Coordinated scheduling technology of multi-level relevance resources based on improved genetic algorithm

Zhibing Lu[1a], Aimin Wang[1b]*, Chengtong tang[1c]

[1]School of Mechanical Engineering, Beijing Institute of Technology, Beijing100081, China

[a]halzb88@163.com, [b]wangam@bit.edu.cn, [c]tangcht@bit.edu.cn

Key words: Multi-level relevance resources, Genetic Algorithm, Job-shop scheduling, Dynamic resources combination, Coordinated scheduling constraint

Abstract. In the actual process of production, there is a practical situation that multi-level relevance resources such as operators, machines, fixtures and cutters participate in the job-shop operation. Different from traditional production scheduling which focuses on machines, this scheduling problem add constraints among operators, fixtures and cutters. This paper presents a new method based on improved genetic algorithm(GA) for multi-level relevance resources coordinated scheduling. This method consists mainly of two parts: (1) dynamic combination for multi-level relevance resources based on improved GA, which meets the matching relationship between multi-level relevance resources and selects the best combination of multi-level relevance resources through fitness calculation. (2) scheduling time calculation for multi-level relevance resources processes(MRRP) is proposed, which according to the processes occupancy of multi-level relevance resources, and used for finding the earliest available time span to insert MRRP. Finally, the results have demonstrated the effectiveness of the method with practical example.

Introduction

Job-Shop Scheduling is a typical NP problem, and mainly focuses on the ability of manufacturing resources. The major resource constraints of traditional production scheduling are machines. But in the actual process of production scheduling, there is a different situation that multi-level relevance resources such as operators, machines, fixtures and cutters participate in the scheduling process. The MRRP can begin machining only when the selected resources are all available. This problem raises new technical challenges of job scheduling.

The deepening development of refining workshop production puts forward stricter control requirement for manufacturing resources such as operators, machines, fixtures and cutters. There is a complex relationship between operators, machines, fixtures and cutters:

(1) The processing method sets optional range of operators, machines, fixtures and cutters for the MRRP;

(2) There is a many to many matching relationship between operators and machines, that an operator can operate several machines and one machine may be operated by more than one operator;

(3) There is also a many to many matching relationship between fixtures, cutters and machines.

Over the years, several people have done the research of multi-level relevance resources scheduling. Aiming at the scheduling problem of multiple devices collaborative processing, Qi Yonghong[1] proposes to split one process into multiple virtual processes. Ding Lei[2] raises a tobacco wrapping job scheduling algorithm based on dynamic combination of manufacturing resources. Wang Feng[3] studies the problem of Job shop scheduling based on combination of machines, creates a mathematical model, and gives the solving methods based on Ant Colony

Algorithm. R. Mencia[4] trys to solve The Job Shop Scheduling Problem (JSSP) with operators based on GA considering makespan minimization.

Aiming at the coordinated scheduling of multi-level relevance resources, this paper presents a multi-level relevance resources scheduling method based on improved GA. Under the basic constraints like process relational constraint and so on, this method dynamically makes resource combinations within the optional resources, in order to get high-quality scheduling scheme.

Description of the Problem

In this paper, the constraints scope of traditional job-shop scheduling resources is expanded from machines to operators, machines, fixtures and cutters. For multi-level relevance resources, we have the following assumptions:

(1) Operators, fixtures and cutters are independent of machines. The optional range of operators, machines, fixtures and cutters for MRRP are set by the processing method.

(2) The MRRP can be machined only when its selected resources are all available.

(3) This paper classifies the multi-level relevance resources into operators, machines, fixtures and cutters. The processes that are machined by four kinds of multi-level relevance resources at the same time are called The Multi-level Relevance Resources Processes(MRRP). The selected resources of one MRRP consist of an operator, a machine, a fixture and a cutter.

(4) There are matching relationships between some operators, machines, fixtures and cutters. For example, some cutters can only be installed on certain machines.

The multi-level relevance resources scheduling problem would be solved by the following four aspects.

Key Technology

Dealing with the many to many matching relationship between multi-level relevance resources

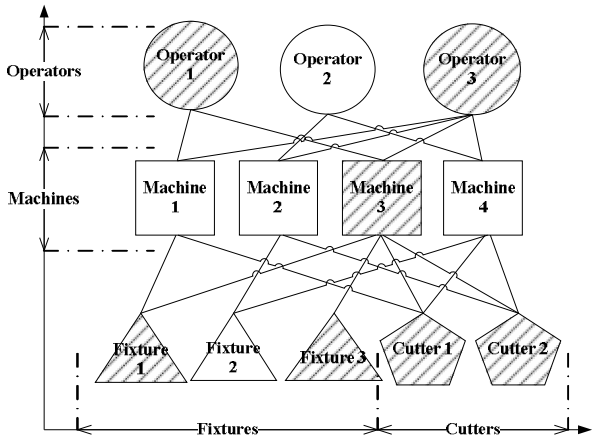

Fig.1 Matching relationships between the optional resources of certain one MRRP

For multi-level relevance resources, the many to many matching relationship is dealt with in the scheduling process. The selected one operator, one machine, one fixture and one cutter for one MRRP are called the Selected Resources Combination. There are matching relationships between the resources of one Selected Resources Combination.

