Benefit Optimization of Small-scale Restaurants Using the Scheduling Optimization Algorithm

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Abstract

At present, the production schedule management of kitchens in small-scale restaurants is relatively poor, resulting in low economic benefits. Improving the efficiency of dish-making not only ensures customer satisfaction but also brings higher economic benefits to operators. In most cases, the order in which the dishes are prepared is contingent on the chef's wishes. However, APS and other planning and scheduling systems have high operating thresholds and costs, and are not suitable for small-scale restaurants. This paper presents a simple solution based on Johnson's algorithm, and compares the scheduling optimization effect of subjective method, improved genetic algorithm and Johnson's algorithm based on a small-scale restaurant kitchen. The results show that both the improved genetic algorithm and Johnson's algorithm can obtain the optimal solution, and their production time both total 100min, but the difficulty and cost of solving the Johnson algorithm are significantly lower than those of the improved genetic algorithm. Johnson's algorithm is obviously more cost-effective for optimizing the preparation order of dishes in small-scale restaurants.

Keywords: *Production Schedule, Economic Benefits, Johnson's Algorithm, Subjective Method, Improved Genetic Algorithm, Small-scale Restaurant.*

1.INTRODUCTION

In the catering industry, the efficiency of dishes production affects many issues such as operating income, operating costs, and customer satisfaction is a concern of all restaurant operators. Improving the efficiency of dish-making not only ensures customer satisfaction, but also brings higher economic benefits to operators. In the context of the COVID-19 pandemic, many locked-down schools, companies, and communities often place orders to restaurants in batches. How to use a simple method to scientifically sort the production sequence of dishes, ensure the shortest idle time of each station, maximize the production efficiency of dishes, and avoid the opportunity cost caused by excessive dish production time has become an important topic. The production schedule of the dishes will greatly affect the profitability of the restaurant.

Most common restaurants use the time of preparing ingredients or cooking time to arbitrarily decide the cooking order of the dishes, such as preparing food with the shorter time first or the shorter cooking time first. Subjective human judgment leads to the lack of a fixed order for the preparation of dishes, easily leading to idle time, which is likely to cause problems such as long serving time and chaotic kitchen work. APS and other planning and scheduling systems are more suitable for use in complex production environments in the manufacturing industry, and their high costs and operating thresholds are not suitable for ordinary small-scale restaurants.

Production scheduling is a widely studied topic, and many algorithms can solve this problem, including tabu search [3][7][8], simulated annealing [5], genetic algorithms [1], and others. Some scholars have proposed an automatic selection method [6]. Having said that, a common problem can be found in the above algorithms. They all require professional personnel to perform calculations or use computers to calculate them, and are not possible to be widely used in ordinary small production workshops.

In order to solve the above problems, this paper aims to divide the production of dishes into two processes: the preparation of ingredients and cooking. Johnson's

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algorithm is used to find the fastest scheduling scheme for ordinary restaurants and provide a simple solution. At the same time, the scheduling optimization effects of Johnson's simple solution method, the subjective method and the improved genetic algorithm are compared in a bid to further verify the applicability and economical efficiency of Johnson's algorithm in the back kitchen of small-scale restaurants.

2.INTRODUCTION to the ALGORITHM

2.1. PRODUCTION SCHEDULING BASED on SUBJECTIVE JUDGMENT METHOD

In most small-scale restaurant kitchens, there is a great deal of randomness in the order in which the dishes are prepared. People subjectively tend to complete the jobs that take less time first. This rule can be expressed as:

$$P_i[K] \leq P_i[K+1] \quad (K = 1,2,3 \dots n) \tag{1}$$

Where, $P_i[K]$ is the K processing time required for the first job at i the first station. In the production schedule of the restaurant's back kitchen, "Job" is the "dish", and "machine" is the preparation station of food material or the cooking station.

When the processing time $P_1[K]$ of the Kth job at the first machine is used as the scheduling criterion, the order of processing dishes at the second machine is required to be the same as the first machine. This is because when the first K dish is processed at the first machine, it must be put into the production of the next step immediately to ensure the shortest total production time.

When the processing time $P_2[K]$ of the Kth job at the second machine is used as the scheduling criterion, it is also required that the order of processing dishes at the first machine is the same as that of the second machine. This is because the first job must complete the preparatory job before the kth dish is put into the production of the second job, to ensure the shortest total production time.

2.2. PRODUCTION SCHEDULING BASED on IMPROVED GENETIC ALGORITHM

It is generally believed that the genetic algorithm has 5 basic components [2].

1) Coding. Genetic algorithms usually do not act directly on the solution space of the problem, but use some encoded representation of the solution for evolution.

