

Research and Applications of Shop Scheduling Based on Genetic Algorithms

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ABSTRACT

Shop Scheduling is an important factor affecting the efficiency of production, efficient scheduling method and a research and application for optimization technology play an important role for manufacturing enterprises to improve production efficiency, reduce production costs and many other aspects. Existing studies have shown that improved genetic algorithm has solved the limitations that existed in the genetic algorithm, the objective function is able to meet customers' needs for shop scheduling, and the future research should focus on the combination of genetic algorithm with other optimized algorithms. In this paper, in order to overcome the shortcomings of early convergence of genetic algorithm and resolve local minimization problem in search process, aiming at mixed flow shop scheduling problem, an improved cyclic search genetic algorithm is put forward, and chromosome coding method and corresponding operation are given. The operation has the nature of inheriting the optimal individual of the previous generation and is able to avoid the emergence of local minimum, and cyclic and crossover operation and mutation operation can enhance the diversity of the population and then quickly get the optimal individual, and the effectiveness of the algorithm is validated. Experimental results show that the improved algorithm can well avoid the emergency of local minimum and is rapid in convergence.

Key words: shop scheduling, genetic algorithm, local minimization, cyclic search

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INTRODUCTION

Depending on the complexity of the research object, shop scheduling problem can be divided into single machine scheduling, parallel machine scheduling, flow shop scheduling and job shop scheduling, job shop scheduling problem is a typical problem and also is one of the most difficult combination optimization problem [1]. In the past decade, scholars from various countries studied extensively on shop scheduling problem, and with further research, the technologies used are more and more sophisticated and complex. Because the scheduling problem involves too many factors, there is no one method can comprehensively and effectively solve the shop scheduling problem, these methods are only effective for a particular or simple scheduling situation. Theoretically, genetic algorithm itself is a very good robust technology that can solve the above defects and problems and get results of shop scheduling problems. The main disadvantage of genetic algorithm is that it can not guaranteed to always get the optimal solution, but with the constant optimization of genetic structure and algorithm, its effectiveness is improving, and the disadvantage now seems not so obvious [3-4]. Task of scheduling is to choose the optimal scheduling, so that in the large scale production process with

large amount of scheduling of workpiece, because of its implicit parallelism of genetic algorithm that it can effectively converge to the target solution and it has certain advantages in a certain scale of scheduling problems [5].

This paper mainly studies the improved genetic algorithm of a kind of cyclic search applied in shop scheduling problem, the crossover operation and mutation operation can have cyclic search in population. The article uses TF (6x6) and LA1 (10x5) standard shop scheduling model to verify the validity of the algorithm [6-7] [10]. Through verification, it can be drawn that improved cyclic search genetic algorithm has the characteristics of quick convergence and prevent from local optimum solution.

GENETIC ALGORITHM PROBLEMS

Genetic algorithm flowchart

In this paper, the major feature of improved genetic algorithm is the use of cyclic search process. And for the objective function of genetic algorithm is used to minimize the completion time of shop scheduling problem. The entire cyclic search process of genetic algorithm is shown in Figure 1, and the genetic algorithm adopted a variety of improved methods.

