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Active Shop Scheduling Of Production Process Based On RFID Technology

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Abstract. In industry 4.0 environment, intelligent technology is almost applied to all parts of the manufacturing process, such as process design, job shop scheduling, etc.. This paper presents an efficient approach to job shop scheduling actively by using RFID to collect real-time manufacturing data. Identified the workpiece by RFID which needs to be machined, it can “ask for” the resource actively for the following process. With these active asking-for strategy, a double genetically encoded improved genetic algorithm is proposed for achieving active job shop scheduling solution during the actual manufacturing process. A case was used to evaluate its effectiveness. Meanwhile, , it can effectively and actively carry out job shop scheduling and has much better convergence effect comparing with basic genetic algorithm. And the job shop scheduler in management center can use the proposed algorithm to get the satisfied scheduling result timely by reducing waiting time and making begin time earlier during transmission between manufacturing process, which makes the scheduling result feasible and accurate.

1 Introduction

With the Cyber-Physical System (CPS), industry 4.0 make the business process, such as manufacturing and sales, much more intelligent and efficient. It has two typical characteristics, intelligence and information interconnected. In modern manufacturing workshop, more and more intelligent technology has been used, more and more enterprise adopt manufacturing execution system (MES) to manage workshop production and shop scheduling[1]. The processing data in the real workshop is extremely complicated due to the collection of logistics and information flow. Thus, effective active job shop scheduling, based on the processing data, can ensure that the real-time production can run efficiently and the products can be delivered to customer on time, which is vital and affect the overall performance of a manufacturing enterprise greatly [2].

RFID makes use of radio frequency signals to acquire the tag information automatically [3]. The advantages of RFID, such as high-speed recognition and high-reliability, are suitable for data collection in the manufacturing process with the requirements of accuracy and real-time[4]. In this paper, an intelligent and active job shop scheduling system, based on RFID, is proposed. By using RFID, the information of the manufacturing equipment and the workpiece can be collected in the intelligent shop floor. And the real-time processing data of the workpiece would be uploaded to the database servers. Based on the real-time processing data collected through RFID actively, the system can analyze the data and extract the necessary variables as the input of the proposed algorithm. By executing the scheduling algorithm, the optimal scheduling solution can be got.

2 Acquire Real-time Process Data Based On RFID

2.1 Data Acquisition Hardware Configuration of Shop Floor

The hardware configuration of shop floor including the network environment, physical position of RFID equipment is shown in Fig.1.

The RFID readers are set up at the entrances and exits of the machining area. The tag is stick on the container of workpiece. When the tag is in the scope of radio frequency signal of the RFID at the entrances, the data stored in the tag about the workpiece should be read, and simultaneity, the start time of this process is recorded. In the scope of the radio frequency signal of the RFID at the exits, the finish time of this process is also recorded. All the data of the workpiece will be uploaded to database servers.

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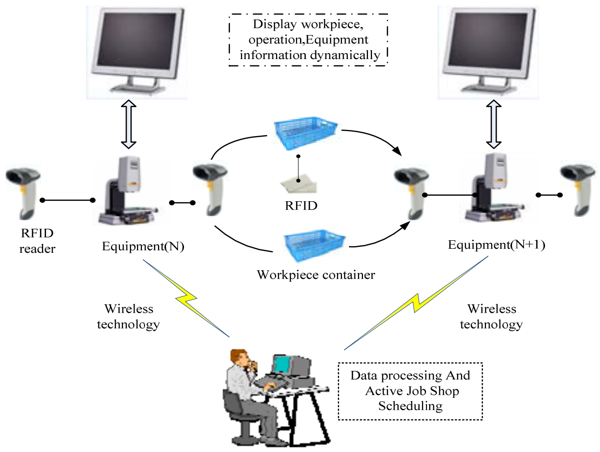

Fig.1 Hardware Configuration of Shop Floor

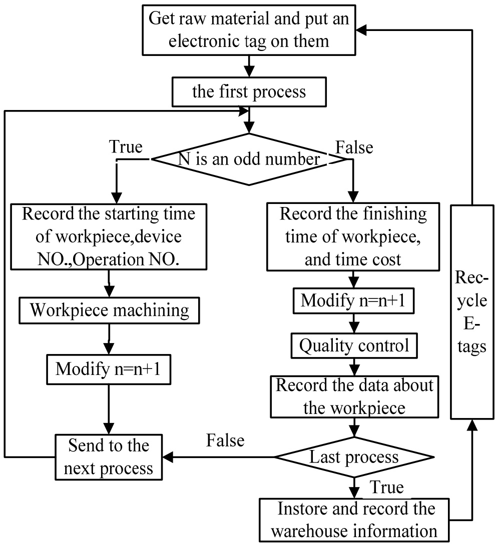

Fig.2 Data acquisition process

2.2 Data Acquisition Process

The flowchart of the entire process is shown in Fig.2.

