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Research on Job Shop Scheduling based on Smart Prediction of Disturbance

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Abstract:

In order to solve the problems of equipment failure and cross process production and collaborative scheduling in discrete manufacturing, this paper proposed a method about a disturbance intelligent reasoning mechanism based on manufacturing big data and improved case-based reasoning. The probability probability of disturbance was analyzed, which the corresponding disturbance similarity threshold was calculated combined with the hierarchical attributes of cases. Combined with prediction of disturbance, in order to minimize the maximum completion time and minimum carbon emission, a hybrid discrete bat algorithm combined with simulated annealing algorithm was designed. Taking the production of engine cylinder head as an example, the proposed algorithm may reduce the production cycle of cylinder and the total carbon emission in the manufacturing process.

Keywords*: Job Shop Scheduling, Disturbance prediction, Cross process, Improved case-based reasoning, Hybrid discrete bat algorithm.*

I. INTRODUCTION

Fire Many uncertain disturbances will occur during workshop production, such as equipment failure, processing delay, emergency order projection, etc. these uncertain disturbances will affect the normal production operation of the workshop, reduce the scheduling effect of the original scheduling scheme, and even invalidate the scheduling scheme. How to deal with workshop disturbance events and ensure efficient and normal production has become a research hotspot in recent years. Armentano et al. [1] solved the minimization problem of production and inventory cost of vehicles with limited distribution cycle and limited volume through tabu search algorithm.

Tian et al. [2] took the disturbance event represented by equipment failure as the trigger point of rescheduling, and proposed an adaptive rescheduling method based on the queue

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control. Li et al. [3] took the workshop real-time order and equipment failure as the rescheduling trigger point, and used the artificial bee colony algorithm integrating tabu search to solve the rescheduling problem triggered by multiple types of events.

The intelligent prediction of workshop disturbance has become the research difficulty of rescheduling solution. Because time-based scheduling can not effectively solve workshop emergencies, and workshop production disturbance is multi-source, the rescheduling trigger mechanism considering the overall situation of the workshop is difficult to meet the requirements of intelligent workshop for real-time decision-making. However, the rescheduling of workshop often falls into the contradiction of how to ensure the effectiveness of scheduling and system stability. In recent years, the continuous development of artificial intelligence technology provides a new idea for the scientific research of job shop rescheduling. Hyung et al. [4] introduced genetic algorithm into the retrieval process of case-based reasoning and realized the generation of case weight through genetic algorithm. Although the above studies consider the generation of workshop disturbance, it is still difficult to solve the workshop rescheduling problem.

II. DISTURBANCES PREDICTION

2.1 Literature Review

With the increasing improvement of science and technology and the continuous expansion of research content, disturbance prediction methods have emerged in different fields and research objects. Disturbance prediction can be divided into three methods: model-based, knowledge-based and machine learning. Among them, the model-based method has good prediction performance because of its strong pertinence, but the implementation cost is high, and the knowledge-based method has the widest application range and less application difficulty, but the prediction accuracy and accuracy was low; as the method based on machine learning is mainly based on algorithm and input data, it has ideal results in the applicability, implementation cost and prediction accuracy of disturbance cost.

2.1.1 Model based approach

When the state of the research object can be established by accurate mathematical expression or the solution of disturbance judgment is obtained by mathematical statistics and transformation, the model-based method can be used to predict the future development trend and law of the object, calculate the difference between the predicted output value and the actual output value, and then predict the time or possibility of failure in advance. Cai guojuan et al.

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fitted the service life of mechanical seals with historical data and compared the normal distribution, normal distribution, exponential distribution and two parameter Weibull distribution respectively. The results show that normal distribution has good performance in predicting the average service life of mechanical seals. Dai Yuchao et al. [5] established the equipment degradation performance model of Wiener process and realized the remaining life prediction of key parts. Chen and Jin [6] established a process model of product quality characteristics based on noise variables and process variables, revealing the relationship between component performance and product quality. He et al. [7] proposed an equipment failure rate function based on proportional risk model, considering that the initial failure rate of equipment obeys Weibull distribution and under the disturbance of equipment performance degradation affecting the failure rate. The method based on mathematical function distribution is not widely used in practical workshop because of its single research object and long test period of parameter adjustment. Heck and McClellan [8] introduced HMM into the machining system and effectively realized the detection and prediction of cutting tool wear. Ferguson makes the HMM state dwell time explicit to form a hidden semi Markov model, which overcomes the limitations of Markov chain hypothesis [9]. With the change of constituent elements in the workshop or the trigger of multivariate disturbance, it is difficult to meet the needs of real-time disturbance prediction.

2.1.2 Knowledge based approach

Knowledge based methods mainly include the failure model and FMEA, the expert system (ES) and rough sets (RS) theory. Xiao et al. [10] expanded the definition of RPN in 2011, multiplied it with weight parameters, and adopted the minimum cut set theory, which has been well applied in multi fault modes and complex systems. Sun et al. [11] established a new FMEA system in 2017. The system integrates database, facilitates self maintenance and information sharing, and realizes connection with other relevant production systems. Yazdi [12] used fuzzy set theory to deal with the possible uncertainty in FMEA evaluation in 2018, and solved the problem of target weight by using analytic hierarchy process and entropy technology. Shafiee et al. [13] proposed a comprehensive fault tree analysis and FMEA model in 2019 to eliminate the defects of weights in traditional methods.

