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The Application Research of Improved Bat Algorithm Based on Chaos for job shop scheduling

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Abstract: An improved bat algorithm is proposed for solving the job shop scheduling problem. Firstly, introduce the characteristic of job shop scheduling problem, Then, we use the advantage of chaos method and combine the simulated annealing algorithm to improve the bat algorithm, and the end, We do a lot of experiments and evaluate the performance of the improved bat algorithm. Compared with the standard bat algorithm, the superiority of the improved bat algorithm is verified.

1. Introduction

The job flow shop scheduling problem has been widely studied in the recent decades. An flow shop system consists of *m* machines in a serial layout where a set of n jobs has to go through first machine one, then machine two, and so on until machine m. That is, all the jobs have identical routes. Each job requires an operation with uninterrupted processing time on each of the machines. Each job can be preceded at most one machine at the same time. The processing of a job on a machine cannot be interrupted. All jobs are independent and are available for processing at time 0; and etc. The aim is to find a sequence for processing all jobs on all machines so that the given criterion is minimized. Although the process constraint of the model is relatively simple, but it has proven more than 3 machine of permutation flow shop scheduling problem is NP problem[1].

More attention has been paid on applying intelligent bionic algorithm to solve the job flow shop scheduling problem in recently decades. Evolutionary algorithms such as simulated annealing algorithm [2], ant colony algorithm [3], PSO algorithm[4] and etc. Evolutionary algorithm can improve the population size and the number of iterations to improve accuracy, the solving time is proportional to iterative times, time efficiency decreased obviously.Some scholars, which based on the simulation the behavior of swarm intelligence, presented for solving combinatorial optimization problems, Such as genetic algorithms, particle swarm optimization, ant colony algorithm, swarm algorithm and this paper will discuss the simulation of plant growth algorithm. These intelligent algorithms have been widely used in many areas, also include job shop production scheduling problem [5-7].

2. Job shop scheduling problem

Job shop scheduling problem studies the flow process of n work pieces on m machines. If the scheduling objective is the maximum completion time, the case of Permutation flow shop scheduling problem mathematics is described as follows: *n* represents the number of jobs, *m* represents the machine number, *prmu* shows that all the workpiece after each machine processing consistency, C_{max} represents the maximum completion time of the work pieces, t_{ij} denotes the processing time of workpiece *i* on machine *j*, $C(j_i, k)$ represents the completion time of workpiece j_i on machine *k*, π represents a sort of all jobs, *T* is collection of all sort. Assume that the workpieces are processed according to machine 1 to m , then the completion time of *n* work pieces on *m* machines can be obtained by formula(1) to formula(5) .

$$c(j_1,1)=t_{j_1,i} \quad (1)$$

$$c(j_i,1)=c(j_{i-1},1)+t_{j_i,i}\ i=2....n \quad (2)$$

$$c(j_1,k)=c(j_1,k-1)+t_{j_1,k}\ k=2....m \quad (3)$$

$$c(j_i,k)=\max\{c(j_i,k-1),c(j_{i-1},k)\}+t_{j_i,k}\ i=2...n,k=2....m \quad (4)$$

$$c_{\max}(\pi)=c(j_n,m) \quad (5)$$

$$\pi'=\arg\{c_{\max}(\pi)=c(j_n,m)\}\to\min,\forall\pi\in T \quad (6)$$

Which formula (5) is the maximum completion time, formula (6) represents the corresponding scheduling scheme of minimize the maximum completion time.

3. The improved Bat Algorithm

3.1 Genetic Algorithm

The bat algorithm (BA)[8] is a new heuristic algorithm [9], it is proposed by XinShe Yang in *2010*. Yang illustrates the basic idea of this algorithm and puts forward the basic assumption of the bat algorithm:

1) All bats use their echolocation perception and the distance of the target, they identify the target and the different of the background obstacles in a mysterious way.

2) The location of bats are x_i, flying with the speed of v_i, they search target at a fixed frequency f, variable wavelength λ and loudness A_i. They can determine the distance between himself and the prey and adjust the pulse wavelength (frequency) automatically, at the same time, when they close to the target, they adjust the pulse frequency $f_i \in [0,1]$.

3) There are a lot of changes in loudness, the assumption it is from the maximum value of A_{max} changes to the fixed minimum value of A_{min}.

In this article, the fitness function's design concept is weight sum conflict type which exists in each chromosome, If one of chromosomes violate rule i, its value will be set to 1 P_i, the conflict which exists to the chromosome carries on the weighting to *sum* and to add on 1, then make reciprocal, the chromosome sufficiency function value is bigger, its next-generation evolution of the probability of survival is larger.

Selecting operation is used to simulate the phenomenon of natural selection in biosphere. It selects a high fitness chromosome from the old population, and put into the matching set, and prepare to chromosome crossover and mutation operation to generate a new population. Higher fitness chromosomes are selected more possibly. We choose a method of local selection method, its truncation selection method.