2) Determination of the Fitness Function. Since genetic algorithms usually perform genetic operations based on fitness values, a reasonable evaluation function can reflect the pros and cons of each individual and adapt to the evolution of the algorithm.

3) Selection of parameters. They usually include the number of populations, crossover probability, mutation probability, number of evolutionary iterations, etc.).

4) Determination of GA operators. They typically include initialization, selection, crossover, mutation, and the operators of migration.

5) The parameter values of the genetic algorithm.

The problem of dish scheduling in the restaurant's back kitchen can be expressed as, there are n dishes that $\{J_1, J_2, \dots, J_n\}$ need to $\{M_1, M_2\}$ be processed in 6two stations (the ingredient-preparing station and the cooking station). Each dish needs to pass through the station in M_1, M_2. The processing time of each station varies according to the dishes prepared. Two performance indicators can be considered at the same time: the minimum completion time and the minimum total load on all stations. The objective functions of these two performance indicators can be expressed as Equation 2 and Equation 3, respectively:

$$minC_{\mathrm{M}} = min\big(max(C_k)\big) \quad 1 \leqslant k \leqslant 2 \tag{2}$$

$$minW_{\mathrm{T}} = min \sum_{k=1}^{m} W_k \tag{3}$$

Where, C_{M} is the total completion time, C_k is the M_k completion time of the station, W_{T} and is the total load of all stations.

The specific model solving process will be discussed in 3.2.2.

2.3. PRODUCTION SCHEDULING BASED on JOHNSON'S ALGORITHM

The applicable conditions of Johnson's algorithm are: N workpiece is processed by a limited set of machine, and all workpieces are processed in the same order on each machine; at the same time, the sequence of processes is strictly stipulated, that is, the workpiece can only enter the next process after completing the previous job. Obviously, when the production of dishes is abstracted into two parts, the ingredient-preparing time and the cooking time, we can use the Johnson algorithm to solve the scheduling problem of the restaurant's back kitchen.

Assumed to $P_i[K]$ be the time when the workpiece J_k was machined on the machine M_i. The total number of dishes to be made is n, respectively, $J_1, J_2, \dots, J_n$ and the number of stations(machines) is 2. When the total time for making dishes F_{max} is as small as possible, the problem is a $n/2/F/Fmax$ problem. For the $n/2/F/Fmax$ problem, both of the following lemmas are satisfied:

Lemma 1: For $\forall P_{11}, P_{12}, P_{21}, P_{22}, P_{31}, P_{32} \in R$, if Equation (4), Equation (5) and Equation (6) are satisfied, then $P_{11} \overline{\oplus} P_{32} \leqslant P_{12} \overline{\oplus} P_{31}$.

$$P_{11} \overline{\oplus} P_{22} \leqslant P_{21} \overline{\oplus} P_{12} \tag{4}$$

$$P_{21} \overline{\oplus} P_{32} \leqslant P_{22} \overline{\oplus} P_{31} \quad (5)$$

$$P_{21} \neq P_{22} \text{ or } P_{11} \overline{\oplus} P_{12} \overline{\oplus} P_{31} \overline{\oplus} P_{32} < P_{22} \quad (6)$$

Lemma 2: For $\forall P_{11}, P_{12}, P_{21}, P_{22}, P_{31}, P_{32} \in R$, if equation (7) is satisfied, then $P_{11} \overline{\oplus} P_{22} = P_{21} \overline{\oplus} P_{12} \cdot P_{21} \overline{\oplus} P_{32} = P_{22} \overline{\oplus} P_{31}$.

$$P_{21} = P_{22}, \text{and } P_{11} \overline{\oplus} P_{12} \overline{\oplus} P_{31} \overline{\oplus} P_{32} \geqslant P_{22} \quad (7)$$

According to Johnson's theorem [4], if the equation (8) holds, there is an optimal schedule that makes the workpiece i rank before the workpiece j; if the equal sign holds, it $i$can be ranked j before or after.

$$P_1[i] \overline{\oplus} P_2[j] \leqslant P_1[j] \overline{\oplus} P_2[i] \quad (8)$$

The theorems can be transformed into simple and understandable steps as follows:

1) Find P the minimum value in.

2) If $P_1[K]$ it is the smallest, it will be Ji arranged to the next task of the processing sequence, and the processing time of the dish will no longer enter the judgment of the subsequent minimum value.

3) If $P_2[K]$ it is the smallest, it will be Ji arranged to the last task of the processing sequence, and the processing time of the dish will no longer enter the judgment of the subsequent minimum value.

4) If $num(\min\{P\}) \geq 1$, Randomly choose a dish J_k.