The whole data acquisition processes are as follows: (1) Initial the electronic tag and put it on the raw material. (2) The count value n stored in the tag is judged. If n is an odd number, it means the beginning of the process, and record the starting time of workpiece, device number, etc., otherwise, record the finishing time, etc., and then, increase the value n by 1, send the workpiece to quality control and record the inspection data. (3)If it is not the last process, the workpiece is transferred to the next step, and repeat the step 2. Otherwise, the workpiece will be put into storage, and record the warehouse information. Then, the electronic tag is taken down to recycle.

3 Active Job Shop Scheduling

In the real manufacturing process, traditional job shop scheduling has precocious phenomenon, bad performance of convergences and real-time[5,6]. This paper proposes a double genetically encoded improved genetic algorithm for active real-time scheduling, which made the job scheduling more intelligent and efficient. And the real-time information of the workpiece type, the real-time machine status, the current operation, operation time and required resources of the next operation, etc., can be collected by RFID. When the real-time acquired information is taken as the input data of the proposed algorithm, more feasible and efficient real-time scheduling solution can be got actively

3.1 Problem Description

The real-time job shop scheduling can be stated as follows. It is given a set of jobs $N_t = \{J_i \mid 1 \le i \le n\}$ to be processed on a set of optional machines $M = \{m_i \mid 1 \le i \le m\}$. The definitions of some symbols are: t--production unit; $O_{i.j}$ --operation j of job J_i; $U_{t,i}$ --the operations of job (workpiece) J_i at t, and $J_i = \{O_{i,j} \mid 1 \le j \le U_{t,i}\}$; $P_{i,j}(m_k)$ --processing time of operation $O_{i.j}$ at m_k ; $S_{i,j}(m_k)$ --starting time of operation $O_{i.j}$ at m_k ; $C_{i,j}(m_k)$ --completion time of operation $O_{i.j}$ at m_k ; $T_i\,(m_k, m_{k+1})$ --the transit time between m_k and m_{k+1} of job J_i .

Assuming that once an operation has started, it could not be interrupted (Except equipment breakdown); different jobs have the same operation priority; there is no constraint among the operations of different jobs; the operation transit time is considered among the machines. The goal is to complete all operations as early as possible, which is known as minimum makespan time[7,8]. And the objective function is:

$$F = \min\{\max(C_{i,U_{t,i}}(m_k))\} . \tag{1}$$

The constraints are:

$$S_{i,j+1}(m_{k+1}) - S_{i,j}(m_k) \ge C_{i,j}(m_k) \tag{2}$$

$$S_{i,j}(m_k) \ge C_{x,y}(m_k) . \tag{3}$$

$$C_{i,U_{t,i}}(m_k) \le D_i \tag{4}$$

$$i, x \in [1,n], j \in [1,U_{t,i}], y \in [1,U_{t,x}], k \in [1,m] .$$

Where D_i represents the due time of job J_i . Eq.2 ensures the right sequence of the operation, $O_{i.j+1}$ of job J_i started only after $O_{i.j}$ finished; Eq.3 ensures each operation can occupy only one machine m_k at a time; Eq.4 guarantees that all jobs are complete before delivery

3.2 Solution to Active Real-time Job Shop Scheduling

Based on the hardware configuration in this paper, when the RFID reader reads the tag of workpiece, the real-time information will be uploaded to the database servers actively. And the real-time information will be put into the improved genetic algorithm with double genetic code, which is proposed in the project for active real-time job shop scheduling. The flowchart of the genetic algorithm is shown as Fig.3.

The main part of the proposed algorithm is: encoding and fitness function of GA; decoding and selection; crossover operation and mutation operation. The details are as follows:

(1) Encoding and Fitness Function of GA. Considering both the operation order and the optional machine of the operation, a double layer encode is adopted. The first layer is used to ensure the consequence of operations. And the second is used to choose the suitable machine. Chromosome Coding is shown as Fig.4.. The total length of chromosome coding is $L = 2\sum_{i=1}^{n} U_{t,i}$, and each double coding corresponds to a scheduling scheme. Fitness function $f = \dfrac{1}{F}$, where F is objective function.

