

Retraction

Retracted: Real-Time Data Scheduling of Flexible Job in Papermaking Workshop Based on Deep Learning and Improved Fuzzy Algorithm

Mobile Information Systems

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] S. Dang and W. Tang, "Real-Time Data Scheduling of Flexible Job in Papermaking Workshop Based on Deep Learning and Improved Fuzzy Algorithm," *Mobile Information Systems*, vol. 2021, Article ID 9930740, 12 pages, 2021.

Research Article

Real-Time Data Scheduling of Flexible Job in Papermaking Workshop Based on Deep Learning and Improved Fuzzy Algorithm

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The traditional real-time data scheduling method ignores the optimization process of job data that leads to delayed delivery, high inventory cost, and low utilization rate of equipment. This paper proposes a novel real-time data scheduling method based on deep learning and an improved fuzzy algorithm for flexible operations in the papermaking workshop. The algorithm is divided into three parts: the first part describes the flexible job shop scheduling problem; the second part constructs the fuzzy scheduling model of flexible job data in papermaking workshop; and finally the third part uses a genetic algorithm to obtain the optimal solution of fuzzy scheduling of flexible job data in papermaking workshop. The results show that the optimal solution is obtained in 48 seconds at the 23rd attempt (iteration) under the application of the proposed method. This result is much better than the three traditional scheduling methods with which we compared our results. Hence, this paper improves the work efficiency and quality of papermaking workshop and reduces the operating cost of the papermaking enterprise.

1. Introduction

With the deepening of economic globalization, the users' demand for products has increased. Multiple species and small batch manufacturing is becoming more and more common with the passage of time. This mode of production makes the production environment more and more complex. How to reduce the unnecessary expenses in production is the key for survival and development of enterprises. More and more enterprises need to make the production more intelligent: a concept known as effective production scheduling. In the past fifty years, as an NP difficult problem, the production scheduling has attracted more and more attention from academia and industrial circles due to its significant economic benefits and its own high challenges [1]. However, in order to describe the actual situation in the production process more accurately and improve the quality of scheduling, it is necessary to conduct a comprehensive

and in-depth study. Aimed at real workshop flexible scheduling problem in recent years, domestic and foreign scholars have done a lot of research work, but because of the complexity of the scheduling problem, no universal method is suitable for all kinds of scheduling problems.

The existing methods can be summarized into three categories: the traditional operational research, heuristic rules, and swarm intelligence optimization algorithms. The traditional operations research method proposed in literature [2] solves the problem by establishing a mathematical model, which is generally only applicable to small scale scheduling problems, and has a strong dependence on the specific problem to be solved, so it cannot ensure delivery on time. The heuristic rule method proposed in literature [3] is a general term for a class of methods that use heuristic information to solve problems. It defines certain rules in advance, then applies them to the scheduling process, and finally produces a scheduling scheme. This rule has the

characteristics of being simple and intuitive, the cost of calculation is small, and it is generally easier to implement. It can be used alone or conveniently in conjunction with other algorithms. Heuristic rule method is suitable for small scale scheduling problems and is less efficient in solving large scale scheduling problems. Finally, the third category, i.e., swarm intelligence optimization algorithm, proposed in literature [4] belongs to the meta-heuristic algorithm, which uses certain natural phenomena or the living habits of certain groups to model and solve problems. The solution process is usually to randomly generate one or more scheduling solutions and then gradually perform iterative optimization through defined rules, which can converge to the optimal solution more quickly and can be applied to all types of optimization problems. However, the method of equipment utilization rate is low. All these three scheduling methods are based on scheduling environment relying on strict limitations, emphasis on all kinds of restrictions, and production information clearly in advance, but in the real production environment, there are a lot of uncertainty factors. Typically, the required information is often unable to obtain in advance, so with the development of fuzzy technology, the application of fuzzy number to represent dealing with uncertain parameters received wide attention by showing the incomparable superiority to other methods and application prospect. Processing time and delivery date are treated as fuzzy numbers, which are more in line with the actual problem associated with production. This kind of scheduling problem is called fuzzy scheduling problem.

In view of the problems associated with traditional methods, firstly, this article introduces the uncertainty in the scheduling process of flexible production system and then describes the scheduling problem and related concepts of flexible workshop with fuzzy operation time interval. In order to minimize *makespan*, a scheduling model based on fuzzy logic and genetic optimization is proposed. Finally, the feasibility of model is verified by an example. The results show that the optimal solution is obtained at 48 seconds and on the 23rd iteration, which is better than the three traditional methods. Therefore, this method can effectively improve papermaking efficiency and save papermaking cost.

The rest of the paper is structured as follows. In Section 2, the real-time data scheduling for flexible jobs in papermaking workshop using an Improved Fuzzy algorithm is discussed. In Section 3, the experimental results are discussed. Finally, we conclude the paper and research gaps are discussed in Section 4.

2. Real-Time Data Scheduling for Flexible Jobs in Papermaking Workshop Using an Improved Fuzzy Algorithm

The basic idea of scheduling problem is to allocate resources to different tasks in a certain period of time. Its purpose is to optimize one or more objectives. Resources and tasks in organization will be in many forms, such as the machines in workshops, the runways in airports, the work teams in construction sites, the processing units in computers. All of

them can be regarded as resources. However, the tasks may be the papermaking processes in production, the takeoff and landing of the airport aircraft, various stages of construction project, and the execution of computer programs. The scheduling is a decision-making process, which plays an important role in most of the manufacturing systems and information processing environments. In addition, it exists in transportation and distribution facilities and other types of service industries [5].

