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Application of Genetic Algorithm on Production Scheduling of Elastic Knitted Fabrics

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Abstract: We develop a scheduling system for elastic knitted fabric production. The system is designed to assist the production controller to schedule production rapidly to satisfy customer orders. In this system, the input data are collected directly from the Enterprise Resource Planning (ERP) system. The input data contains the basic information regarding customer orders such as order number, order volume and so on. In this study, we use the genetic algorithm to be the analytical tool. The system can automatically schedule production depend on the fitness function. Moreover, the system provides to adjust manually by just drawing the mouse cursor onto the selected job to the position they like and release the mouse and the system will reschedule the production. The system is designed to be easy to use, flexible, automatic and adjustable. For this reason, the system is suitable to the production of the elastic knitted fabric.

Key words: Production scheduling, genetic algorithm, knitted fabric

INTRODUCTION

Elastic yarn which is a highly stretchable synthetic fiber than human hair was one of the most important discoveries in textile industry in the 20th century. It has unique characteristics in comfort wear, wrinkle resistance, elasticity and form fitting. Therefore, the production of elastic fabric has long been a focused issue since it was developed.

The production processes of the elastic fabric are very complex and require much domain knowledge. This makes it very difficult to arrange the production scheduling well. A good scheduling system of elastic fabric production is thus greatly needed. However, it is not easy to find a suitable scheduling system for a company since the operational environment and constraints are usually very different for different companies. Many businesses schedule production depending on the experiences of senior schedulers. Owing to the complexity of production situations and some inherent constraints of the company and human, it may produce unexpected results. It is, therefore, very important to provide a scheduling system that can help controller to arrange fabric production more easily, automatically, conveniently and flexibly.

The purpose of this study is to develop a scheduling system for elastic knitted fabric production. We employ the Genetic Algorithm (GA) which is demonstrated by many previous studies to be very effective to schedule production to get a good solution in short time. The system is designed to be flexible, automatic and adjustable and suitable to the production of the elastic knitted fabric.

MATERIALS AND METHODS

In this study, we use the Genetic Algorithm (GA) to solve the production scheduling problem. The scheduling problem is NP-hard problems[1]. No known algorithms can generate the optimum solutions in an amount of time that grows according to a polynomial function for such problems. But, we can quickly get approximate solutions within short time by using GA. In this section, we will briefly present the GA.

Genetic Algorithm (GA): Recently, many researchers applied genetic algorithms to solving the problems of scheduling production. GA is a global search method. It is firstly proposed by Holland[2] in 1975. The method mimics the biological process of natural selection and evolution[3-4]. GA assigns a fitness value to each individual in the population according to the specific fitness function. GA uses the fitness function to evaluate the adaptive degree of parent and offspring

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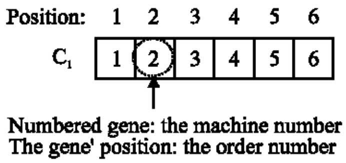

Fig. 1: The encoding of a chromosome

chromosomes. The first step of GA, we need to analyze the specific problem properties. Then, we need to decide the encoding, the fitness function and the number of initial population, the genetic operator and the genetic parameter. The genetic operators, selection, crossover, mutation, iteratively proceed to generate next offspring. The best-fit chromosomes in the parents and offspring will be selected for the next generation. Those processes are iterative until either a limited number of generations are reached or no further improvement can be reached. The genetic operators will be explained in more detail in the following.

Encoding of chromosome: In GA, a problem's solutions are represented as chromosomes. A chromosome stands for a feasible solution of a problem. The chromosomes are randomly generated. The chromosome C_k is represented by a sequence of genes g_i i = 1...n, where n is the number of an order[5,6]. Each gene g contains two bits of information: (1) gene' position represents the order number and (2) the number of gene indicates the machine number. We use the Fig. 1. as an example. The chromosome has six machines, M1, M2, …, M6. There are six genes in the chromosome C_1. The chromosome C_1 represents the first chromosome in the population and it is consisted of the six genes, 1, 2, …, 6. Using this chromosome as an example, $g_2 = 3$ indicates that machine 3 is assigned to order 2.

