

Solving Flexible Job Shop Scheduling Problem based on Improved Genetic Algorithm

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1. Introduction

In the process of globalization of market, the production methods of enterprises are characterized by multiple varieties and small batches, which make the products that processed by enterprises become more varied and smaller in scale. Faced with the challenges brought about by the transformation of traditional production methods, to ensure the normal production activities of enterprises, it is more important to optimize the limited resources of enterprises. The problem of shop scheduling optimization is to allocate available resources to multiple production tasks systematically, to accomplish certain production goals. The classic job shop scheduling can no longer solve the problems which brought by the transformation of the manufacturing industry's manufacturing methods, flexible job shop scheduling problem (FJSP) will be developed on the basis of the classic job-shop scheduling problem (JSP). In the actual factory workshop, flexible job shop scheduling has more practical value, it takes into account both machine selection and process sequencing issues. Through flexible job shop scheduling optimization, companies can maintain continuous production stability, and produce more varieties and quantities of products in a unit of time. At the same time, the quality of the product can also be guaranteed.

Flexible job shop scheduling problem is a much more complex NP-hard problem, more difficult to solve, it is impossible to find the exact optimal solution for the problem. After 1990s, with the rapid development of computer science, optimization technology and other disciplines, researchers use heuristic algorithms to solve flexible job shop scheduling problems. The application of Genetic Algorithm in Flexible Job Shop Scheduling Problems Domestic and foreign scholars has done a lot of research and got a lot of scientific research results. For example, Ishikawa S [1] designed a hierarchical mixed-space genetic algorithm, using genetic algorithms in two layers of space of machine and process; S.K. Zhao [2] designed a algorithm which combined genetic algorithm and variable neighborhood search, shortening the maximum completion time of the flexible job shop scheduling problem by improving the use efficiency of the machine; X.R. Wang, B.Z Li [3] proposed an ant colony-genetic



hybrid algorithm, firstly, ant colony algorithm is used to solve the problem of machining path selection, then solving the classic job shop scheduling problem by used genetic algorithm; Q. Liu, C.Y. Zhang [4] designed an initial population generation method ,crossover operator and mutation operator, then proposed a process which based coding method and a decoding method that can generate active scheduling; L. Tao, Z.H. Yan [5] considered that the genetic algorithm has a stronger global search ability and the ant colony algorithm has a better feedback mechanism, a hybrid algorithm is designed, several sets of optimization solutions generated by genetic algorithm are used as the initial pheromone of ant colony algorithm, the convergence speed is improved and the local solution is avoided; Z.Y. Yu, Y. Yuan, X.J Li [6] proposed a method of initial population generation, the quality of the population is improved under the premise of ensuring the initial population diversity.

2. Organization of the Text

2.1. Mathematical model of flexible job shop scheduling problem.

In 1990, Bucker and Schlie proposed that the job-shop scheduling problem, each process of the job could be processed on different machines, this was the first time that the flexible job shop scheduling problem was proposed. Flexible job shop scheduling problem can be described as n workpieces are processed on m machine, there are several processes for each workpiece, process order has been determined according to process requirements, each process can be processed or unprocessed on a certain number of machines by a certain process. The purpose of scheduling optimization is to arrange a machine for processing reasonably for each process and determine the starting time for all the processes assigned to each machine, make the function of the whole system close to or reach the optimal state.

The following assumptions are needed when the flexible job shop scheduling problem is solved:

- (1)The processing of the previous process of the same job can only be processed in the next process;
- (2)A working procedure of the job cannot stop until it is processed;
- (3)There is no restriction between the processes of different jobs;
- (4)A machine can only handle one process at the same time;
- (5)All jobs have the same priority;
- (6)At the same time, it does not take into account the effect of random factors such as mechanical failure.

For the actual job workshop operating needs, minimizing the maximum completion time as a scheduling optimization target, Its objective function is

$$\text{Min } C_{\max} = \min \{ \max C_i, i=1, 2, 3, \dots, n \} \quad (1)$$

S. t.

$$\begin{cases} E_{ijk} - E_{i(j-1)m} \geq m_{ijk} \\ E_{egk} - E_{ijk} \geq m_{egk} \\ E_{ijk} \geq m_{ijk} \end{cases} \quad (2)$$

In the formula: i represents the number of job; j indicates the number of process; C_i is the completion time of the job J_i ; m_{ijk} is the processing time of the process j of job i on the machine k; E_{ijk} is the completion time of the process j of job i on the machine k.