The manufacturing industry is an industry that makes materials, energy, equipment, technology [6–8], capital, information, and human resources, needed by the society. The production workshop is a manufacturing system with the interactive relationship between manufacturing resources and production and processing tasks. It is composed of manufacturing resources and production tasks. The workshop scheduling is the arrangement of processing tasks on the processing time and manufacturing resources for realizing the manufacture process. There are many possibilities for this combination, so it is necessary to optimize the production workshop scheduling [9].

In the process of workshop manufacturing, how to allocate resources for the production and processing tasks and thus to realize the optimization of production scheduling is the problem of workshop scheduling. The problem of workshop scheduling involves the following basic elements: task, resource, time, and performance index of scheduling optimization. Based on these basic elements, the commonly used classification methods are shown in Table 1 [10].

This article mainly focuses on the research of flexible job shop scheduling in task types. The basic research ideas are shown in Figure 1.

Based on the scheduling problems in the workshop, the flexible work system is formulated for fuzzy scheduling in the flexible job shop (Section 2.1). Fuzzy parameters are designed, variables are described, objectives and constraints are set, and the model is optimized to construct a fuzzy scheduling model of flexible job data, and the optimal solution of the model is obtained by genetic algorithm (Section 2.2). Finally, experimental analysis is carried out to verify the effectiveness of the method (Section 2.3).

2.1. Description of Flexible Job Shop Scheduling Problem (FJSP). The idea of job shop scheduling is that each paper in the job set is processed in a fixed order on all machines, and each process corresponds to a machine. In Figure 2(a), the working procedure of paper can only be executed after finishing the last process. In the actual production environment, the machine of a certain process is not unique. In Figure 2(b), the process can be selected from machines and equipment, i.e., the FJSP problem [3].

The flexible job shop scheduling can be described as follows: there are n pieces of paper to be processed, and the aggregation of paper is (A_1, A_2, \dots, A_n) . There are m machines with different functions (M_1, M_2, \dots, M_n) . The completion of paper needs multiple working processes, and there is an ordered constraint between each process. Each process can be conducted on different machines. The goal

TABLE 1: Types of shop scheduling problems.

Basic elements	Type	Explanation
Task	Single machine scheduling problem	There is only one machine in the processing system, and there is only one working procedure for the work pieces to be processed. All work pieces are processed on this machine, and each working procedure needs to be optimized. Single machine shop scheduling is the simplest scheduling problem.
	Parallel machine scheduling problem	The processing system has a group of machines with the same function, and there is only one process/task for the work piece to be processed. Each process can be processed by any one of the processing equipments with the same function.
	Job shop scheduling problem	The working system has a group of machines with different functions. The work pieces to be processed include multiple processes. The processing routes of work pieces are different from each other. Each process is processed on a machine that has been uniquely designated in advance.
	Flexible job shop scheduling problem	Flexible job shop scheduling problem is an extension of job shop scheduling problem. Each process may be processed by multiple machines. The processing equipment of each process of the part may not be specified in advance and may be unique. The process can be processed by any one of a group of processing equipment with the same function.
	Flow shop scheduling problem	The machining system has a group of machines with different functions, and the work pieces to be processed include multiple processes. Each process is processed on one machine, and the processing routes of all work pieces are the same.
Resources	Open shop scheduling problem	There are multiple processes for parts, but there is no sequence between them. One process can only be processed on single processing equipment, and single processing equipment can only process one process at the same time.
	Hybrid shop scheduling problem	In the actual production process, we often encounter the combination of the above types of scheduling problems, such as the combination of job shop scheduling and flexible job shop scheduling, and the combination of job shop scheduling and flow shop scheduling.
	Single resource workshop scheduling	There is only one resource that restricts the production capacity of the workshop, the most common one is machine tool equipment resources.
Time	Double resource shop scheduling	At the same time, there are two kinds of resources that restrict the production capacity of the workshop. In addition to the common machine equipment resources, the other resource may be the operating technicians of the machine equipment, or some type of tools.
	Multiresource shop scheduling	At the same time, there are more than two kinds of resources needed for workpiece processing, which restrict the production capacity of the workshop. These resources include machine tool equipment, operators, material delivery system, and other auxiliary resources. Multiresource workshop scheduling problem is the most complex one.
Optimization target	Deterministic scheduling	The processing time and related parameters of the workpiece are known quantities.
	Uncertain scheduling	The processing time and related parameters of workpiece are uncertain random variables.
Optimization target	Single target workshop scheduling	This kind of job shop scheduling problem has only one optimization objective.
	Multiobjective shop scheduling	This kind of job shop scheduling problem has two or more optimization objectives. For multiobjective scheduling problems, there is usually no optimal solution, so it is necessary to balance and choose the optimal solution among the noninferior solutions.

of scheduling is to select the most appropriate equipment for each process and thus to determine the processing sequence and the optimal scheme of optimizing the specified evaluation index [11]. Finally, it is necessary to draw Gantt chart and optimize a certain performance index. Generally, the method of drawing Gantt chart is to arrange the time of working procedures from starting point to ending point in production activities, so as to calculate the starting time and the earliest completion time and then find out the key path by the constraints. The paper in the machine system generally needs to meet the following constraints, as shown in Table 2.

Due to the influence of numerous factors, the paper processing time and delivery time are not always accurate.