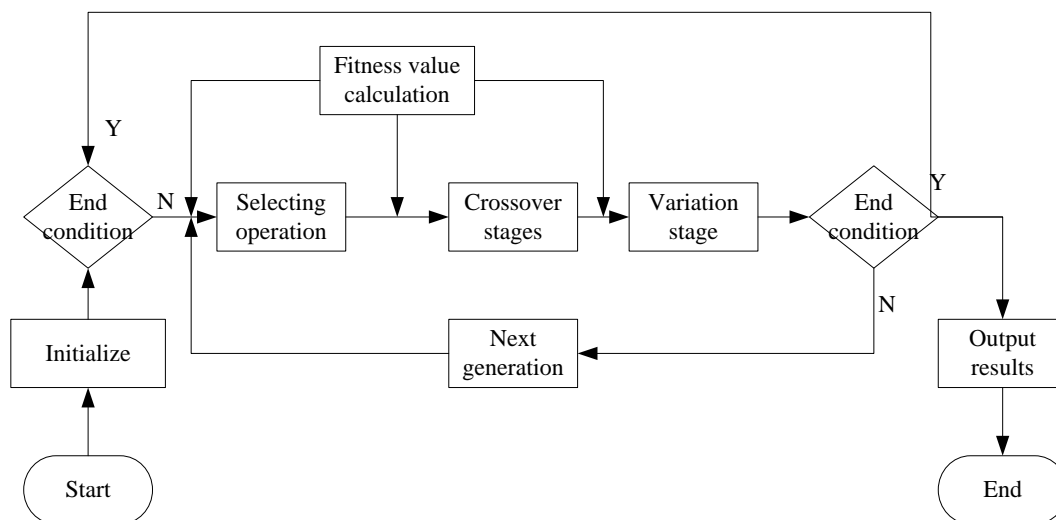


Figure 1 - The flow chart of genetic algorithm

In this paper, the improved genetic algorithm can be divided into selecting operation, crossover stage and mutation stage three sections, and each stage includes Optimal strategy so that the optimal solution of current population will not be lost in

searching process. Before crossover operation, this figure set an initial value so that the genetic algorithm will not in an infinite loop forever. Since the crossover operation is a cyclic search process, the loop termination condition is set when the crossover operation finds better individuals than

its parent or when the number of cycles is equal to the initial value, the search stops. The optimization and improvement of crossover operation enables the genetic algorithm quickly finds the optimal solution.

Chromosome design

For genetic algorithm, a chromosomal gene represents the problem faced by the genetic algorithm. Currently, for shop scheduling problem most algorithms used notation such direct

Chromosome	2	1	1	3	1	2	3	2	3
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Figure 2- The structure of Chromosome

In this 3 x 3 encoding, one chromosome is made up of nine genes. In this chromosome, 1 represents the first workpiece 1, 2 represents the workpiece 2, 3 represents the workpiece 3; each gene has a priority, and the priority of genes on the left are higher than the genes on the right. In other words, each gene starts to schedule from the left.

GENETIC MANIPULATION

Crossover operation

In order to enhance the effectiveness of cyclic algorithm, crossover operation retaining the characteristics of the current population while generating new individuals. There are many cross methods such as: multiple point crossover, uniform crossover, partial uniform crossover, order crossover, periodic crossover, and so on. In the algorithms partial exchanging crossover operation has been modified, which can be summarized as follows:

The following symbols indicate specific meanings: PA and PB represent the parent chromosome; CA and CB represent child chromosome; Point and NextPoint represent two cross points; BlackA and BlackB represent partial chromosome in PA and PB;

(1) Randomly generates a value between 5 and Length-10 as the length of cross block, in which



Figure 3 - Select cross point and crossblack

encoding [8-9]. And this direct encoding takes operation sequence as a kind of scheduling, in which each gene represents an operation. This encoding is characterized by whatever order it exchanges; it will generate an effective sequencing scheduling [8]. For a scheduling problem with n workpieces and m machines, each chromosome has n x m genes that will appear m times in each chromosome, and each time represents a unique operation. A coding with 3 x 3 shop scheduling problem is shown in Figure 2.

Length represent the length of the entire chromosome, and the value is the length of partial scheduling in exchanging between the parent individuals;

(2) Randomly select a position in parent individual PA, the second position will be equal to the value of the first position plus the crossblack length generated before. Therefore crossblack crossBlackB is generated by the gene chosen between the two positions;

(3) Repeat the previous operation of parent individual PB to generate crossBlackB, but in this process, the selected position of the parent individual PB should be different from the position of parent individual PA, if the location is same, crossover operation would be meaningless;

(4) Respectively find out the same genes as crossBlackB and crossBlackA in child individual PA and PB, and these same genes are set to 0;

(5) Respectively transfer genes with value of 0 to the headmost of the individuals;

(6) Exchange genes with value of 0 in CA and CB with crossBlackA and crossBlackB.

The Select cross point and crossblack is shown as Figure 3. The delete exceeded genes is shown as Figure 4. The child chromosome CA and CB is shown as Figure 5.