Table 1. The schedule of processing task machines and processing time

Job	Process	M_1	M_2	M_3	M_4	M_5	M_6
J_1	O_{11}	2	3	4	—	6	—
	O_{12}	—	3	—	2	4	—
J_2	O_{21}	4	3	1	—	—	6
	O_{22}	3	—	5	4	2	11
J_3	O_{31}	2	4	—	3	5	—
	O_{32}	—	—	9	—	13	12

Flexible job shop scheduling problem can be divided into partial flexible job shop scheduling problem and full flexible job shop scheduling problem according to machine flexibility. As shown in Table 1: The "—" in the table indicates that the corresponding work process is not allowed to be processed on the machine, at this point, the example in the table is partial the flexible job shop scheduling problem. In contrast, the completely flexible job shop scheduling problem relieves the machine selection.

2.2. Genetic Algorithm Design.

1960s, Professor John Holland of the Michigan State University, his colleagues and students designed an artificial system for the optimization of complex systems—Genetic Algorithm through the simulation of the biological genetic evolution mechanism widely existing in the natural world,, it uses selection, crossover, mutation and other operations to simulate biological reproduction, mating and gene mutation widely existing in biological natural evolution, the genes on chromosomes are used to find good chromosomes to solve some problems.

(1) Chromosome coding and decoding

Flexible job shop scheduling needs to solve two problems: the problem of which machine to process on each process; the time problem of starting the processing machine after all processes are determined. This paper uses the chromosome encoding method of literature [8], a chromosome consists of a process sequencing part and a machine selection part. Two parts of chromosomes form a solution to the problem of scheduling optimization together.

Take Table 1 as an example, figure 1 shows a scheduling solution, the first part is process chromosome, the latter part is the machine chromosome, and the length of each part of the chromosome is equal to the total number of processes. So the total length of a chromosome is 12, 2 times the total number of 6. The gene of the process chromosome is [3 2 2 1 3 1]: two of "1" represent the two processes of the job J_1 , the first "1" represents the first process O_{11} of the job J_1 , the second "1" represents the second process O_{12} of the job J_1 and so on. The processing sequence of each job is O_{31} — O_{21} — O_{22} — O_{11} — O_{32} — O_{12} ; the gene of the machine chromosome is [4 1 2 5 3 2]; it represents the processing machine of various processes of the job, the corresponding process is O_{11} , O_{12} , O_{21} , O_{22} , O_{31} , O_{32} . From table 1, it is known that process O_{11} can be processed by machine M_1 , M_2 , M_3 , M_5 respectively, and the gene "4" in the machine chromosome represents process O_{11} to select the fourth machine M_5 to process. Empathy, the process O_{12} can be processed by machine M_2 , M_4 , M_5 respectively, and the gene "1" in the machine chromosome represents process O_{12} to select the first machine M_2 to process. In addition, the insertion greedy decoding method mentioned in literature [9] is used directly in this paper.

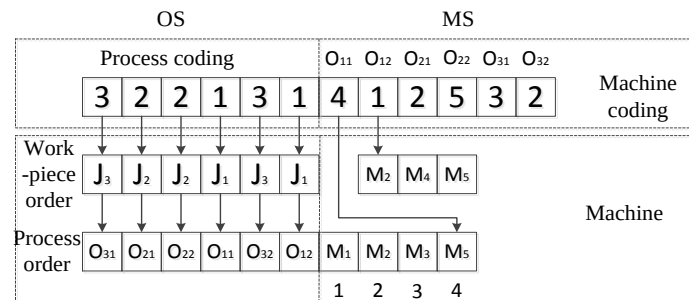


Figure 1.FJSP chromosome coding

(2) Fitness function and selection operation

Fitness function is used to evaluate the quality of individual chromosomes, the greater fitness value of the individual, and the higher probability of inheritance to offspring. On the contrary, the smaller individual's fitness value, the lower probability of inheritance to offspring. The optimization objective function of the flexible job shop scheduling problem is minimizing the maximum completion time ($C_{\max}$), so the formula of fitness function is

$$f_n = a / (C_{\max} - b) \quad (3)$$

In the formula: $C_{\max}$ is the maximum completion time for each individual, a and b are constants.