The manager or decision-maker can only provide a rough data and the possible range of data change. For this uncertainty, the traditional method is to approximate the imprecise number as an exact number and then solve it by the method of solving the exact problem. This method has two disadvantages. One is that the model may change, leading to the deviation of the solution. The other is that the solution is not in line with the traditional expression and it is not intuitive [12]. The random probability distribution function is used to represent the distribution of parameters. This method requires that the historical data of parameters must be known. In fact, it is very difficult to obtain these data. In addition, the optimization based on random method is also very difficult in processing.

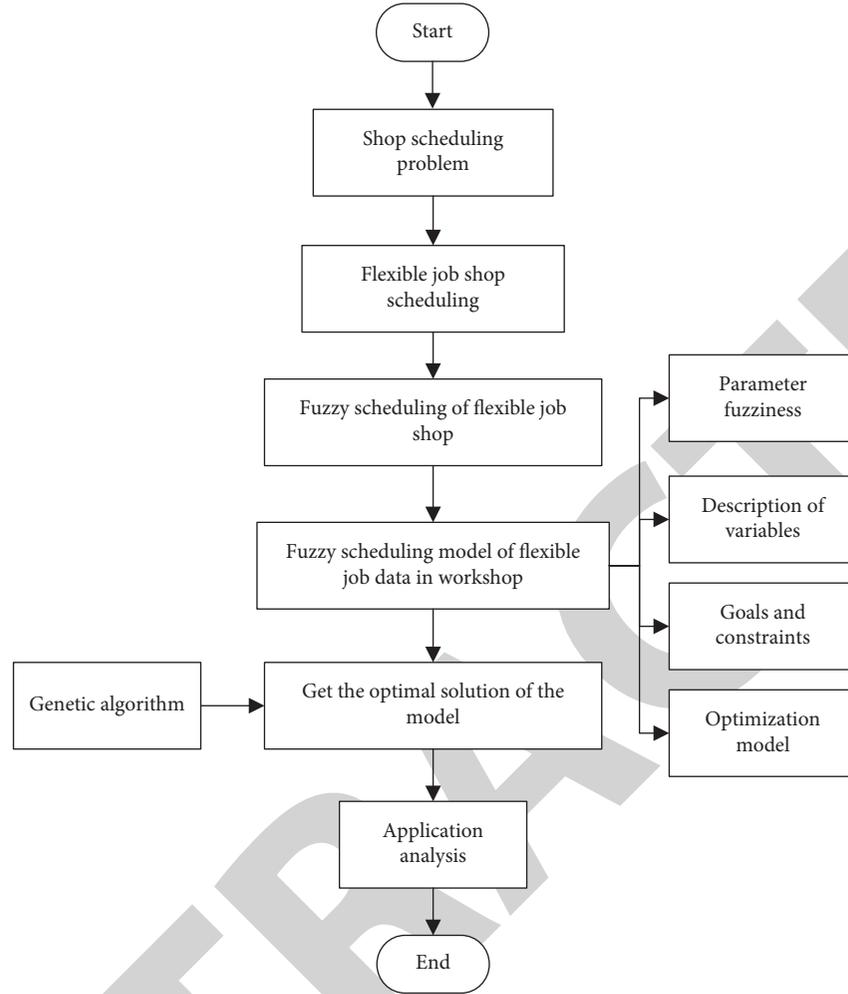


FIGURE 1: Research ideas of scheduling.

With the development of fuzzy technology, the fuzzy number is used to express and deal with uncertain parameters. This problem has been widely studied, which shows the advantages and its application prospects. The processing time and delivery time processed by fuzzy number are more in line with the actual production. This kind of scheduling problem is called fuzzy scheduling problem [13]. With the development of fuzzy mathematics, the idea of fuzzy mathematical programming is applied to the scheduling field. The fuzzy scheduling has become an

important branch of uncertain scheduling problems. The scheduling problem of fuzzy delivery time and fuzzy processing time has become a research hotspot.

2.2. Fuzzy Scheduling Model of Flexible Job Data in Papermaking Workshop

2.2.1. Description of Variables. The variables required by the model are shown in Table 3.

$$R_{ijegk} = \begin{cases} 1, & \text{if } j\text{th process of paper } i \text{ and } g\text{th process } g \text{ of paper } e \text{ are executed on the same machine } k, \\ & \text{if process } j \text{ is prior to process } g, \end{cases} \quad (1)$$

$$X_{ijk} = \begin{cases} 1, & \text{if the } j\text{-th process of paper } i \text{ is performed on machine } k, \\ 0, & \text{other.} \end{cases} \quad (2)$$

In this equation, $i, j, k, m_{ijk}, D_i, r_i,$ and w_i are the input variables. $S_{ijk}, E_{ijk}, MP_k,$ and MS are the output variables.

R_{ijegk} and X_{ijk} are decision variables. Compared with the traditional job shop scheduling model, the fuzzy job shop