The optional range of operators, machines, fixtures and cutters for certain MRRP and the matching relationships between the resources are illustrated in Fig.1. There is matching

relationship between the resources that are connected by a straight line. For example, between the shaded resources in figure 1, there are matching relationships, which mean operator 1 and operator 3 can operate machine 3, and fixture 1, fixture 3, cutter 1and cutter 2 can be installed in machine 3.

The matching relationships between multi-level relevance resources are stored in the matching relationships bank that is established in processing method. The matching relationships bank confirms the matching relationships between operators, machines, fixtures and cutters. Because of the matching relationships between resources, when one process selects one machine, the optional scope of operators, fixtures and cutters will change.

Dynamic combination of multi-level relevance resources

When one multi-level relevance resource is being scheduled, the algorithm will dynamically combine resources within the optional multi-level relevance resources. Some combinations that don't meet the matching relationships will be abandoned. For one process, maybe more than one resources combination meets the matching relationships. Different selection of resources combination means different result of job shop scheduling. Considering the scheduling target, for every MRRP the algorithm select the best combination from these resources combinations.

As illustrated in Fig.2, the MRRP T3-1 has C1, C2 two resources combinations and different combination produces different scheduling result. To get the best job shop scheduling result, how to select resources combination should be our research content.

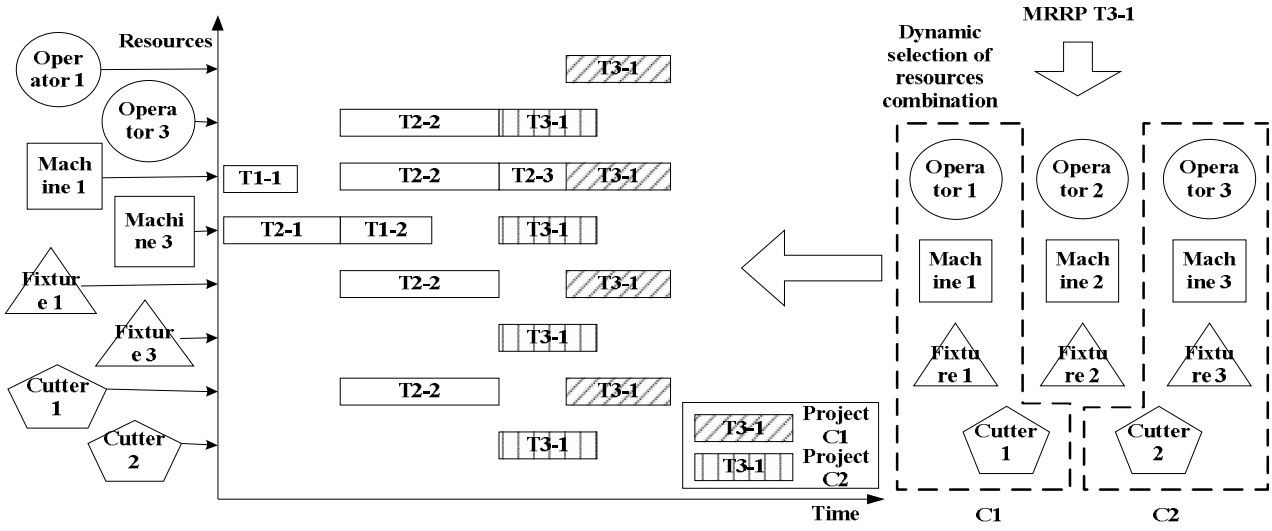

Fig.2 Dynamic resources combination

In scheduling time span of one process, the resources in the process's selected resources combination must be available. In scheduling process of certain one MRRP, the process should be inserted in the earliest available time span when all the selected resources are available. As illustrated in Fig.2, for one process, each selected resource has the same process occupation time span.

Appointment of resources for MRRP

In the actual manufacturing process, some process has had mature processing method. For example, selecting which resources for some processes to meet the processing quality has accumulated enough experience. This means some MRRP have fixed resources combination.

