari, VT Pham. A chaotic system with a single unstable node [J]. Physics Letters A, 2015, 379(36):2030-2036.
[5] Thammawichai M, Kerrigan E C. Energy-efficient real-time scheduling for two-type heterogeneous multiprocessors[J]. Real-Time Systems, 2016:1-34.

[6] Xiaoyun Xia, Yuren Zhou. Research Progress of Ant Colony Optimization Algorithm[J]. Journal of Intelligent Systems, 2016, 11(1):27-36.