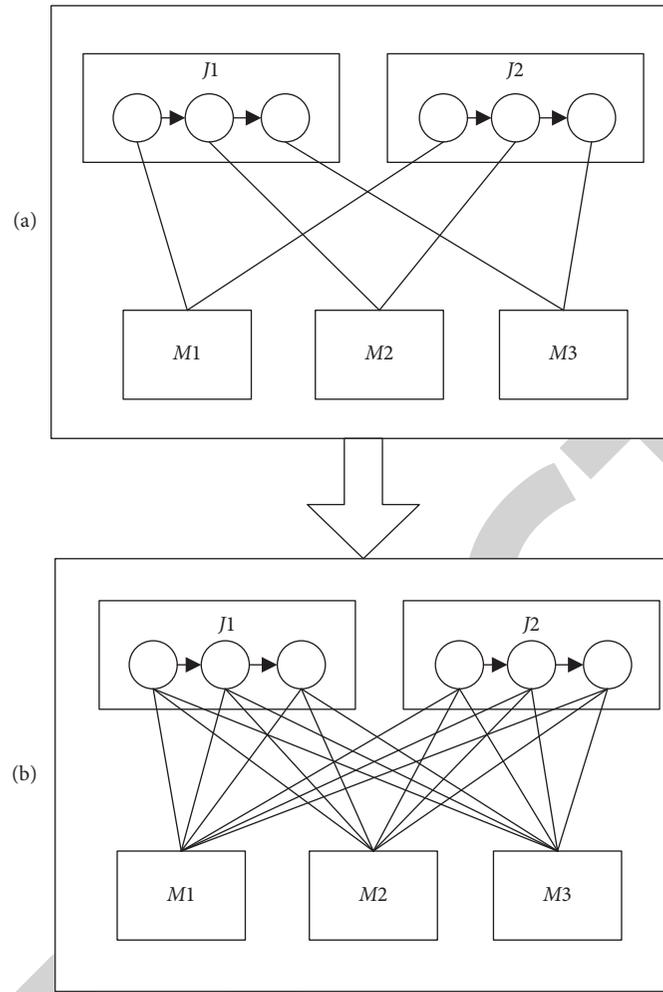


FIGURE 2: Comparison of JSP problem and FISP problem.

TABLE 2: Imposed constraints on machine system.

Serial number	Constraint condition
1	The process of machining on a machine at a certain time is unique.
2	Once a process is started, it cannot be stopped unless there is a machine fault, unless all the processes to be processed are finished.
3	There is often no coupling between papers, the sequence of processes is given in advance, and there is no sequence constraint between different processes.
4	When $t=0$, there are no other constraints, and all of them can be operated on optional machines.
5	All machines are idle at $t=0$ and can be processed.
6	At a certain time point, the operation equipment that can be selected for a certain process of paper is unique.
7	After one of the working procedures of the paper is processed, it is immediately moved to the machine that processes the next working procedure, and the moving time of the machine can be ignored.

scheduling model adds variables to describe the processing cost, production profit, and other influence factors. These variables improve the practical application ability of scheduling system, which is in line with the objective needs of enterprise. Meanwhile, they greatly improve the complexity of model solution, which is also one of the main difficulties in subsequent algorithm researches [14].

2.2.2. *Parameter Fuzzification.* The fuzzy scheduling is a scheduling method developed on the basis of workshop scheduling, which is more close to the actual production. In the fuzzy scheduling, the operation time of paper J_i on machine M_i is not determined, but various factors in production are comprehensively considered, such as the proficiency of workers, the operation of equipment, raw

TABLE 3: Description of variables.

Variable	Explain
i	Paper serial number, $i = 1, 2, \dots, N$ (N is the number of paper)
j	Process number of paper i , $j = 1, 2, \dots, J$ (J is the number of processes)
k	Machine serial number, $k = 1, 2, \dots, K$ (K is the total number of machines)
m_{ijk}	Processing time of the j -th process of paper i on machine k
S_{ijk}	The start time of the j -th process of paper i on machine k
E_{ijk}	Completion time of the j -th process of paper i on machine k
MP_k	Completion time of all paper on machine k
MS	Final finish time for all paper
D_i	Delivery time of paper i
r_i	Penalty coefficient for early completion of paper i
w_i	Penalty coefficient for delayed completion of paper i

materials, and other uncertain factors that may affect production. Triangular fuzzy numbers $(P_{ij}^1, P_{ij}^2, P_{ij}^3)$ are used to denote the processing time of paper as shown in Figure 3. $P_{ij}^1, P_{ij}^2, P_{ij}^3$ denote the early completion time, on-time completion, and delay in paper processing completion, respectively. A mapping relationship is established between the processing of any paper i in a period of time $x \in [P_{ij}^1, P_{ij}^3]$ and the extent of paper belonging to the completion set in this period. That is the membership function $F_{ij}(x)$. $F_{ij}(x)$ represent the membership degree of paper i belonging to the completion set in the processing time x [15].

The fuzzy delivery time \tilde{D}_i is represented by the satisfaction of relative completion time of paper, and it is denoted by two tuples (a_i^1, a_i^2) . a_i^1 and a_i^2 denote the on-time delivery time and delayed delivery time of paper J_i . If the paper is completed within the window $[0, a_i^1]$ of delivery time, the satisfaction of this paper is 1. If the paper is completed outside the delivery time window, the satisfaction is denoted by a linear membership function (Figure 4).

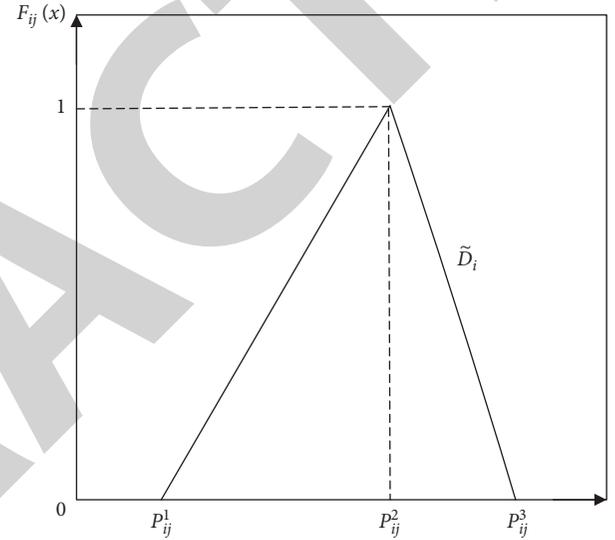


FIGURE 3: Fuzzy machining time.