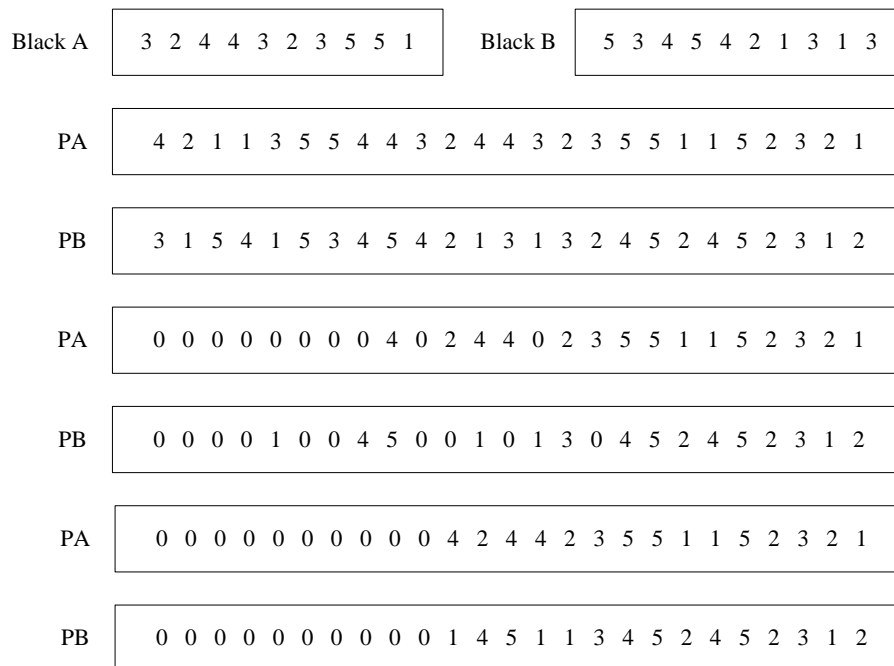


Figure 4 Delete exceeded genes

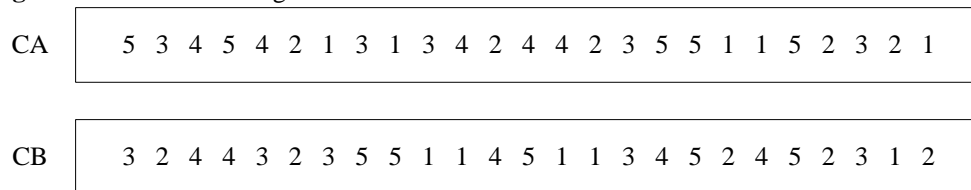


Figure 5 Child chromosome CA and CB

Mutation operation

When the child generated after crossover operation no longer evolving and do not reach the optimal solution, it means algorithm converges too early, namely precocity. The origin of precocity is in the lack of effective gene, but mutation operation can overcome this situation to a certain extent, and increase the diversity of the population. The basic content of mutation operator is to change the gene value in some gene locus of individual strings in population. Mutation operation of genetic algorithm is by using the method of transformation namely to firstly randomly select genes in individuals, and then to reverse the order of these genes as in Figure 2.4. However, if the exchanged genes are the last two, individuals generated by mutation operation will be the same as its parent.

To avoid this situation, in mutation operation set the number of selected gene blocks are more than two. Implementation of mutation operation is as follows:

- (1) Randomly select a value between 3 and Length-1 as variation length, wherein Length represents the length of chromosomes.
- (2) Randomly select a position in parent individuals, the second position will be equal to the value of the first position plus the previous selected value, so variation block is made up of the genes between these two variation blocks.
- (3) Change the order of the genes in variation block to generate new gene block, by this gene block replace new gene block in step 2. The new chromosome M1 is the child chromosome. The mutation operation is shown as Figure 6.

PA	4 2 1 1 3 5 5 4 4	3 2 4 4 3 2 3 5 5 1	1 5 2 3 2 1
M1	4 2 1 1 3 5 5 4 4	1 5 5 3 2 3 4 4 2 3	1 5 2 3 2 1

Figure 6 -mutation operation

CYCLIC SEARCH GENETIC MANIPULATION

Cyclic crossover search

The main purpose of this stage is to find a good solution for the area between the two parents, relying on space search technology to complete the search process of the area, the relationship between the searching area and the parent individuals should be linear relation^[9]. The stage will be able to find an area and have thorough search. As to global search, if it is possible, it is better to search in the region between two parent individuals. Until the adaptation value of an individual is larger than the one of the worst individual in population is found, it will meet the termination condition. The latest search individual will become the latest child of the next generation, in this process it is possible to control the search area, and the worst individual will be retained as the others, so that a parent can get out the restriction of local minimum.

