Solving Flexible Job Shop Scheduling Problem in Cloud Manufacturing Environment Based on Improved Genetic Algorithm

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Abstract. In this paper, aiming at the new characteristics of flexible job shop scheduling in cloud manufacturing environment, this paper studies the residual capacity utilization of cloud manufacturing enterprises, considers the idle time of equipment, studies the workshop scheduling method with idle time, and constructs the scheduling framework of cloud manufacturing operation workshop. The production tasks accepted on the platform are carried out together with the tasks assigned by the workshop itself, with the goal of minimum penalty total cost, and the improved genetic algorithm is used to solve the optimal scheduling sequence of the workpiece. The validity of the proposed method is verified by using the benchmark example.

1. Introduction
At present, most of the research focuses on cloud manufacturing are on the perspective of cloud platform to carry out the classification and optimization of manufacturing resources[1], but the research on enterprise-level production scheduling in the context of cloud manufacturing is still very rare. Due to the zero-work production characteristics of the flexible work shop, after the initial scheduling of the shop floor, the processing equipment of the workshop inevitably has an idle time period[2]. Under the premise of ensuring the smooth operation of the initial task scheduling of the workshop, the idle time period of the processing equipment is fully utilized, and the small-volume cloud tasks that arrive at any time are reasonably dispatched, and the collaborative production of the self-owned tasks and the cloud tasks is the scheduling of the cloud manufacturing enterprise.

2. Description of flexible job shop problems in cloud manufacturing environment

2.1. Problem characteristics
In the cloud manufacturing environment, The cloud manufacturing enterprise encapsulates the remaining capacity of the equipment in the workshop to the cloud platform, and the cloud platform feeds the matching result to the resource provider, so that the workshop in the enterprise matches and dispatches the result of the cloud feedback[3]. In the traditional job shop production task, the machine is in an idle state before the start of the machining task, so the machining time of the machine is continuous. As shown in the traditional work shop in Figure 1, the machine can be processed at any time, only need to complete the shop task[4]. However, after joining the cloud platform order, it hinders the original traditional job shop scheduling task. As shown in Figure 1, the cloud manufacturing
enterprise job shop can be seen that the machine M1 is being used by the shop itself in two fixed time periods. The production task is occupied, then the production tasks accepted by the cloud platform cannot be processed within the time when the machine M1 is locked, which brings new changes to the flexible job shop scheduling. This paper proposes flexible operation in the cloud manufacturing environment. Research on the remaining capacity of equipment in the workshop.

![Diagram](image)

**Figure 1.** Cloud manufacturing task - workshop processing.

2.2. *Problem analysis*
Since the process of the shop task occupies the processing machine, when the cloud task processing is performed, the start time and the end time on the processing machine 2 and the machine 4 cannot fall within the time interval that has been locked by the task of the shop itself. That is, the locked device machine is not within the selected range, and it cannot process the cloud task, and the cloud task processing process start time is longer than the locked time zone end time, or the cloud task processing process ends. The time is less than the start time of the locked time zone. In this way, the final completion time of the cloud task will be delayed or even delayed.

If the benefits of accepting cloud tasks can be greater than the penalty costs, then the company still has revenues, which is of great significance to the economic growth of enterprises and the rational use of resources.

2.3. *Cloud manufacturing enterprise scheduling framework*
The scheduling framework is shown in Figure 2. The scheduling of cloud tasks is based on the successful completion of the tasks of the workshop itself, with the goal of improving the utilization of manufacturing resources.
Step 1: First, the cloud manufacturing enterprise workshop optimizes the resource scheduling according to the requirements of the production tasks of the workshop itself, and forms an initial scheduling plan. At the same time, through the analysis of the equipment capacity, the remaining production capacity of the workshop is clarified, and its package is released to the cloud platform\(^5\).

Step 2: Know the remaining capacity of the cloud manufacturing enterprise workshop equipment, perform cloud task scheduling according to the process requirements of the cloud order task, clarify the workpiece scheduling sequence of the cloud order task and the start time and completion time of each process, and finally decide the optimal cloud order task scheduling solution.

2.4. Problem mathematical model

The objective function is established as follows:

\[
G = \min \left[ e_i \sum_{j=0}^{n-1} \max(0, c_i - d_i) \right]
\]  

Equation (1) represents the penalty cost of the delay of the cloud order. Where “\( e_i \)” is the penalty factor; “\( c_i \)” is the completion time; “\( d_i \)” is the delivery date.

In view of the new problems arising from flexible job shop scheduling in the cloud manufacturing environment, in addition to the constraints that traditional workshops should consider, some new constraints have emerged:

- The order receipt received on the cloud platform should be greater than or equal to the penalty cost generated by the shop task: \( P - G \geq 0 \), where \( P \) is the order revenue on the cloud platform, and \( G \) is the penalty cost generated by the shop task;
- The start and end times of the shop task’s operations on the processing machine cannot fall within the time interval that has been locked by the cloud platform.