2.2.3. *Targets and Constraints.* Targets and constraints include the objective function, the constraints themselves, and the optimization model. We discuss them here.

(a) Objective Function

Minimize the total cost of paper, or reduce the free-load running time of machine and the actual working time of guarding the machine.

$$\min(HS) = \max_{k=1, \dots, K} (HP_k). \quad (3)$$

Make the circulation time of paper in the system the shortest; $\min(MS) = \max_{k=1, \dots, K} (HP_k)$; i.e., the penalty for delayed completion of the paper is zero; $0 = \sum_{i=1}^N w_i \cdot \max(0, E_{ij,k} - D_i)$; i.e., the penalty for early completion of paper is the minimum value [16].

(b) Constraints

Sequential Constraints. the processing sequence between adjacent working procedures of the same paper:

$$E_{ij,k} - E_{i(j-1)_m} \geq m_{ijk}, \quad (4)$$

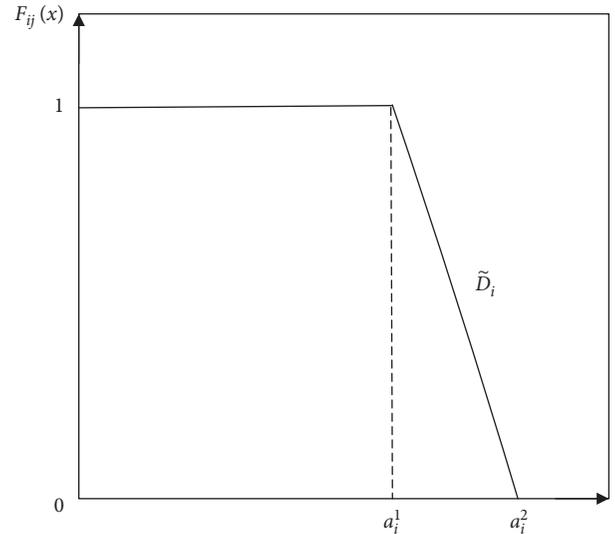


FIGURE 4: Delivery date of fuzzy number.

which indicates that the j th working procedure of paper i must be started after finishing the $j - 1$ th working procedure.

Resource Constraint. after one processing task on the same machine is completed, we can start another task.

$$E_{egk} - E_{ijk} \geq m_{egk}. \quad (5)$$

At any given time, machine k cannot process any two different papers at the same time, and it is unable to process any two different processes at the same time [17].

Cost Constraints. the processing cost per unit time of each machine is different, and the power consumption for startup is different, so the labor intensity of workers is different. After adding the actual weight coefficient, a processing cost constraint condition is formed:

$$HP_k = MP_k \cdot H_k, \quad (6)$$

$$HS = \sum_{k=1}^K HP_k. \quad (7)$$

They represent the completion cost of all paper on machine k and the total completion cost of all paper.

Other Constraints. the completion time of any process cannot be less than its processing time.

$$E_{ijk} \geq m_{ijk}, \forall j. \quad (8)$$

2.3. Optimization Model. In this paper, two kinds of models for job shop scheduling are built. The first model only considers the fuzzy processing time, and the second model comprehensively considers the fuzzy processing time and fuzzy delivery time. The following two types of models are described in detail [18].

2.3.1. Job Shop Scheduling Model under Fuzzy Processing Time. In the job shop scheduling problem, for a given set of paper, if the processing time of each paper is accurate, according to the processing time, the paper can be arranged from small to large (SPT criterion), so that the optimal scheduling scheme of minimum flow time can be obtained. But if the processing time is fuzzy, because it involves the sum and comparison of fuzzy numbers, scheduling scheme cannot be simply obtained by SPT criterion [19].

In (9), d denotes the feasible scheduling set of the paper. For a given schedule $Q \in d$, let $f(Q)$ represent the corresponding objective function value. The scheduling model of minimum fuzzy process time is

$$\min_{Q \in d} f(Q) = \max_{1 \leq i \leq n} \{\bar{D}_i\}. \quad (9)$$

In this equation, $\{\bar{D}_i\}$ denotes the comprehensive evaluation index of the i th paper.

2.3.2. Scheduling Model under Fuzzy Processing Time and Fuzzy Delivery Time. The fuzzy delivery time of fuzzy scheduling problem is shown in Figure 4. If the paper is completed in delivery time window, it will not be punished. If the paper is completed outside the delivery window, a penalty is caused. The process meets the following basic assumptions: (1) the paper is waiting for processing at the same time, and the preparation time is 0; (2) the paper is not allowed to be interrupted and it has no priority. The machine can only process one paper; (3) the delivery window is sufficiently small: $(e_i^n - e_i^m) \cdot (\min_{i \in n} \{p_i\})$, $\forall i \in n$, v is the advanced weight, and z is the delay weight [20].

The penalty function is shown as follows:

$$d(e, Q) = \sum_{1 \leq i \leq n} [v \max(0, e_i^m - D_i) + z \max(0, D_i - e_i^n)]. \quad (10)$$

The minimum scheduling model of earliness/tardiness penalty is shown as follows:

$$\min_{Q \in d} f(e, Q) = \min_{Q \in d} f(e', Q'). \quad (11)$$

The goal is to find the best common delivery time e' and the best order Q' , so as to minimize $f(e, Q)$.