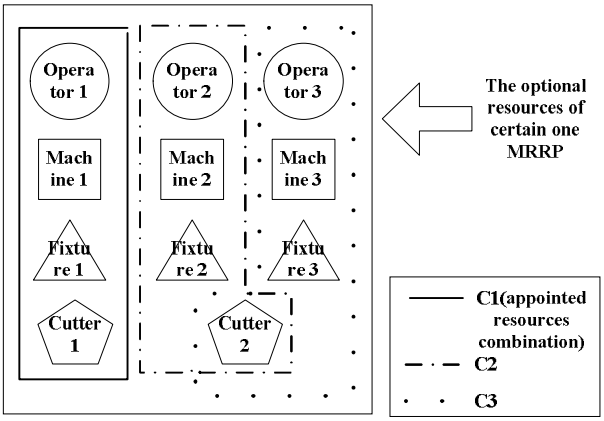

Fig.3 The appointment of resources combination for one MRRP

As illustrated in Fig.3, within the optional resources for certain one MRRP, there are C1, C2, C3 three resources combinations, but only C3 is available because of appointment by processing method.

The Improved GA

The improved GA is different from tradition GA in two parts: specific constraints and coding methods for genes. Chromosome structure is shown in Fig.4 Chromosome adopts the two-dimensional coding method, the first dimension consists of parts' indexes; the second dimension consists of the MRRP selected resources' indexes that are respectively the index of one operator, one machine, one fixture and one cutter from left to right. In the first dimension of chromosome, different processes of the same part are represented by the same character. Scanning the first dimension from left to right, the number of the same character that appears means the index of the process in the part.

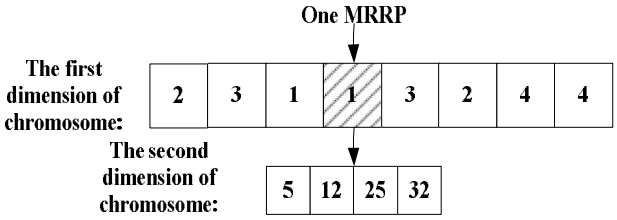

Fig.4 The structure of chromosome

The main progress for algorithm is shown in Fig.5 Considering the matching relationships constraint, coordinated scheduling constraint of multi-level relevance resources and resources appointment constraint for MRRP, the MRRP select resources combination, then through crossover and mutation of GA the algorithm generates scheduling results.

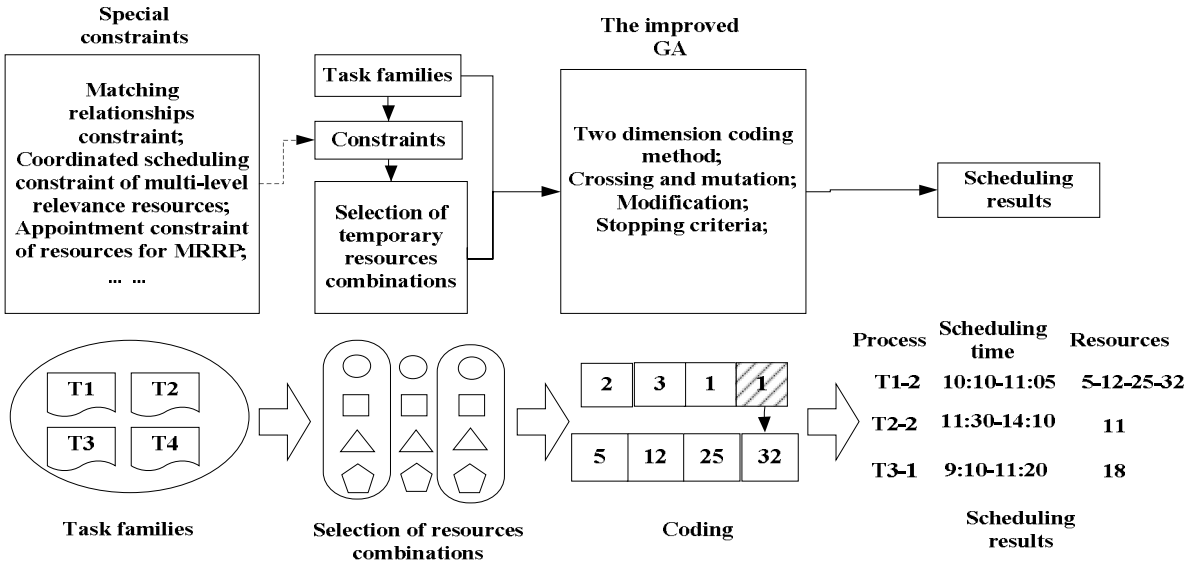

Fig.5 The main progress of algorithm

Case Study

Table 1. Quantity of Resources and Processes

	Operators	Machines	Fixtures	Cutters	Parts	Processes
Quantity	10	20	10	10	50	300

Table 2. Partial Matching Relationships between Resources

		Machine Resources								
		M001	M002	M003	M007	M009	M011	M013	M015	M019
Operator Resources	o1	1	0	0	0	1	0	0	0	1
	o9	0	1	1	1	0	0	1	0	1
Fixture Resources	F4	0	1	0	0	1	0	0	0	1
	F10	0	1	0	0	0	1	0	0	0
Cutter Resources	C3	0	1	0	0	1	1	0	0	1
	C4	1	0	1	0	1	0	0	1	1