5) The optimal sorting can be obtained by looping through the first four steps.

It is worth mentioning that the process relationship between the two machines is similar to that described in 2.1. The order in which the dishes are processed at the preparation station should be the same as at the cooking station to keep the total production time to a minimum.

3.EXPERIMENTAL ANALYSIS

3.1. EXPERIMENTAL DATA

The preparation of dishes is divided into two parts: ingredient-preparing time and cooking time. Among them, the preparation of ingredients is the pre-procedure job before the dishes are officially entered into cooking, such as cleaning, sorting and so on. Cooking can be understood as the process of transforming ingredients into food. An order received by the chef of a restaurant is selected as shown in Table 1.

Table 1: Orders received by the chef of a restaurant at one point in time.

Dishes (Order)	Ingredient-preparing (Station 1)	Cooking (Station 2)
Dish 1	5	21
Dish 2	4	3
Dish 3	9	5
Dish 4	10	6
Dish 5	5	9
Dish 6	10	11
Dish 7	7	4
Dish 8	6	8
Dish 9	8	12
Dish 10	7	16

Table 1 shows the time required to complete the preparation of ingredients and the time required to complete the cooking job for dishes 1 to 10 in an order. Each dish must be processed in station 1 and station 2 in turn.

3.2. ESTABLISHMENT and SOLITION of THREE SCHEDULING MODELS

3.2.1. SCHEDULING MODELS for SUBJECTIVE METHODS

According to the method described in Section 2.1, when scheduling is performed according to the ingredient-preparing time and the cooking time,

Table 2: The optimal processing sequence corresponding to the two subjective scheduling criteria.

Order / Criterion	1	2	3	4	5	6	7	8	9	10
Ingredient-preparing time	2	1	5	8	7	10	9	3	4	6
Cooking time	2	7	3	4	8	5	6	9	10	1

respectively, the rules can be expressed as equation (9) and equation (10).

$$T_{J1} \leq T_{(J+1)1} \quad (J = 1,2,3 \ldots,10) \quad (9)$$

$$T_{J2} \leq T_{(J+1)2} \quad (J = 1,2,3 \ldots,10) \quad (10)$$

We can easily obtain the optimal machining sequence corresponding to these two scheduling criteria.

3.2.2. SCHEDULING MODEL BASED on IMPROVED GENETIC ALGORITHM

Encoding and decoding refer to the mutual conversion between solutions and chromosomes, which are the primary and key issues in applying genetic algorithms. In this paper, by determining the sequential processing sequence between processes, a chromosome is formed, which is a feasible solution for the kitchen schedule.

Let the total number of processes be l, the first process of the corresponding first dish to the last process of the last dish, and the process numbers are $1,2,\ldots,l$ represented by respectively. Scan chromosomes from left to right, and the $i$sequence number that appears i for the j first time in a dish indicates the first process of the dish j. Suppose a feasible gene sequence can be expressed as 1-2-1-2, and the corresponding sequence of steps is expressed as$O_{11}-O_{21}-O_{12}-O_{22}$. That is, the first step of the first dish, the first step of the second dish, the second process of the dish and the second process of the second dish.

When decoding, the order of the processing procedures at each station is determined according to the gene sequence, that is, it is converted into an ordered procedure table. Each procedure is processed one by one with the earliest allowable processing time according to the procedure table, thereby generating a feasible scheduling plan.

In this paper, the population is initialized by the global search method proposed by Zhang Guohui et al. The process of this method is described in detail by Zhang, Guo hui and others [9], and will not be repeated in this article.

In the selection mechanism, this paper adopts the roulette mechanism. Let the population size be t, the i fitness value of the individual in the population is fi, and the selection of chromosomes can be expressed as:

$$F=\sum_{i=1}^{t} f_i \tag{11}$$

$$P_{si}=f_i/F \tag{12}$$

$$P_{ci}=\sum_{j=1}^{i} P_{sj} \tag{13}$$

$$p=rand(0,1) \tag{14}$$

Where, F is the total fitness of the population, P_{si} is the $i$probability that the individual is selected, and P_{ci} is the i cumulative probability of the individual. If $p\le P_{c1}$ then the first individual is chosen, if $P_{c,i-1}\le p\le P_{ci}$ then the ith individual is chosen.

In terms of crossover, we randomly divide all dishes into two sets J_{s1} and J_{s2}. The progeny chromosome c_1/c_2 inherits the genes corresponding to the dishes in the set J_{s1}/J_{s2} in the parent chromosome p_1/p_2. After p_1/p_2 deletes the genes that have been determined in c_1/c_2, the remaining genes are filled into the remaining loci of c_1/c_2 in order.