2.4. Calculation of Optimal Solution of the Model. After the establishment of the multiobjective fuzzy scheduling model of job shop, the corresponding algorithm should be constructed to optimize and solve the problem. The job shop scheduling problem is the NP difficult problem. How to develop an effective algorithm to solve the scheduling problem has always been an important issue in the field of scheduling and optimization. The job shop fuzzy scheduling problem is more complex than the general scheduling problem. It is not only necessary to arrange the sequence of working procedure, but also to consider the machine selection. The number of feasible solutions is much more than that of traditional scheduling problems. How to find the optimal solution within a large range of feasible solutions is the main problem of genetic algorithm [21].

In the past thirty years, people have simulated the biological system and its behavior characteristics from different perspectives, forming new disciplines which have significant impact on the development of modern science and technology. For example, the fuzzy set theory is generated by the simulation of human thinking mode. The artificial neural network [22–26] theory is generated by the simulation of human brain nerve. The immune algorithm is generated by the simulation of animal and plant immune mechanism in nature. The evolutionary computing theory is generated by the simulation of biological evolution mechanism in nature [27, 28]. Generally, the imitation based on

biological evolution mechanism forms three typical optimization calculation models, respectively.

- (i) Genetic algorithm (GA)
- (ii) Evolution strategy (ES)
- (iii) Evolutionary programming (EP)

In this article, the genetic algorithm is used to optimize the fuzzy scheduling model. The basic elements of genetic algorithm include chromosome coding, population initialization, selection, crossover, and mutation. The basic flow of general genetic algorithm is described in Figure 5.

The flexibility of job shop scheduling makes the solution more complex. It is not only necessary to sort the working procedures, but also to select a machine for each working procedure. Based on the basic process of genetic algorithm, the fuzzy scheduling model of flexible job shop is solved. The specific steps are shown in Figure 6.

Step 1. Parameter setting: the size of the population is determined as N , and the number of iterations is g .

Step 2. Genetic code: the scheduling problem is encoded as a double chromosome structure.

Step 3. Generation of initial population: N individuals are randomly generated to form the initial population and the initial evolution algebra $t = 0$.

Step 4. Determine the objective function of flexible job shop scheduling problem, and transform the objective function into adaptive fitness function.

Step 5. The fitness value of each chromosome in the population is calculated by the adaptive fitness function. If the fitness value meets the end condition or the number of iterations is $t = G$, the operation is ended and the optimal solution is output. Otherwise, the next step is performed.

Step 6. Select a certain number of individuals by roulette selection, and perform the genetic operation on these individuals.

Step 7. Using deep neural network: calculate the crossover probability and mutation probability, and perform the adaptive genetic evolution operation according to crossover and mutation operation, so that new generation of population is obtained.

Step 8. Let $t = t + 1$, and return to Step 5.

3. Experimental Analysis

In order to verify the performance of improved genetic algorithm, a standard example was adopted for testing. The operating system is Windows XP, and the main frequency of CPU is 2.60 GHz. The memory is 2.0 GB. The programming language is Visual Basic. The traditional JSP problem can be regarded as a special case of unique and fixed FJSP of machine selection chain. Therefore, this algorithm can be applied to solve JSP and FJSP problems.

3.1. Parameter Setting. In this example, the simulation parameters include number of paper $N = 4$; number of

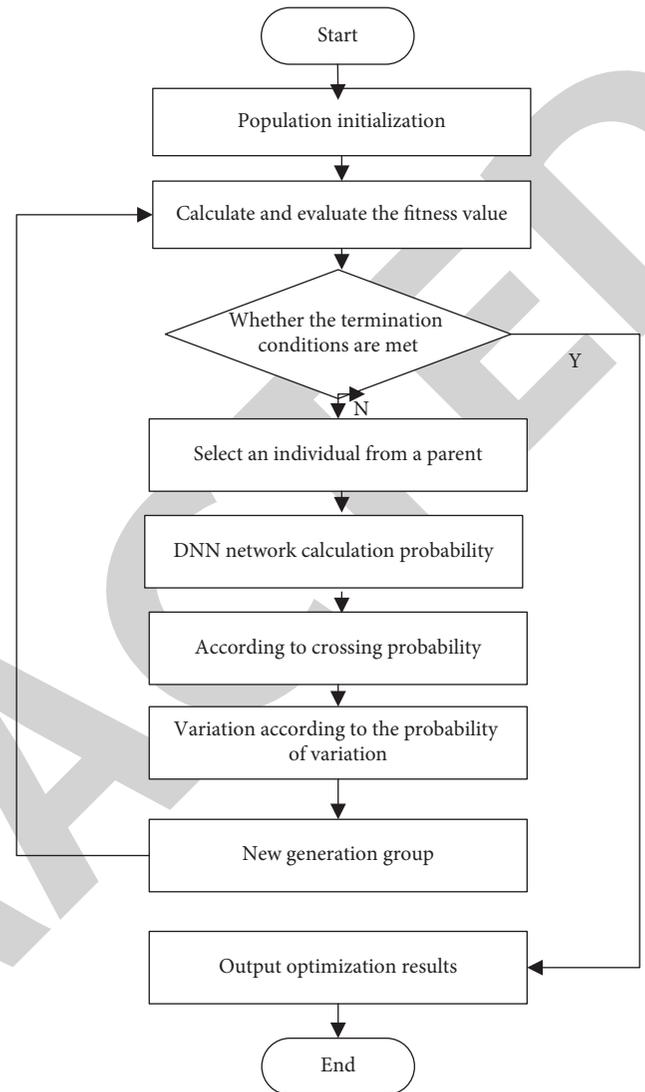


FIGURE 5: Basic flow chart of genetic algorithm.

machines $M = 10$; number of workers $W = 7$; number of individuals $Z = 50$; number of iterations $Y = 100$; selection probability $P_g = 0.9$; cross probability $P_c = 0.8$; and variation probability $P_m = 0.1$. The paper processing process was repeatedly simulated ten times.