Initial population: In GA, we must generate a number of chromosomes as the initial population which is the initial feasible solutions (generation 0)[6]. In this study, we adopt the random method to generate the initial population. The number of the initial population is an important parameter. A suitable number can be assigned to get a good initial solution.

Fitness function: As we complete the encodings of chromosomes, we need an evaluation method, fitness function, to measure the performance of the chromosomes. In this study, the scheduling which has the shortest total completion time stands for a high utilization of machines. We will find the shortest total completion time of scheduling by the fitness function. Hence, the

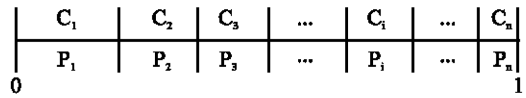

Fig. 2: Chromosome and its selection probability

controller can assign the orders to machines well according this scheduling.

Genetic operator

Selection: In each generation, offspring chromosomes will be generated through recombination processes by crossover and mutation. Therefore, we need two parent chromosomes to generate offspring. In this study, we adopt the rule of roulette wheel selection to select the parent chromosomes. This rule must consider the quality of parents. We use the C_i to represent the ith chromosome in the population. Each chromosome has a selection probability, P_i, which is proportional to its fitness value, f_i. First, all chromosomes are sorted according to their fitness values in descending. Then, the selection probability of each chromosome is calculated by dividing its fitness value to the sum of all fitness value of all chromosomes in the population. This process is repeated until the desired number of parents is obtained. A range of [0, 1] will determine the selected parent. This selection rule is similar to a roulette wheel with each slice proportional in size to the fitness value[6]. If the selection probability is greater, the chance to be chosen to be parent is also greater. The chromosome and its selection probability are shown in Fig. 2.
where

$$P_i = \frac{f_i}{\sum f_i}, \sum P_i = 1, i = ...n \quad (1)$$

Crossover: Crossover is a reproduction process. Genes which form two selected parents are recombined to generate new offspring chromosomes. Three typical crossover rules, one-point crossover, two-point crossover, uniform-point crossover, are used most. In this study, two-point crossover is employed. In two-point crossover, two crossover points are selected randomly and then the genes between two crossover points are exchanged between the parents. The procedure of two-crossover is shown in Fig. 3.

Mutation: The mutation operator will help the search to escape the local optimal solution and ensure the accessibility of the global optimal solution[6]. In this study, we randomly select two genes and swap their values. A sample mutation process is illustrated in Fig. 4.

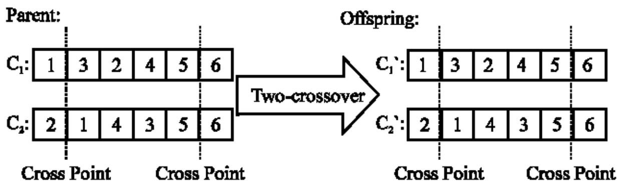

Fig. 3: Two-point crossover

Analysis

Structure of system: The system is consisted of three parts: the input database, the analytical tools and the presentation of output data. The detailed descriptions of the three parts are as follows.

Input database: The input data of the system are collected directly from the internal ERP system of a company. The input data contains the basic information about customer orders such as customer name, order number, order receipt, due day, order volume and fabric color and so on.

Analytical tools: Nowadays, there are many analytical tools, which can provide us to obtain the problem's solutions. The analytical tools include exact algorithms and heuristics, etc. These algorithms, exact algorithms, will help us find the optimal solution for the particular problem. But, we must take much more time to obtain the optimal solution by using this kind of algorithms. On the contrary, the heuristics algorithms will help us find the solution much faster than exact algorithms. These heuristics algorithms provide the good solution but not optimal solution for the problem. In this study, we use the genetic algorithm which is one of heuristics algorithm to find the solution. By using GA, we can obtain near optimal solution in an amount of time.

Presentation of output data: In order to help managers easily to understand the scheduling results and to quickly make decisions, the system uses the visualized Gantt charts to illustrate the output results.