In terms of mutation, this paper randomly selects genes at two positions from the chromosome, and then exchanges their positions, which ensures that this mutation method produces a feasible solution.

In this paper, we set the maximum number of iterations to be 200, the crossover probability to be 0.8, and the mutation probability to be 0.2. The above method is compiled and solved using Matlab. The optimal processing sequence can be obtained as shown in Table 3.

Table 3: The optimal processing order based on the improved genetic algorithm.

Order / Station	1	2	3	4	5	6	7	8	9	10
ingredient-preparing	1	8	7	3	10	5	2	6	9	4
cooking	1	7	8	3	2	10	5	4	9	6

Table 4: Optimal machining sequence based on Johnson algorithm.

Order / Station	1	2	3	4	5	6	7	8	9	10
ingredient-preparing	1	5	8	10	9	6	4	3	7	2
cooking	1	5	8	10	9	6	4	3	7	2

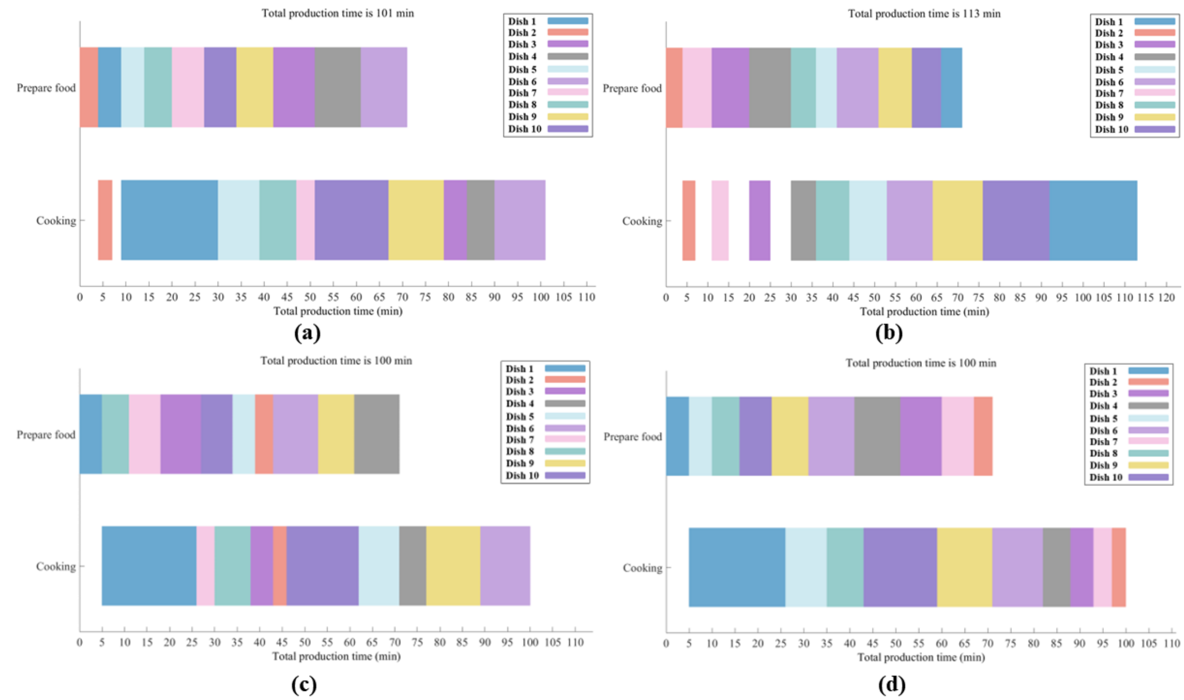

Figure 1: Gantt chart corresponding to each scheduling scheme: (a) subjective method (based on ingredient-preparing duration), (b) subjective method (based on cooking duration), (c) improved genetic algorithm, and (d) Johnson algorithm.

3.2.3. SCHEDULING MODEL BASED on JOHNSON'S ALGORITHM

Based on the simple solution steps proposed in Section 2.3, the optimal scheduling order can be easily found. Specific steps are as follows:

1) Find the minimum value among all times, $\min\{P\} = P_2[2] = 3\text{min}$. It satisfied $P_2[2] \epsilon P_2[K]$, the dish 2 is designated as processing step 10. Move the processing time of the dish out of the judgment range of the subsequent minimum value.

2) Continue to find the minimum value, $\min\{P\} = P_2[7] = 4\text{min}$. It satisfied $P_2[7] \epsilon P_2[i]$, dish 7 is set as processing step 9. Move the processing time of the dish out of the judgment range of the subsequent minimum value.