3.2. Evaluation Index. The performance index of workshop scheduling problem is the standard for production managers to evaluate the scheduling scheme. According to the different production demand, the scheduling indexes are different. Based on the summary of workshop scheduling performance indexes by Jia Zhaohong and Zeng Qiang, this article divided the performance indexes of workshop scheduling into the following categories: performance indexes based on completion time, performance indexes based on delivery time, performance indexes based on cost, performance indexes based on machine load and processing quality. Now, the performance indexes based on completion time are selected. The completion time refers to the time of

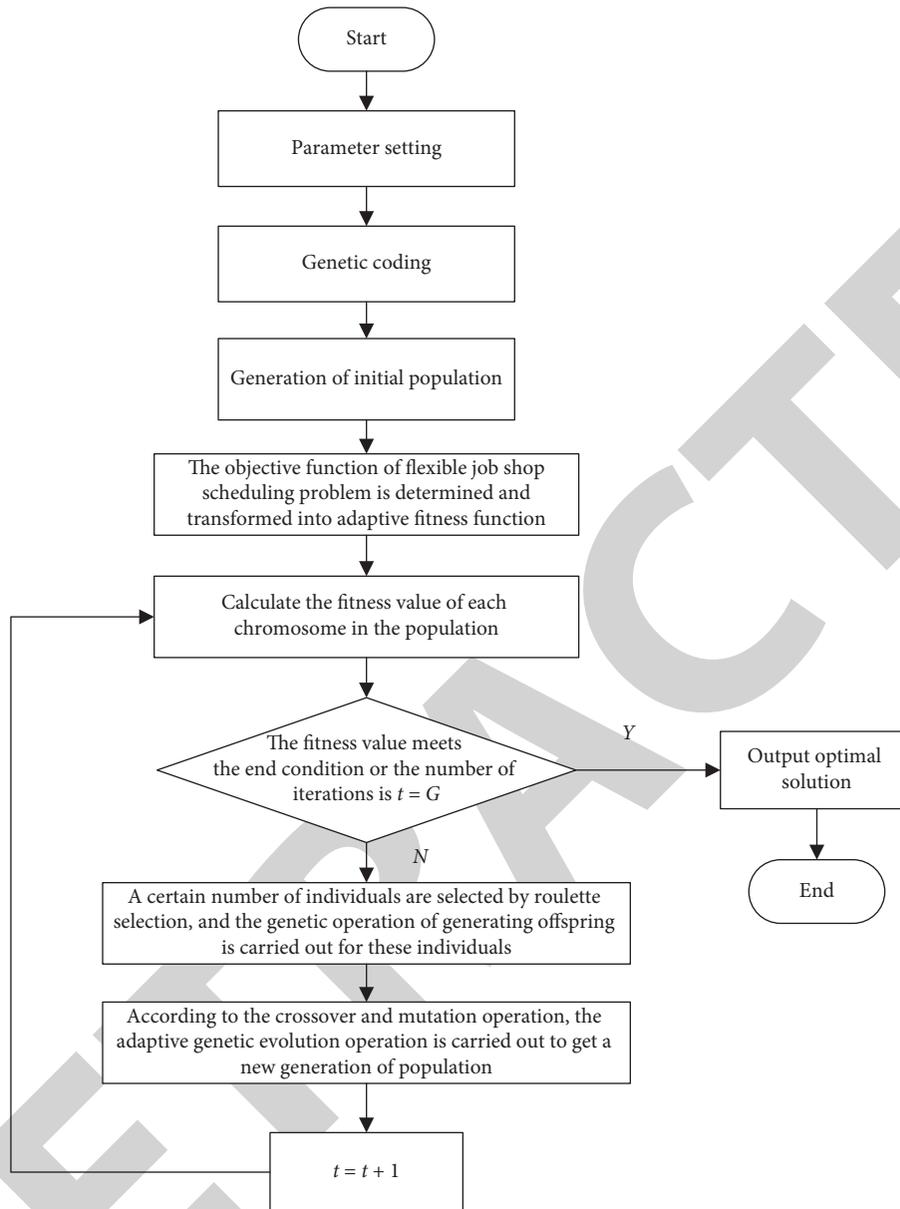


FIGURE 6: Fuzzy scheduling model solution of flexible job shop based on genetic algorithm.

finishing all the papermaking processes. The performance index based on the completion time is the most fundamental index to measure the scheduling performance, which can reflect the production efficiency of workshop, so it is also the most widely used performance index in the field of workshop scheduling research. It mainly includes maximum completion time, average completion time, maximum passing time, total flow-through time, weighted flow-through time, average flow-through time, and weighted average flow-through time.

3.3. Result Analysis. The experimental results verify that the proposed scheduling method is an optimization method with high quality and fast convergence speed. In order to ensure the reliability of the experimental results, select a workshop real data comparison contrast experiment. The

experimental simulations were performed using MATLAB software. The method of this paper is based on operational research method, heuristic rules, and swarm intelligence optimization algorithm of workshop flexible job data scheduling method. The experimental parameters are the same as the improved algorithm.

Table 4 shows that the proposed method can get the optimal solution for 48 sec at the 23rd attempt. Respectively, the other three methods converge to the optimal solution for 52 sec at the 40th attempt, for 50 sec at the 38th attempt, and for 61 sec at the 44th attempt. Through comparison, we can see that the proposed method has many advantages. It not only makes the maximum completion time shorter, but also accelerates the convergence.