The process of cyclic crossover search is based on the basic optimization of crossover operation; the entire process is summarized as follows:

- (1) Select the optimal individual in current population as the child;
- (2) Randomly select two individuals in the population, and operate the two individuals as in step (3) - (5);
- (3) Randomly select two cross points, generating two sub individuals with crossover operation;
- (4) If the optimal individuals generated by the crossover operation is worse than the worst individual in current population, or the times of repeating search are smaller than the initial values, go to step (3) to continue the search;
- (5) Select the optimal individual produced in (4) as child individual;
- (6) When the number of child individual is equal to the number of setting population, the algorithm will stop searching.

Cyclic mutation search

The common mutation operation only provides a random element to search, using mutation individual to substitute parent individual and its adaptation value. But it is difficult to reflect features of shop scheduling by only using mutation operation, so this paper studies a method that can make the search process develop toward a good direction, in this method only if the adaptation value of generated mutation individual is higher than parent individual, it will replace parent individual.

The process of cyclic mutation search is based on the basic optimization of mutation operation; the entire process is summarized as follows:

- (1) Select the optimal individual in current population as the individual of next generation;
- (2) Randomly select individuals to operate (3) - (5);
- (3) Generate a mutation individual with mutation operation;
- (4) When the adaptation value of generated mutation individual is smaller than the one of parent or the times of cyclic search are smaller than the initial value, go to (3) to continue the search;
- (5) Select the optimal individual generated in operation (4);
- (6) When the individual number of the next generation is equal to the population number, the algorithm will stop searching.

EXPERIMENTAL RESEARCH AND DATA

Apply this algorithm to the benchmark issues of FT06 and LA01 to verify the validity of it^[10], as shown in Table 1 and Table 2. Parameters of this algorithm are shown in Table 3, which are obtained after repeated tests, and each test uses these parameters. The results are shown in Table 4 below.

Table 1 Example of FT06

workpiece number	processing sequence number, machine number, processing time					
1	1,3,1	2,1,3	3,2,6	4,4,7	5,6,3	6,5,6
2	1,2,8	2,3,5	3,5,10	4,6,10	5,1,10	6,4,4
3	1,3,5	2,4,4	3,6,8	4,1,9	5,2,1	6,5,7
4	1,2,5	2,1,5	3,3,5	4,4,3	5,5,8	6,6,9
5	1,3,9	2,2,3	3,5,5	4,6,4	5,1,3	6,4,1
6	1,2,3	2,4,3	3,6,9	4,1,10	5,5,4	6,3,1

Table 2 Example of LA01

workpiece number	processing sequence number, machine number, processing time					
1	1,2,21	2,1,53	3,5,95	4,4,55	5,3,34	
2	1,1,21	2,4,52	3,5,16	4,3,26	5,2,71	
3	1,4,39	3,5,98	3,2,42	4,3,31	5,1,12	
4	1,2,77	2,1,55	3,5,79	4,3,66	5,4,77	
5	1,1,83	2,4,34	3,3,64	4,2,19	5,5,37	
6	1,2,54	2,3,43	3,5,79	4,1,92	5,4,62	
7	1,4,69	2,5,77	3,2,87	4,3,87	5,1,93	
8	1,3,38	2,1,60	3,2,41	4,4,24	5,5,83	
9	1,4,17	2,2,49	3,5,25	4,1,44	5,3,98	
10	1,5,77	2,4,79	3,3,43	4,2,	5,1,96	