3) Continue to find the minimum value, $\min\{P\} = P_1[1] = P_2[3] = P_1[5] = 5\text{min}$. Here, choose to $P_1[1]$ enter the sorting, $P_1[1] \epsilon P_1[K]$ and it is satisfied, set dish 1 as processing procedure 1. Move the processing time of the dish out of the judgment range of the subsequent minimum value.

4) Continue to find the minimum value, $\min\{P\} = P_2[3] = P_1[5] = 5\text{min}$. Here, choose to $P_2[3]$ enter the sorting, it satisfied $P_2[3] \epsilon P_2[i]$, then put dish 3 in the last position of the undefined process, that is, the processing process 8. Move the processing time of the dish out of the judgment range of the subsequent minimum value.

Repeat the above steps to get the optimal scheduling order: 1-5-8-10-9-6-4-3-7-2. As mentioned in 2.1, if the total production time is required to be the shortest, the order of processing dishes at Station 1 and Station 2 should be the same. The optimal processing sequence can be obtained as shown in Table 4.

3.3. EVALUATION of SCHEDULING RESULTS

In order to verify the superiority of the simplified steps based on Johnson's algorithm for small-scale restaurants, the total production time finally obtained by the three methods was compared. According to the optimal processing sequence obtained by the three methods in Section 3.2, we can calculate the corresponding total production time as shown in Table 5.

Table 5: Comparison of the total production time of each scheduling method.

scheduling method	total production time
Subjective method (based on ingredient-preparing duration)	101min
Subjective method (based on cooking time)	113min
Improved genetic algorithm	100min
Johnson's algorithm	100min

Draw a Gantt chart to more intuitively observe the differences between the scheduling schemes. The Gantt chart is shown in Figure 1.

According to Figure 1, when scheduling is done with subjective methods, the "cooking" station has standby time due to the randomness of the ordering. resulting in a longer total production time. However, when the improved genetic algorithm or Johnson's algorithm is used for analysis, there is no standby time, and the optimal solutions are obtained for both sorting. From the histogram, the duration relationship between the four can be seen more intuitively.

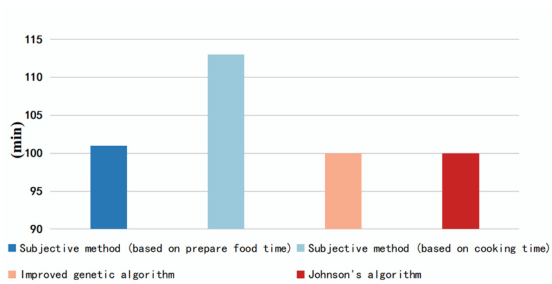

Figure 2: The total production time of the four schemes.

In Figure 2, the total production time is the shortest when the genetic algorithm or Johnson's algorithm is used for analysis. But it is worth mentioning that the solution steps of Johnson's algorithm are far simpler than the improved genetic algorithm when it is used for small-scale restaurant kitchens. Therefore, Johnson's algorithm has unique advantages in such small-scale problems.

4.CONCLUSIONS

The production efficiency of dishes affects the economic income of small-scale restaurants to a great extent. At present, the production schedule management of kitchens in small-scale restaurants is relatively poor, resulting in low economic benefits. However, APS and other planning and scheduling systems have high operating thresholds and costs, and are not suitable for small and medium-sized restaurants. There isn't yet an easy and low-cost way to instruct non-professionals to sequence the kitchen's orders and cook.

In this paper, the simple application steps of Johnson's algorithm are presented. In this simple step, we compared the effect of the subjective method, improved genetic algorithm and Johnson algorithm on the optimization of the kitchen scheduling problem. The effect of Johnson's algorithm on small-scale restaurant production efficiency is verified.

The results show that the improved genetic algorithm and Johnson's algorithm have the best performance over the subjective scheduling method in terms of total production time, and their production time both total 100min. At the same time, based on the given application steps of Johnson's algorithm, the difficulty of solving Johnson's algorithm is much lower than that of the genetic algorithm. It is proved that Johnson's algorithm has great advantages in solving this kind of problem. On the one hand, Johnson's algorithm can shorten the total production time of dishes, so as to increase the restaurant's operating income; On the other hand, the method has low cost and low operating thresholds, avoiding unnecessary scheduling costs.

It is worth mentioning that the research in this paper focuses on the optimization of the total production time. The influence of total production time on small-scale restaurant economic benefit is mainly considered. Future research may further the influence of dish quality control and dish types on small-scale restaurant economic benefits. The solution and discussion methods in this paper are also applicable to scheduling optimization problems in other scenarios.

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