Dynamic Scheduling Method of Production Plan in Automobile Manufacturing Workshop

Nver Ren¹ and Maoying Li*²

¹China Automotive Technology & Research Center Co., Ltd., Tianjin, China
*Corresponding author’s e-mail: limaoying@catarc.ac.cn

Abstract. In order to adapt to the needs of dynamic adjustment of production plan between different automobile manufacturing workshops and deal with emergencies, a dynamic scheduling method of production plan based on genetic algorithm is proposed in this paper. According to the requirements of different workshops, multi-layer fitness functions are designed, buffer zones are set between workshops, and the production planning scheduling is dynamically adjusted by sliding window. The experimental results show that the dynamic scheduling method proposed in this paper has the advantages of high efficiency and adjustment.

1. Introduction

The production planning scheduling of automobile manufacturing workshop is an important factor to improve the production level of automobile manufacturing enterprises. Excellent production planning scheduling algorithm can help enterprises to improve production efficiency, and achieve the purpose of optimal production under limited capacity. Tabu Search[1], simulated annealing[2], genetic algorithm and other heuristic algorithms can be used to solve the problem of production planning scheduling. Genetic Algorithm, as a classical intelligent optimization algorithm, is widely used in production planning scheduling problems due to its ease of use, robustness and extensibility. However, many studies are based on static constraint information such as material and production capacity, and do not consider production constraints of different workshops and dynamic events such as machine failure, order insertion and order cancellation. In order to alleviate this problem, a dynamic scheduling method based on genetic algorithm is proposed in this paper, which can adjust the production plan rapidly and dynamically.

2. Research status

2.1. Production planning scheduling

At present, the production schedule of many automobile manufacturing enterprises is mainly prepared by production planning staff according to the summarized production experience. However, there is no comprehensive consideration of real-time information, resulting in the difference between the production schedule and the actual production demand of the workshop.

2.2. Genetic algorithm

Genetic Algorithm (GA) was first proposed by Professor J.H. Holland in the United States in 1975. Many scholars have devoted themselves to applying genetic algorithm to production planning scheduling problems. Homayouni et al.[3] propose an operation-based multistart biased random key genetic algorithm (BRKGA) coupled with greedy heuristics to select the machine processing each
operation and the vehicles transporting the jobs to operations. Akbari et al.[4] use the modified operators of the cuckoo optimization algorithm and the genetic algorithm to achieve a relatively optimal solution with less execution time than the cuckoo optimization algorithm.

3. Problem description
Automobile manufacturing workshop mainly includes stamping, welding, painting and assembly workshop, as shown in Figure 1. Each car needs to enter four workshops in turn. However, the optimal production constraints and objectives of the four workshops are different.

![Figure 1. Production and assembly process of an automobile manufacturing workshop.](image)

The dynamic scheduling problem of production plan can be described as: considering the production order of N cars in different workshops. The objective of the problem is to obtain the optimal production plan of N cars, so as to optimize the corresponding evaluation index.

4. Dynamic scheduling based on sliding windows
In order to ensure the smooth progress of production, some automobile enterprises will set up buffer zones between workshops, which can accommodate a fixed number of vehicles. The production sequence of these vehicles can be adjusted before moving to the next workshop. This can not only alleviate the constraint conflicts between workshops, but also deal with the dynamic problems in the production process.

![Figure 2. The working principle of the sliding window.](image)

The sliding window[5] algorithm can transform the dynamic problem into a continuous multiple static problem, and the nested loop problem into a single loop problem, reducing the time complexity. The fixed length vehicle production plan is put into the sliding window, and the genetic algorithm proposed above is used to adjust the production plan dynamically. The working principle of the sliding window is shown in Figure 2.

Every fixed time T, it is necessary to reschedule the vehicles in the sliding window by using the method mentioned above. At the initial moment, we generate the initial production schedule based on static information. During the production process, buffer zones adjust production plans according to emergency situation and the optimization objectives of different workshops. The production sequence
of vehicles entering the next workshop is calculated in real time according to the buffer zone and related dynamic constraints.

5. Production scheduling based on genetic algorithm

Genetic algorithm is a method to search the optimal solution by simulating the natural evolution process. The selection, crossover and mutation of chromosomes in the process of biological evolution lead to the evolution and evolution of organisms.

![Flow chart of production planning scheduling algorithm based on genetic algorithm.](image)

Therefore, the main steps of genetic algorithm include coding, random generation of initial population, individual fitness calculation, selection operation, crossover operation, mutation operation, etc., and continue to iterate until the termination condition is satisfied or the maximum number of iterations is reached, and finally the individual with the maximum fitness is output as the optimal solution. In this paper, t is used to represent the generation, and P(t) and C(t) are used to represent the parent generation and the descendant generation respectively. The production planning scheduling algorithm process based on genetic algorithm in this paper is shown in Figure 3.

5.1. Coding based on BOM

BOM (Bill of Materia) is the master data of automobile manufacturing enterprises. Suppose the number of vehicles to be scheduled is n, then the chromosome length is n, and each vehicle can obtain relevant information by querying the BOM.