The choice of operation is to inherit the individuals with high fitness value to the offspring; its role is to prevent the loss of effective genes. At the same time, high-quality chromosomal genes are more likely to be passed on to offspring, so as to improve the global convergence and operation efficiency. This paper adopts the method of Roulette, the random number $\text{rand} [0, 1]$ is generated when the selection operation is executed, If the random number is satisfies

$$\sum_{i=1}^{i-1} f_i / \sum_{i=1}^N f_i < \text{rand} [0, 1] \leq \sum_{i=1}^i f_i / \sum_{i=1}^N f_i \quad (4)$$

Select the individual i to keep to the offspring.

(3) Crossover operation

The crossover operation can preserve the better quality genes in the population, at the same time; good individuals can be produced by crossover and recombination of genes, making the genetic algorithm have better global search ability.

Crossover operation of process sequencing section: First, the set of jobs are randomly divided into two subsets G_1 and G_2 ; Then ,copy the subset G_1 contained in the parent P_1 to the same location in the offspring C_1 , copy the subset G_2 contained in the parent P_2 to the same location in the offspring C_2 ; Finally, the subset G_1 contained in the parent P_1 are filled to the vacant positions in the offspring C_2 , the subset G_2 contained in the parent P_2 is filled to the vacant position in the offspring C_1 , and the gene sequence is unchanged.

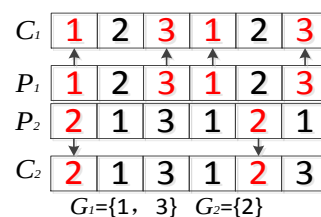


Figure 2.Crossover operation based on process coding

Crossover operation of machine selection section: First, two genes in the machine's chromosome are randomly selected; then, the chromosomal genes of the parent P1, P2 in corresponding positions are exchanged, the order of other machines remains the same, and the entire crossover operation are completed eventually.

(4) Variation operation

In this paper, a simple and effective method of chromosome mutation is designed, the mutation operation is divided into two steps: First, two genes are selected randomly from the chromosomes that determine the order of processing for each procedure and are swapped for position, due to the process of chromosome coding can ensure that the mutation will not produce an invalid solution; Then, determining the exchange of those two steps, according to the principle that the less processing time, the greater probability of the in optional machining machine centralization can be selected, selecting the processing machine to replace the original processing machine. And the selected machine cannot be the same as the original processing machine.

(5) Genetic algorithm flow

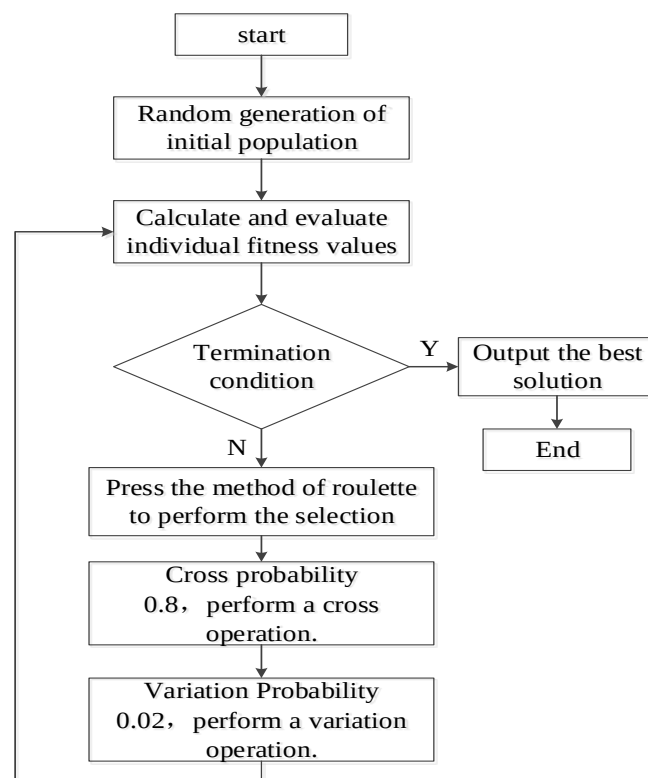


Figure 3.Genetic algorithm flowchart

2.3. Example verification and result analysis.

The genetic algorithm was designed by the MATLAB language to write the running code in this paper, the specific parameters of genetic algorithm settings: Initial population size $NIND=200$, Maximum iteration number $MAXGEN=100$, crossover probability $P_c=0.8$, variation probability $P_m=0.02$. In order to verify the effectiveness of the proposed algorithm in this paper, example data of flexible job shop scheduling problem with literature [7], literature [8] and literature [9] was tested.