Table 3. Optional Resources of Partial MRRP

MRRP	Optional Multi-level Relevance Resources			
	Operators	Machines	Fixtures	Cutters
P1-1	o1,o3,o8,o9	M001,M003,M010	F1,F5,F6	C4,C6,C8
P7-3	o3,o8,o9	M003	F6	C4
P10-6	o5,o7,o9	M007,M009,M015	F4,F8,F9	C4,C5,C7
P15-3	o3	M010	F1	C6
P20-2	o3,o5	M016	F2,F8	C7,C9
P23-1	o3,o7,o9	M011,M013,M020	F3,F7	C2,C3,C9,C10
P50-8	o3,o8,o9,o10	M003,M017	F6,F7	C4,C10

Table 4. The Selected Resources Combination of MRRP

MRRP	Selected Resources Combination			
	Operators	Machines	Fixtures	Cutters
P1-1	o3	M001	F6	C8
P7-3	o8	M003	F6	C4
P10-6	o9	M009	F8	C7
P15-3	o3	M010	F1	C6
P20-2	o5	M016	F2	C9
P23-1	o7	M020	F3	C10
P50-8	o10	M017	F7	C4

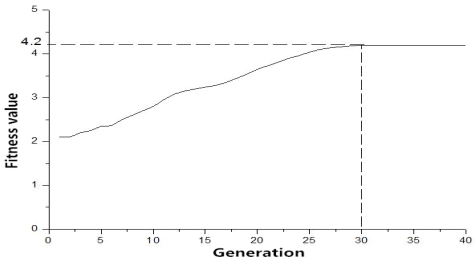

Fig.6 Convergence processes of proposed instances

To meet the requirement of practical production situation, a scheduling software system based on GA is developed using C++. The experiments are designed to check the effect of the coordinated scheduling technology. The case data are from one Chinese manufacturing company.

The quantity of resources and processes is shown in table 1. Partial matching relationships between resources are shown in table 2 in which “1” means there is matching relationship between the two resources and ”0” means not.

Optional resources of partial MRRP are shown in table 3 and the information is set by processing method before job shop scheduling. As is illustrated in table 3, processing method has appointed the resources combination {o3, M010, F1, C6} for process P15-3.

Dealt with by the improved GA, MRRP obtain their selected resources combination partly shown in table 4. The result indicates that it meets the matching relationships constraint, coordinated scheduling constraint of multi-level relevance resources and resources appointment constraint for MRRP.

As illustrated in Fig.6, when population generation is 30, the fitness value increases from 2.1 to 4.2. This verifies the improved GA can quickly produce convergent scheduling results.

Conclusion

In order to solve the coordinated scheduling problem of multi-level relevance resources, we propose the coordinated scheduling technology based on improved GA. The special problems are analyzed to get certain constraints and the according model is built. The improved GA is built based on the objective function and constraints. The performance and result quality are tested with proposed instances.

Advantages of the proposed algorithm are summarized as follows:

(1) Considering the matching relationships constraints between resources, coordinated scheduling constraints of multi-level relevance resources and resources appointment constraints for MRRP, the algorithm dynamically combines resources to produce better scheduling results.

(2)The proposed model not only focuses on punctual completion rate, but also considers average utilization percent of operator, machine, fixture and cutter. This is a suitable model for Chinese manufacturer in current fierce market competition.

(3)The algorithm achieves a fast convergence. Practical example shows that this algorithm is correct and can produce scheduling results in a short time.

References

[1] Qi Yonghong, Xie Zhiqiang. Research on Integrated Scheduling Algorithm with Multiple-Devices-Operation of Complex Product[D]. Harbin University of Science and Technology 2014;1: 1-55.

[2] Ding Lei, Wang Aimin, Ning Ruxin. Tobacco Packaging Scheduling Technology Based on Manufacturing Resources Dynamic Combination [J]. China Mechanical Engineering 2010;21: 1441-1446.

[3] WANG Feng, LIN Jie. Study of Job Shop Scheduling Based on Combination of Workpieces

[J] . Computer Engineering and Applications 2009; 45:26-29.

[4] Rau Mencia, Maria R.Sierra, Carlos Mencia. A genetic algorithm for job-shop scheduling with operatorsenhanced by weak Lamarckian evolution and search spacenarrowing[J]. Nat Comput 2013; 13:179–192