5.2. Fitness calculation

In order to satisfy the optimal constraints and the optimal objective function of the production workshop, this paper designs a multi-layer fitness function, that is, the inner layer fitness and the outer layer fitness.
5.2.1. Inner layer fitness.
According to the production requirements of automobile manufacturing workshop, each workshop will put forward several production constraints, and each constraint has different types and priorities. The main types of constraints are as follows:

- Agglomerate constraints: for example, cars with red colors should be produced for 5 consecutive times.
- K in M constraint: for example, for every 100 cars produced, 10 black cars should be included.
- Position constraint: for example, car A with sunroof must be produced in position 10-15.
- Interval constraint: for example, every 10 cars must produce a B car with leather seats.

Production constraints are divided into strong constraints and soft constraints. We should consider meeting strong constraints first. Therefore, the constraint conditions are given priority, which is 0-9, 0 is strong constraint, 1-9 is soft constraints, the priority is lower and lower. According to the priority, represented by pri, this paper assigns a weight to the constraint condition, represented by $k$. The formula is as in equation (1):

$$
k = \frac{1}{\text{pri} + 1} \quad (1)$$

Therefore, in order to describe the fitness of chromosomes, the inner layer fitness $ada_{\text{inside}}$ of the algorithm is represented by the chromosome violation times * corresponding weight $k$. The formula is as in equation (2):

$$
ada_{\text{inside}} = \sum_{m=1}^{m} k_{m} \times \text{times}_{m} \quad (2)
$$

So, $m$ is the number of constraints. The inner layer fitness reflects the degree to which chromosomes meet the strong and soft constraints, but there may be multiple chromosomes with the same inner layer fitness, which requires additional fitness for further evaluation.

5.2.2. Outer layer fitness.
Optimal production is the pursuit of minimum cost and maximum production. The optimization objectives of different workshops are usually different. The outer layer fitness $ada_{\text{outside}}$ should be a comprehensive index based on the production experience and production requirements of different enterprises. In this paper, we set up the following:

- welding workshop: we take the replacement times of production models as the objective function;
- painting workshop: we take the replacement times of color of production vehicles as the objective function;
- assembly workshop: we take the production leveling as the objective function.

Among the individuals with the best inner layer fitness, the individual with the best outer layer fitness is selected as the final result.

5.3. Genetic operator
Genetic operators include selection operators, crossover operators and mutation operators. The appropriate operator can quickly convergence, avoid falling into the local optimal solution.

5.3.1. Selection operator.
The selection operator determines which chromosomes will be generated in the next generation population. This paper uses the roulette selection.

5.3.2. Crossover operator.
The crossover operator determines how the selected chromosome multiplies into a new generation. This article uses partial mapping crossings.
5.3.3. *Mutation operator.*

The mutation operator determines how a chromosome mutates to become a new chromosome. This article uses basic bit variation.

6. **Experimental result**

6.1. **Implementation details**

The data in this paper are derived from the simulated workshop data of automobile enterprises. Parameters are set by default as follows: chromosome length is 400, crossover probability is 0.6, mutation probability is 0.2, population size is 800, and number of iterations is 500.

6.2. **Framework applicability**

In order to evaluate the performance of the production plan dynamic scheduling method based on genetic algorithm, experiments with different constraint combinations are carried out. Each constraint combination contains more than 20 constraints. The outer layer fitness of the optimal individual with different iteration times was calculated for 5 constraint combinations, and the experimental results are shown in Figure 4.

![Figure 4. The outer layer fitness of 5 different constraint combinations decreases with iterations.](image)

6.3. **Compare with other methods**

The fitness of the optimal production schedule under static and dynamic conditions is compared. In the static situation, tabu search and genetic algorithm are used to schedule the production according to the static information. In this paper, we propose to consider dynamic constraints, solve constraint conflicts and emergencies in different workshops through sliding window, and adjust the production plan many times in real time. The experimental results are shown in Table 1.

| Constraint combination ID | Static scheduling (tabu search) optimal outer layer fitness | Static scheduling (genetic algorithm) optimal outer layer fitness | Our method optimal outer layer fitness | Fitness improvement |
|---------------------------|------------------------------------------------------------|---------------------------------------------------------------|--------------------------------------|---------------------|
| 1                         | 81                                                         | 77                                                            | 64                                   | 17%                 |
| 2                         | 50                                                         | 55                                                            | 42                                   | 16%                 |
| 3                         | 19                                                         | 23                                                            | 10                                   | 47%                 |
| 4                         | 33                                                         | 28                                                            | 17                                   | 39%                 |
Through comparison, it is not difficult to draw a conclusion that the method in this paper has better performance. Compared with the static scheduling method, the fitness of the optimal individual of the dynamic scheduling method is lower, that is, the number of violations of constraints is less, and a better production scheduling is obtained.

7. Conclusion
This paper presents a dynamic scheduling method based on genetic algorithm, which can effectively alleviate the static and dynamic constraints between different manufacturing workshops. The experiment shows that the dynamic scheduling method of production plan has the advantages of good effect and adjustment.

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