3. Implementation of genetic algorithm

3.1. Chromosome encoding and decoding

In this paper, we use the chromosome coding method in Document [6]. A chromosome consists of a process ordering part and a machine selection part. The former determines the process ordering of the workpiece, and the latter determines the processing machine of each process.

This paper adopts a plug-in greedy decoding method [7].

**Figure 2.** Cloud manufacturing enterprise flexible job shop scheduling framework.
3.2. Fitness function

The fitness function is used to evaluate the individual quality of the population. This paper directly transforms the objective function into an adaptation function.

3.3. Cross operation

This article uses two crossover methods: one is cross operation based on process ordering [8]; the other is cross operation based on machine selection.

The cross-operation process of the machine selection part: randomly select two intersection points in the machine chromosome; exchange the chromosomal genes of the corresponding position of the father, and the order of processing of other machines remains unchanged until the entire cross operation is completed.

3.4. Mutation operation

In this paper, a simple and effective chromosomal variation method is designed. The mutation operation is divided into two steps [9].

3.5. The specific steps of the genetic algorithm

Step 1: Parameter setting;
Step 2: Initialization, randomly generating N individuals;
Step 3: Actively decoding, calculating and evaluating the fitness value of the individual in the population;
Step 4: If the number of iterations reaches the set value, the termination operation is satisfied and the result is output; otherwise, step 5 is performed;
Step 5: Using the method of roulette, performing a selection operation to generate a child generation population;
Step 6: Perform cross operation according to the cross strategy;
Step 7: Perform the mutation operation according to the mutation strategy;
Step 8: Actively decode, calculate and evaluate individual fitness values, determine critical paths and key processes;
Step 9: Perform a variable neighborhood search on 20% of the individuals in the population, and obtain a better solution for each individual, and replace the current poor solution with the updated superior individual; otherwise, keep the original individual unchanged.
Step 10: Generate a new population and perform step three.

4. Simulation experiment results

In order to verify the effectiveness of the improved genetic algorithm applied to the flexible job shop scheduling problem in cloud manufacturing environment, the implementation code of the algorithm is written in C++ programming language. The operating environment is: Intel (R) Core(TM) i5-4590 CPU @ 3.30GHz, memory (RAM) is 8.00GB. The specific parameters of the genetic neighborhood algorithm are set as follows: initial population size 400 to 1200, maximum iteration number 200 to 800, crossover probability 0.8, and mutation probability 0.02 to 0.3.

The initial time for setting the schedule starts from 0, that is, the shop starts the machining process from time 0, and sets the machine M2 and machine M4 locked by the tasks on the cloud platform in the time interval [5, 10] and [20, 30]. That is, in the time period [5, 10], the machine M2 has to process the workshop itself. In the time period [20, 30], the machine M4 has to process the workshop itself and cannot be used to process the cloud order task, wherein the delivery date is At time 90, the revenue on the cloud platform is P=0.5, and the penalty cost is C=0.1. The algorithm solves the standard example 10*6 and runs the experiment 100 times to get the experimental optimal solution to 96. The completion time is greater than the given intersection. The delivery period, but the income P on the cloud order is greater than the penalty cost, and the enterprise has revenue.
As shown in Figure 3, the red part indicates the time period when the machine is occupied. When the cloud order task is processed, it will avoid the locked time period.

![Figure 3. Standard study 10×6 result Gantt chart](image)

The examples in this paper are tested by the algorithms of literature and literature. The average solution and the optimal solution are shown in Table 1. According to Table 1, the algorithm proposed in this paper is compared with other algorithms. The feasibility of solving the process with genetic algorithm is relatively high, and it is easy to find the optimal solution.

| Scheme Comparing          | Algorithm | Document [10] | Document [1] |
|---------------------------|-----------|---------------|--------------|
| Number of workpieces      | 10        | 10            | 10           |
| Number of operations      | 6         | 6             | 6            |
| Number of machines        | 6         | 6             | 6            |
| Average solution          | 101       | 105           | 103          |
| Optimal solution          | 96        | 100           | 98           |

5. Conclusion
In this paper, aiming at the new characteristics of flexible job shop scheduling in cloud manufacturing environment, this paper studies the residual capacity utilization of cloud manufacturing enterprises, constructs the scheduling framework of cloud manufacturing operation workshop, and uses the improved genetic algorithm to solve the optimal scheduling sequence of workpieces. Arranging resources, improving the utilization rate of resources, and improving corporate income have practical significance for China's manufacturing development and corporate benefits.

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