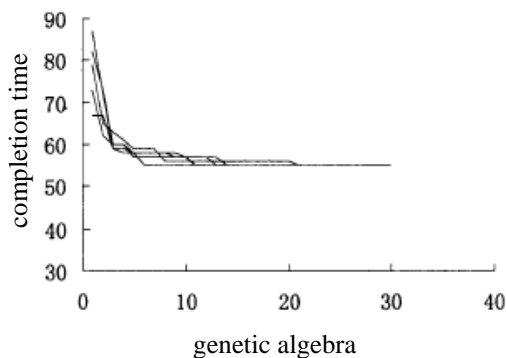
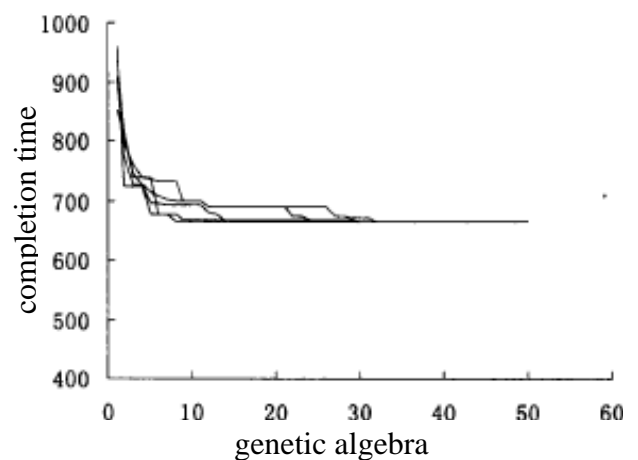
Table 3 Parameters of Genetic Algorithm

issue	population	algebra	crossover probability(%)	variation probability(%)	crossing number	variance
FT(6*6)	20	30	80	20	15	5
LAI(10*5)	50	50	80	20	30	10

Table 4 Results of Experiment

issue	optimal results	mean time(s)	test time
FT(6*6)	55	12	5
LAI(10*5)	666	56	5

As can be seen from Figure 7 and Figure 8, the genetic algorithm proposed in this paper has good convergence and rapidity.

**Figure 7** Convergent curve of genetic algorithm for FT(6X6)**Figure 8** Convergent curve of genetic algorithm for LA1(10x5)

ALGORITHM COMPARISON

To further verify the effectiveness and practicality of this algorithm, this paper compares the improved genetic algorithm with the general genetic algorithm, using problem of MT (6x6). As can be seen from Figure 9, compared with the general genetic algorithm, the improved genetic algorithm uses shorter completion time, and the child optimization need less algebra, so the genetic algorithm has the characteristics of fast search speed and uniform convergence curve.

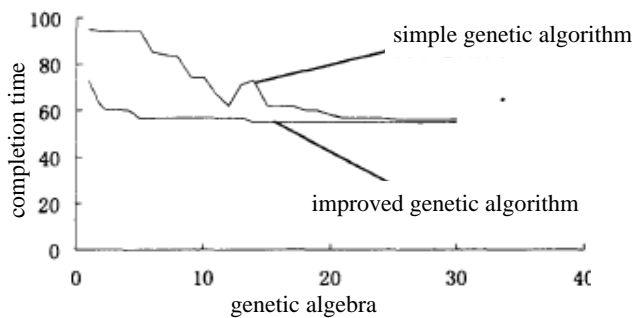


Figure 9 - Compare of Convergent curve

CONCLUSION

So far a lot of genetic algorithms can not solve shop scheduling problem very well, so this paper proposes an improved genetic algorithm to solve the local minimization problem in searching process, the operation of this genetic algorithm has the property of inheriting the optimal individual of a parent generation and can avoid the emergence of local minimum, and the cyclic crossover operation and cyclic mutation operation can enhance the diversity of the population and then get the optimal individual quickly. The results and data show that the improved algorithm can well avoid the emergence of local minimum, overcome the defects of uneven convergence, and converge rapidly. In this shop scheduling problem, the time parameters are assumed to be fixed, but this assumption is established only in the case of totally automatic operation. Therefore, taking the influence of human factors into account, the assumption of shop scheduling problem is difficult to set up. But with the development of technology, it is believed that the automatic unattended operation will be realized in the future, so this method still has a very broad application prospects. In future study, the time parameters should be assumed to be uncertain, which will be closer to the actual situation in order that the shop

scheduling both can be fully automatic and can add manual operation.

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