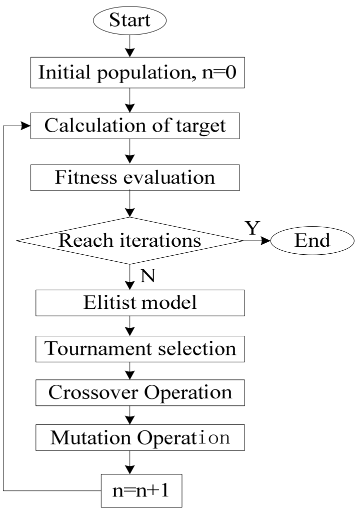

Fig.3 Genetic algorithm flowchart

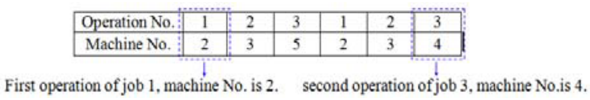

Fig.4 Chromosome Coding

(2) Decoding and Selection. Arrange all the operations in the feasible earliest location one by one during decoding, choosing the machine for every operation based on the machine gene first; then, arrange the operation order on every machine based on the operation gene. Elitist model and tournament selection is adopted for selection. Elitist model copy one percent of the best parent to the next generation directly. If the random number is less than R (R is a parameter, usually set to 0.8), tournament selection choose the superior one between the randomly generated samples; if not, choose another.

(3) Crossover Operation. Crossover operation includes crossover for machine gene and crossover for operation gene. The procedure of crossover for operation gene is: all the workpieces are divided into two sets P1 and P2. Progeny chromosome Child1/Child2 will inherit the workpiece gene in P1. The remaining position of Child1/Child2 is filled with the set of Parent2/Parent1 gene in P2 sequentially, as is shown in Fig.5.

Multipoint crossover is used for crossover of machine gene. Generating a random set which is composed of 0 and 1, its size is equal to the length of the chromosome. The parent genes are exchanged where the position is corresponded to the random number 0. And the result is the progeny gene. If the number of the machine generated in the crossover is more than the available machines, choose an available machine randomly, as is shown in Fig.6.

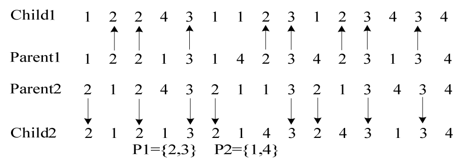

Fig.5 Crossover for operation

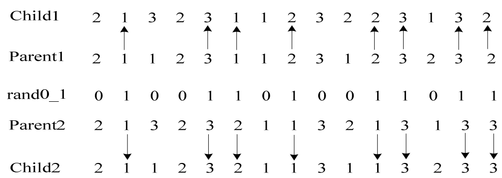

Fig.6 Crossover for machine

(4) Mutation Operation. It includes the mutation of operation code and machine code. The mutation of the operation code uses swap mutation. Select two position for mutation randomly, and then exchange the genes of the corresponding position of the operation code in the first tier and the code of operation machine in the second tier, as is shown in Fig.7.

The machine code mutation chooses one location for mutation randomly of the machine code in the second tier. Then, choose one device number from the set of optional machines in the corresponding position. Finally, replace the original serial number with the device number, as is shown in Fig.8.

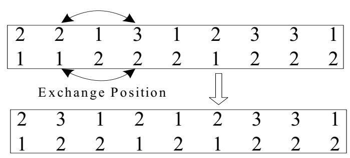

Fig.7 Mutation of operation

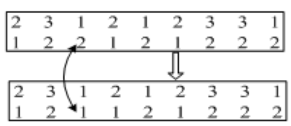

Fig.8 Mutation of machine

4. Case Study

In order to verify the validity of the improved double coding genetic algorithm proposed in this paper, 10 jobs and 10 optional machines of shop scheduling problem were analyzed. The machine and the operation time are indicated in the Fig.9.

In MATLAB, the improved double coding genetic algorithm proposed in this paper and the basic genetic algorithm are used to analysis the case. The parameters of the genetic algorithm are set as follows: Population size N = 100, the number of iterations is 100, mutation probability Pm = 0.1, crossover probability Pc = 0.8, run 10 times, choose the average of the optimal solution. Genetic algorithm iteration contrast diagram and Gantt chart scheduling of the proposed algorithm are shown in Fig.10 and Fig.11 after running the algorithm. Fig.10 shows that the proposed double coding genetic algorithm is superior to the basic genetic algorithm in improving the quality and efficiency, and the convergence effect is also much better. Fig.11 shows the result of active job shop scheduling, and iOj on the rectangle symbols that the rectangle corresponding to the operation j of job i. The chart shows that the highest utilization machines are machine 4 and machine 6.