The earliest expert system, Deneral, came out in Stanford University in 1965 [14], which mainly experienced five stages: rule-based, object-based, case-based, model-based and network-based. Rule based es [15] is also the most widely used, and the expert knowledge can be expressed in the form of if-then rules. Guo Yu and Yang Yu [16] combined neural network and grey rough set to effectively improve the accuracy of fault prediction.

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2.1.3 Method based on machine learning

The disturbance prediction methods based on machine learning can be divided into two categories: supervised learning and unsupervised learning.

Zhang Yifei and Zhao Kai [17] took frequency combination as rotor data attribute and used the decision tree to build rotor operation fault model. The results show that it has high accuracy in rotor fault prediction. Ji and Wang [18] put forward the concept of job shop scheduling disturbance prediction, and verified the feasibility of the method by decision tree method.

The disturbance prediction method based on machine learning does not need the analytical model or expert knowledge of the known research object, only the historical data or real-time data of individual or system operation, and applies machine learning related technologies to find the laws hidden behind the data. It is a method with low relative cost and excellent prediction accuracy, which can be used in high information level it has been well applied and implemented in practical engineering problems. However, for the problems of different research objects and models, choosing appropriate machine learning methods and improving them to improve the prediction accuracy is a problem to be solved in the future.

2.2 Data Processing

The characteristics of disturbed data are multi-source, heterogeneous and nonlinear. According to the different impact of disturbance on products and processes, the impact of disturbance on production is recorded. After preprocessing, it is stored in a separate database through the industrial Internet.

The disturbance data record includes the following contents. On the one hand, observe the impact of disturbance on production by recording the occurrence time and frequency of disturbance, select appropriate data storage methods from the analysis of influencing factors of disturbance to the optimization of disturbance, reasonably improve and use the disturbed data, so as to prepare for subsequent disturbance analysis. On the other hand, to optimize the process from process analysis to product performance, the decision tree method can be used to find the bottleneck to solve these problems. Select the appropriate data mining model and data knowledge discovery model according to the different needs of products, equipment and workshops. Distributed computing framework for massive data processing, that is, storm for real-time data processing. Perform data preprocessing to eliminate redundant and noisy data.

Data processing is briefly described as follows:

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Firstly, the disturbance classification and parameter matrix library was established to collect real-time disturbance influence data, so as to obtain the amount of data.

Second, data cleansing operations can reduce redundancy. The data cleaning process is as follows: 1) define the data cleaning operation of input and constraints; 2) Select data from the data warehouse cube; 3) Check whether each cell of the data cube meets the predefined constraints; 4) If the conditions are not met, the unit will be deleted from the data cube; 5) Repeat 2 to 4) until all data cubes are traversed; 6) The output and return has cleaned up the data cube.

Third, the cleaned life cycle data is usually still fragmented. Data integration operations must be performed. Through meta model instantiation, sharing and data integration models are realized.

Then, the dimension of data compression is calculated. Data transformation strategies include smoothing, aggregation, normalization and discretization.

Finally, the cyclic data stored in XML. XML is preprocessed, which is often used to describe the cycle of semi-structured data; in order to standardize the data format, the data is uniformly stored in the relational database management system.

2.3 Improved Case-Based Reasoning

At present, the decision-making cases of complex and changeable disturbance events are not clearly expressed in workshop rescheduling. In this paper, the reasoning research based on manufacturing big data and case search is used. Firstly, the characteristic attribute weight of disturbance is determined, the corresponding similarity calculation formula is designed, and the order relationship analysis method is improved in combination with index contribution rate and kernel density estimation, it reduces the impact of human subjectivity on the evaluation results and improves the accuracy of case matching. Classify the disturbance, finally determine the threshold of each attribute, improve the intelligent prediction accuracy of disturbance, and prepare for the next rescheduling

If there is no disturbance event during the processing of a workpiece in a process, the value of the status information is 0. If a disturbance event occurs in the processing of this process of the workpiece, the value of the status information is the class diagram of the workshop disturbance according to the previous data, and the sub disturbances of each disturbance continue to be numbered according to the above rules. If a disturbance event of processing

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equipment occurs in a process of a workpiece, the value of the status information is 3, which represents the type of workshop disturbance through numerical elements.