We introduce four chaotic sequences which independent of each other in the algorithms. Records as: T_{kl}, T_{k2}, T_{k3}, T_{k4}. In theory, we use the chaotic sequence, present in random distribution characteristics in short-term (adjacent several value), and the whole sequence is in the (0, 1) with no interval repeat ergodic sequence. This kind of short term random characteristics helps population present individual diversity in the short term, avoid the local optimum, and the chaos ergodicity may overcome "repeatability" and "blindness" possible in the simple random operation, thus, can further ensure the multiplicity of the chromosome, avoid premature convergence and unnecessary repeat search and improve the search efficiency.

4. The experiment results and discuss

In order to explain the performance of the proposed algorithm, the numerical examples used in this paper are generated by random method. Examples are 10 Liao benchmark problems [9]. Each example contains 5 stages. The number of parallel machines in each phase is distributed between 3 and 5. The range of the workpiece processing time is [1, 1000]. On this basis, the assumption that all the machines are not always available,they may have a failure, the failure of the machine will be immediately repaired, where the time of machine failure and repair spent are subject to normal

distribution. In the experiment, there are 5 failures in the setting of the machine, and the mean value of fault time is 200, 400, 600, 800 and 1000 respectively. The mean value of the time used in the repair is 20 and the variance is 5. Run environment of algorithm is MATLAB (R2010b) under Win7 operating system. Under two situations of the algorithm in preempt-resume (case 1) and preempt-repeat (case 2) solving results respectively as shown in Table 1 and 2.

Table 1 Comparison results on benchmark problems of Casel

Problem	PSO			RKGA			BA			IBA		
	AVE	MIN	SD	AVE	MIN	SD	AVE	MIN	SD	AVE	MIN	SD
j30c5el	511.7	507	2.4	513.0	505	3.9	508.9	505	1.4	502.6	499	1.3
j30c5e2	670.3	670	0.4	670.5	670	0.8	669.6	669	0.0	669.4	668	0.0
j30c5e3	663.6	657	3.7	667.5	655	7.5	659.3	654	1.6	653.5	649	1.3
j30c5e4	631.3	628	2.1	630.7	626	3.1	629.0	626	1.1	622.0	619	0.9
j30c5e5	668.5	666	1.7	671.7	666	4.5	662.5	661	0.3	662.1	660	0.2
j30c5e6	675.4	670	3.3	679.0	670	5.6	669.0	664	2.4	663.1	659	2.0
j30c5e7	686.1	684	1.8	686.0	683	2.5	683.3	681	0.8	680.5	679	0.2
j30c5e8	737.9	732	3.2	738.3	731	5.1	734.0	730	1.7	729.0	727	0.9
j30c5e9	708.8	705	2.0	709.8	703	5.1	705.1	701	1.5	699.0	696	1.0
j30c5el0	650.5	641	5.3	648.8	636	7.2	642.2	636	2.1	634.0	629	1.3
Average	660.4	656	2.6	661.5	655	4.5	656.3	653	1.3	651.7	649	0.9

Table 2 Comparison results on benchmark problems of Case2

Problem	PSO			RKGA			BA			IBA		
	AVE	MIN	SD	AVE	MIN	SD	AVE	MIN	SD	AVE	MIN	SD
j30c5el	561.6	557	5.1	562.1	555	8.7	559.5	553	2.3	552.2	547	2.4
j30c5e2	720.0	701	4.4	723.8	701	7.8	716.2	700	3.1	700.0	695	2.2
j30c5e3	747.5	739	6.0	748.6	735	6.2	742.9	735	4.4	722.8	710	4.0
j30c5e4	702.2	696	7.5	701.3	694	8.1	697.4	687	5.8	685.0	672	5.5
j30c5e5	733.7	726	8.7	734.1	726	13.5	731.4	725	5.8	724.8	707	3.3
j30c5e6	737.1	730	3.6	737.0	720	6.0	730.6	717	3.0	717.7	706	8.4
j30c5e7	752.2	745	4.3	751.8	743	6.9	747.8	740	3.7	731.6	721	4.2
j30c5e8	836.7	802	10.4	839.2	792	14.9	826.3	789	9.4	786.3	769	6.4
j30c5e9	799.4	791	6.8	800.2	789	15.4	793.5	787	5.7	766.4	758	4.5
j30c5el0	748.9	740	3.2	746.2	715	11.6	738.0	711	9.1	718.1	708	8.3
Average	733.9	723	6.0	734.4	717	9.9	728.4	713	5.3	710.5	699	4.9

From the test data can be seen, for the selected Liao problems, the improved bat algorithm has good optimization performance in the field of combinatorial optimization, and it is an effective tool for solving the permutation flow shop scheduling problem.

5. Conclusions

This paper proposes an improve bat algorithm, the improve bat algorithm is applied to solve the job shop scheduling problem, the performance has been improved obviously, the improvement is more obvious. Experiments show that: The algorithm is effective and robust, it is feasible and effective for solving the job shop scheduling problem. It shows a good application prospect in production scheduling field.

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