Job	Operation	Machines And Operation Time									
		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
J1	011	1	4	6	9	3	5	2	8	9	5
	012	4	1	1	3	4	8	10	4	11	4
	013	3	2	5	1	5	6	9	5	10	3
J2	021	2	10	4	5	9	8	4	15	8	4
	022	4	8	7	1	9	6	1	10	7	1
	023	6	11	2	7	5	3	5	14	9	2
J3	031	8	5	8	9	4	3	5	3	8	1
	032	9	3	6	1	2	6	4	1	7	2
	033	7	1	8	5	4	9	1	2	3	4
J4	041	5	10	6	4	9	5	1	7	1	6
	042	4	2	3	8	7	4	6	9	8	4
	043	7	3	12	1	6	5	8	3	5	2
J5	051	7	10	4	5	6	3	5	15	2	6
	052	5	6	3	9	8	2	8	6	1	7
	053	6	1	4	1	10	4	3	11	13	9
J6	061	8	9	10	8	4	2	7	8	3	10
	062	7	3	12	5	4	3	6	9	2	15
	063	4	7	3	6	3	4	1	5	1	11
J7	071	1	7	8	3	4	9	4	13	10	7
	072	3	8	1	2	3	6	11	2	13	3
	073	5	4	2	1	2	1	8	14	5	7
J8	081	5	7	11	3	2	9	8	5	12	8
	082	8	3	10	7	5	13	4	6	8	4
	083	6	2	13	5	4	3	5	7	9	5
J9	091	3	9	1	3	8	1	6	7	5	4
	092	4	6	2	5	7	3	1	9	6	7
	093	8	5	4	8	6	1	2	3	10	12
J10	010，1	4	3	1	6	7	1	2	6	20	6
	010，2	3	1	8	1	9	4	1	4	17	15
	010，3	9	2	4	2	3	5	2	4	10	23

Fig.9 Known data of the case

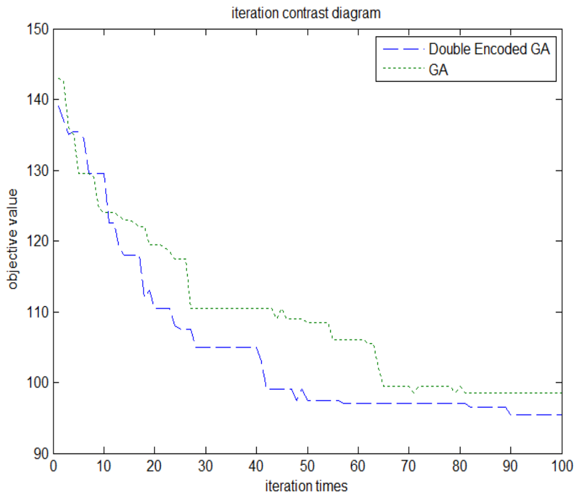

Fig.10 Iteration contrast diagram of GA

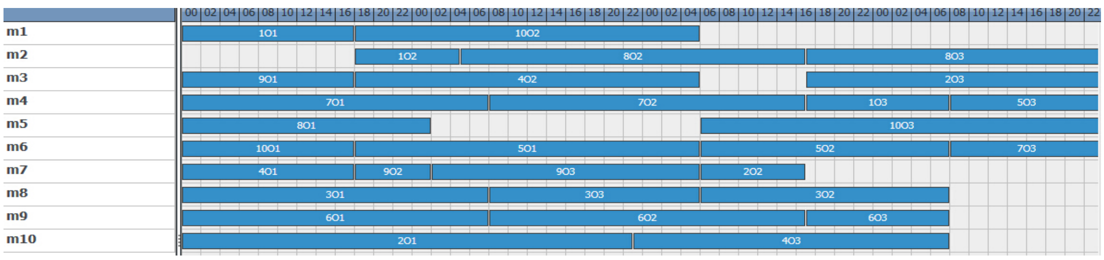

Fig.11 Gantt chart scheduling of the proposed algorithm

5. Summary

Job shop scheduling problem is one of the NP-hard problems. It is also very difficult to apply the scheduling algorithm conveniently and efficiently in real industry. This paper proposes a novel approach to simplify the scheduling problem, increase the feasibility of the schedule result and make the manufacturing execution process more intelligent and efficient, which adopt real-time manufacturing information acquired from RFID, appropriate and leisure resources asked by certain workpiece, and certain operation time into an improved genetic algorithm. Based on those real-time states of manufacturing resources, it makes the schedule result more effective and reliable.

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