From the comparison of the operation results of Table 2, we can see that three test cases have achieved good test results when solving the maximum C_{max} objective function. The objective function value obtained from this paper is equal to or better than the optimal solution obtained from other literatures. For example, when solving 4 x 6 problems: Compared with the literature [9], the average

convergence time has been greatly improved in the case of the maximum completion of the same situation, but it still needs to be improved compared with the literature [8]. When solving 6 x 6 problems: Compared with the literature [11], the maximum completion time is reduced by 2 units of time; Compared with the literature [12], the maximum completion time is reduced by 4 units of time, the average convergence time has a certain improvement at the same time. When solving 6 x 10 problems: Compared with the literature [7], In the case of the same maximum completion time, there are other aspects need to improve; Compared with the standard GA, the best value, worst value, and average maximum completion time are yielded much better results.

Table 2. Comparison of operation results

$n \times m$		Literature			Improved Genetic Algorithm			
		C_{best}	C_{worst}	$Av(t/s)$	C_{best}	C_{worst}	$C_{average}$	$Av(t/s)$
4×6	[8]	17	17	10.43	17	20	18.3	9.17
	[10]	17	17.2	24.4				
6×6	[11]	39	—	32	37	42	38.9	16.40
	[9]	41	—	43				
6×10	[7]	45	51	$C_{average}$ 47.8	45	53	47.6	24.23
	GA	50	54	$C_{average}$ 51.2				

Figure 4,6,8 represent that Gantt graph for optimal solution of 4 x 6 case problems, 6 x 6 case problems, 6 x 10 case problems. The three digit number “***” represents the process of the work piece in the Gantt chart. For example, “101” represents the first process O_{11} of the job J_1 , “201” represents the first process O_{21} of the job J_2 , “302” represents the second process O_{32} of the job J_3 . Figures 5, 7 and 9 show the population mean and solution changes of the optimal solution of the three example problems respectively.

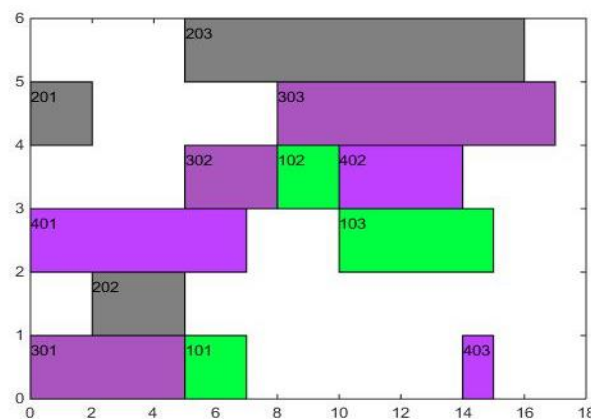


Figure 4. The solution of 4x6($C_{max}=17$)

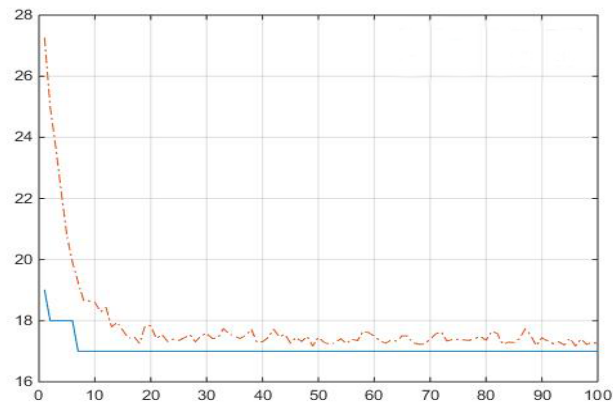


Figure 5. The opulation mean and optimal solution change of 4x6

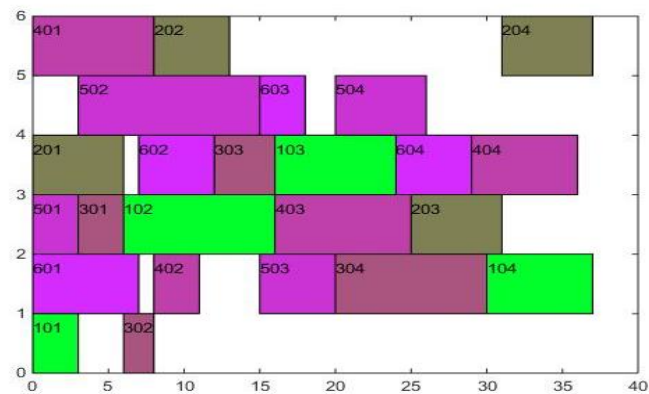


Figure 6. The solution of 6x6($C_{max}=37$)