Method of solution:

The problem: The processes of the elastic fabric production are very complex. This, therefore, makes it that to arrange the production scheduling well is difficult. A good scheduling system is thus greatly needed. In this study, we arrange the production scheduling for parallel machines of single station. The problem considered here is to get the minimum total completion time for the design scheduling while satisfying all the constraints of orders.

Fitness function: The fitness function measures the fitness of an overall assignment of orders to machines.

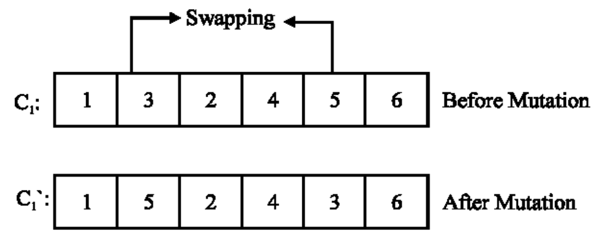

Fig. 4: Mutation on an enumerated chromosome

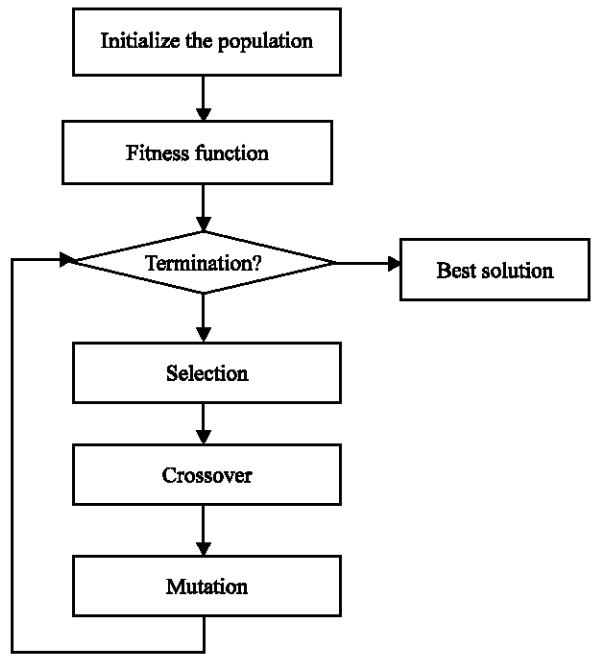

Fig. 5: Procedure for finding a solution

The problem of the production scheduling can be described mathematically as

$$\text{Minimize} \sum_{i=1}^{n} T_i \quad (2)$$

Subject to:

$$T_i \leq D_i \quad (3)$$

,where T_i is the completion time of i order and D_i denotes the due date of order I. The scheduling fitness function is Eq. (2), which is to minimize the sum of the completion time for all orders. Constraint (3) represents the completion time that must be less than the due day for all orders.

Procedure for finding a solution: In this study, we use the genetic algorithm to find the good production solution