Figure 7 shows the change process of the weighted target value in the algorithm. It can be seen from the figure that the

TABLE 4: Result analysis.

Project	Optimal algebra	Computing time (s)
Article method	23	48
Operational research method	40	52
Heuristic rule method	38	50
Swarm intelligence optimization algorithm	44	61

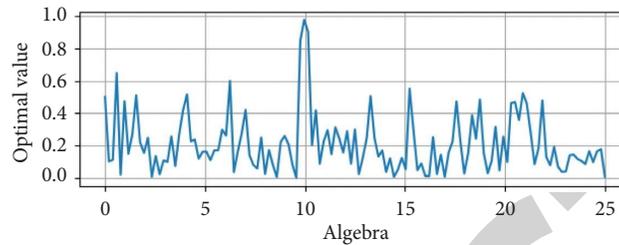


FIGURE 7: The change process of the optimal value.

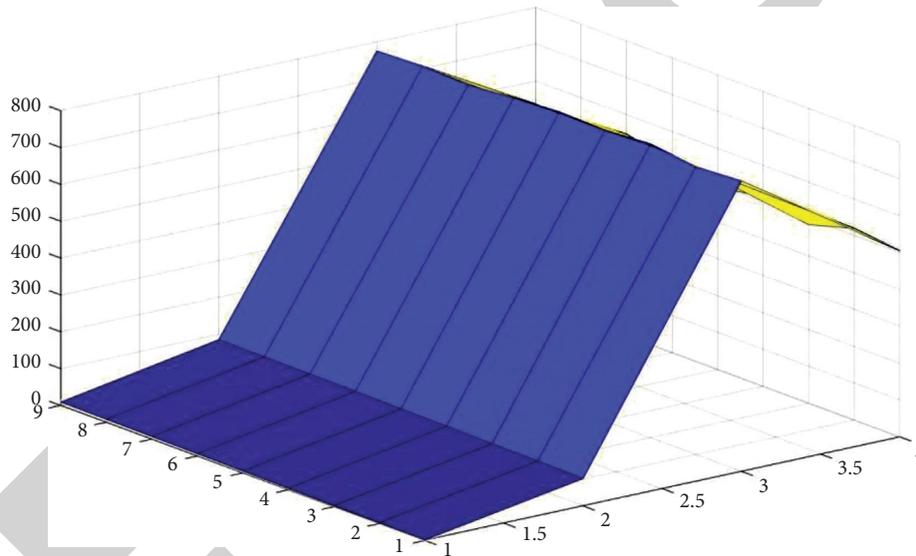


FIGURE 8: The final Pareto solution set.

overall trend of the optimal value is gradually optimized as the algebra of the algorithm increases, but, locally, the change of the optimal value has more fluctuations.

The Pareto solution set finally solved by the Pareto optimization method has multiple solutions or individuals, which can provide multiple feasible optimization solution sets for comparison for flexible job shop scheduling. The distribution of Pareto solutions in the time-cost-quality space is as follows, highlighted by Figure 8. Optimize the target weights according to the set schedules, and calculate the algorithm fitness value of each individual solution in the Pareto optimization solution set. This value is unique, and the final satisfaction of the decision optimization is done by calculating the fitness value and selecting the smallest value individual or solution. The corresponding scheduling plan Gantt chart is shown in Figure 9.

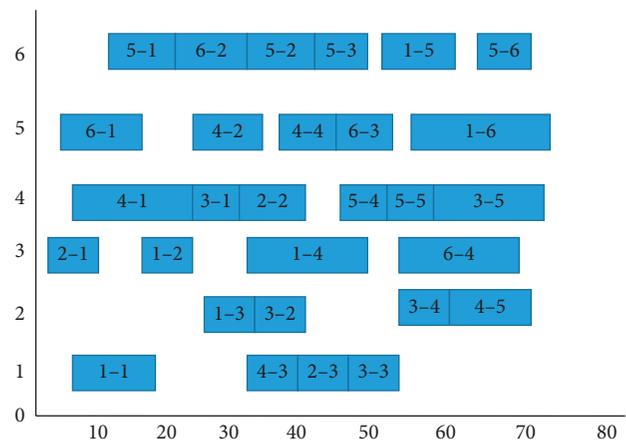


FIGURE 9: Gantt chart.

4. Conclusions

Job shop scheduling problem (JSSP) is one of the most famous machine scheduling approaches and at the same time extremely difficult combinatorial optimization problems. The main reason is the complexity and dynamic characteristics in the scheduling environment. Meanwhile, a large number of randomness and factors which are difficult to be quantified make the problem more difficult to be solved. With the development of fuzzy mathematics, the idea of fuzzy mathematical programming is applied to the scheduling field, forming an important branch of uncertain scheduling: fuzzy scheduling. The traditional real-time scheduling methods cannot deliver on-time, inventory problem of high cost and low equipment utilization rate; therefore, this paper puts forward an algorithm based on improved fuzzy flexible job real-time data scheduling method of papermaking workshop. On the basis of the scheduling problem in the flexible job shop, a fuzzy scheduling model for flexible job data in papermaking workshop was established. Through the comparison experiment, we can see that the method in this paper has more advantages, which not only makes the maximum completion time shorter, but also speeds up the convergence speed, thus achieving the purpose of this study. In the future, the utilization rate of scheduling equipment will be considered as a research method to further improve the proposed method.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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