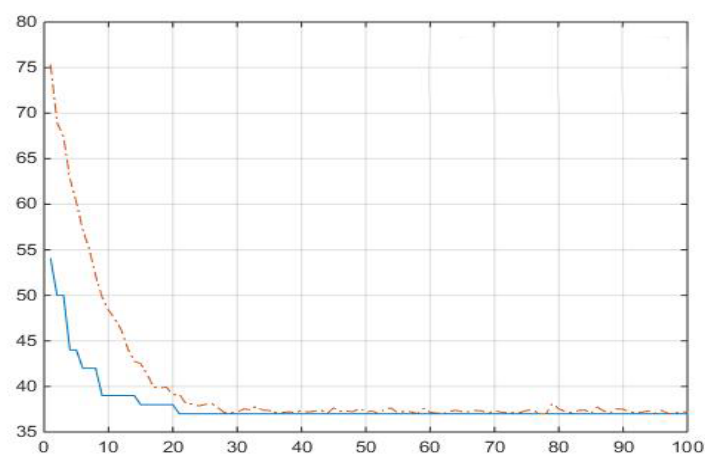


Figure 7. The opulation mean and optimal solution change of 6x6

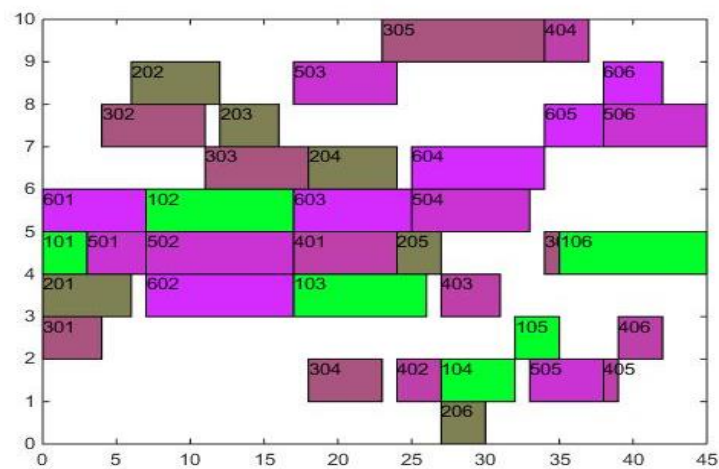


Figure 8. The solution of 6x10($C_{max}=45$)

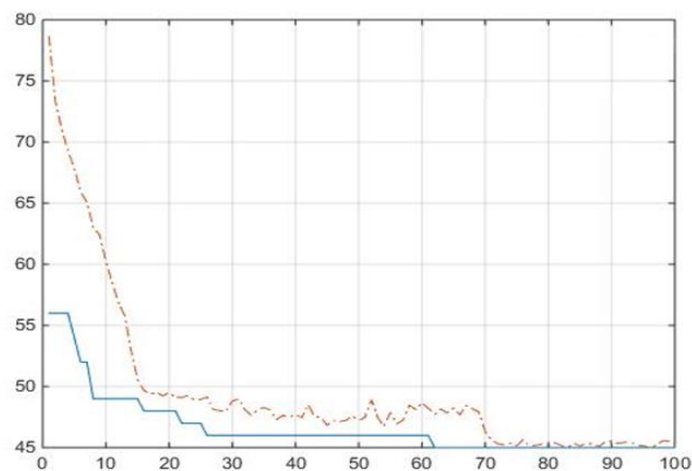


Figure 9. The population mean and optimal solution change of 6x10

3. Conclusion

In this paper, an improved genetic algorithm is designed to solve the problem of flexible job shop scheduling. In the design of genetic algorithm, chromosome coding is based on the workpiece processes and machining machines. In addition, a simple and effective mutation method is also designed. Under the premise of guaranteeing the correct operation result, the calculation speed of the algorithm is improved. Finally, examples simulation are used by MATLAB R2014b and compare with relevant examples' data, the effectiveness of the algorithm is verified.

Acknowledgments

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