The similarity matching algorithm of characteristic attributes of workshop disturbance cases is introduced, and the order relationship analysis method is used to solve the end attribute weight set. The final weight value is determined by kernel function to improve the accuracy of case matching, and the coping strategy of disturbance is determined by calculating the similarity between target cases and historical cases. Based on the order relation analysis (G1), this paper introduces the index contribution rate and kernel density estimation to improve it and reduce the influence of human subjectivity on the evaluation results

This paper defines $\omega_i(i=1,2,\cdots,m)$, which ω_i is from ω sample values. $\hat{f}_h(\omega)$ was defined $f_h(\omega)$ as Kernel density estimation.

$$\hat{f}_h(\omega)=\frac{1}{mq}\sum_{i=1}^{m}K(\frac{\omega_i-\omega}{q}) \qquad \omega\in R \tag{1}$$

K(x) refers to kernel function, which Epanechnikov kernel function was selected in this paper.

$$K(x)=\{\begin{matrix}0.75\times(1-x^2) & x\in[-1,1]\\ 0 & x\notin[-1,1]\end{matrix} \tag{2}$$

The kernel function is used to solve the probability density curve of the sample vector, and the value of the independent variable corresponding to the highest point of the curve is the optimal solution of the attribute set.

III. ALGORITHM DESIGN

3.1 Problem Description and Modeling

Each production line sends multiple orders to the previous operation, and determines the processing batch and processing sequence. After a batch of orders are processed in the previous operation, they are distributed to the production line required by the subsequent operation according to the sequence designed by the algorithm. When all the distribution tasks of the transportation batch are completed, return to the previous operation and wait for the next distribution. When the WIP arrives at the post process, if the production line is busy, it needs to

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queue up for processing. After processing, the whole processing process of the order ends. The goal of scheduling is to minimize the maximum order completion time and the buffer time of each order in the production line queue at the same time. The objective function, that is, the sum of the minimized maximum completion time and the queue waiting time of each order before the production line is F (x).

$$F\ （X）= \omega_1 \min(\max_{j\in[1,n]} C_j) + \omega_2 \min(\sum_{i=1}^{n} E_i) \tag{3}$$

$\omega_1 . \omega_2$ refers to minimizing the maximum completion time in the objective function.

$$C_{co_2} = \varepsilon \int_0^{C_{MAX}} (\sum_{v=1}^{s}\sum_{k=1}^{m} Q_{k,v} x_{k,v}(t) + \sum_{k=1}^{m} Q_k y_k(t))dt \tag{4}$$

$\omega_1 . \omega_2$ refers to minimizing the maximum completion time in the objective function.

C_{co_2} refers to CO2 total emission;Qkv refers to unit energy consumption of machine;xkv refers to time of each machine.

3.2 Hybrid Discrete Bat Algorithm

As a new heuristic algorithm, bat algorithm inherits the advantages of harmony algorithm and particle swarm optimization algorithm, uses the echolocation principle to search multiple regions in the solution space to be optimized at the same time, and realizes the dynamic conversion between global search and local search through the frequency tuning principle, so as to obtain better convergence than other algorithms. In order to avoid the shortcomings of bat algorithm, such as slow convergence speed and easy to fall into local optimization, simulated annealing algorithm is nested in bat algorithm to solve the cross process collaborative scheduling problem.

Firstly, Initialization. Set the number of iterations t = 1; Initializing the position, speed, frequency, loudness, initial temperature, termination temperature and retreat coefficient of bat population[19, 20];

Secondly, calculate the initial solution

Then, the updated position was accepted through the simulated annealing mechanism of variable temperature;

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Then, solve the optimal path and determine the objective function;

Update current position objective function loudness and pulse rate;

Considering the influence of disturbance, correct it;

At last, number of iterations was reached.

IV. SIMULATION STUDY

Simulation experiments were used to verify the effectiveness of the hybrid discrete bat algorithm. The experimental object was the engine cylinder head production workshop.Cylinder head is shown in Figure 1.

Fig 1: Cylinder head

By simulating the processing time of each process in MATLAB and considering the disturbance, the Gantt chart was shown in Figure 2. Compared with the previous data, the total time and total carbon emission of the improved algorithm decreased, as was shown in Fig. 2.

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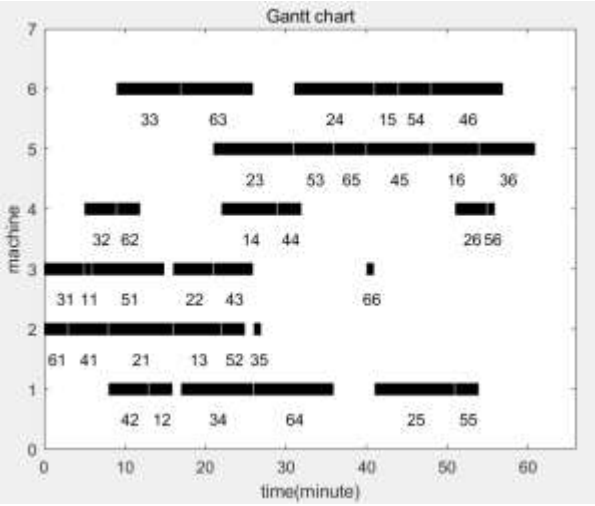

Fig 2: Gantt chart

V. CONCLUSION

In this paper, considering the workshop disturbance, an improved bat algorithm is designed, and the production scheduling problem of engine cylinder head production workshop is simulated. The simulation results show that the designed algorithm reduces the total waiting time and has good convergence. The follow-up research will focus on the intelligent prediction of disturbance, combine the threshold of disturbance with the convergence of scheduling algorithm, consider the actual production situation of workshop, and improve the applicability of the algorithm.

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