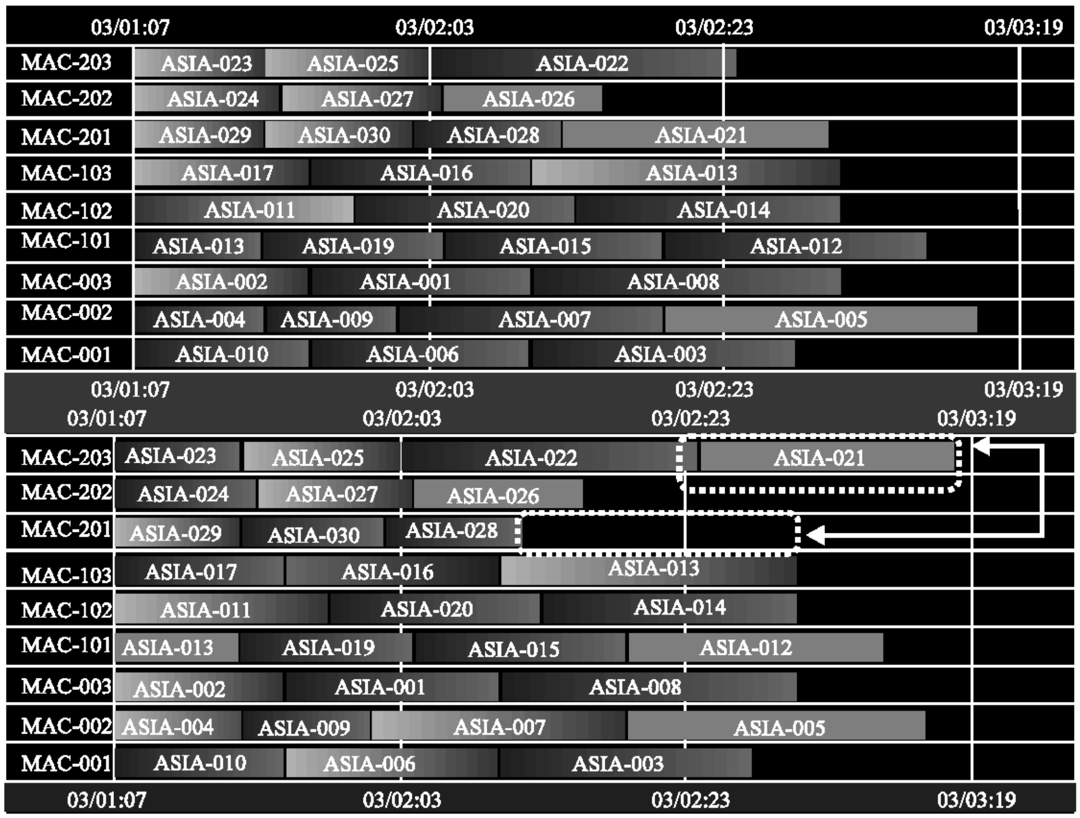

Fig. 6: The production plan after adjusting manually

for the elastic knitted fabric. The steps of scheduling the elastic knitted fabric production to find a good solution are described as follows.

- Generate the initial chromosomes (scheduling) randomly.
- Calculate the fitness value of each chromosomes by using fitness function.
- Select two chromosomes to be parent form the initial chromosomes by using the rule of the roulette wheel selection.
- Generate offspring chromosome from selected parents by two-point crossover.
- Allow offspring chromosomes to mutate.
- Calculate the fitness values of each offspring chromosomes by fitness function.
- Replace the least fit of the offspring and parent chromosomes.
- Terminate if the number of predefined cycles has been reached, otherwise go to step 3[7].

The procedure of scheduling for the elastic knitted fabric production is shown as Fig. 4.

RESULTS AND DISCUSSION

To examine the arranged production of the proposed system, we choose 25 customer orders from ERP system of the company as input data. In this study, the two-point crossover is employed. The related parameters are set as follows.

Probability of crossover: 0.8;
Probability of mutation: 0.05;
Population size: 100;
Termination condition: after 100 generations.

Figure 5 shows the automatic scheduling results. In the scheduling results, the different colors denote the fabric color for customer orders (Fig. 5). And, the bar length indicates the processing time of an order, i.e., the difference between the starting time and the finish time of an order in a machine.

Therefore, the manager can control the production in advance. Besides, manager can manually adjust by simply select job to be changed and move the mouse and then the system will reschedule the production. We can see the different between Fig. 5 and Fig. 6 after using the manually adjusted function. Managers can flexibly arrange the production.

CONCLUSIONS

We have designed a scheduling system for elastic knitted fabric production based on genetic algorithm. The system is designed to assist the production controller to schedule production within short time to satisfy customer orders. The system can automatically schedule according to the fitness function. Besides, the system provides a manually adjusted function, which can change the scheduling easily by just drawing the mouse cursor onto the selected job to be changed to the position they like and release the mouse. The system provides the company of elastic knitted fabric many advantages that can be easy to use, flexible, automatic and adjustable. Therefore, the system is suitable to the production of the elastic knitted fabric.

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