Research on Cut Order Planning for Apparel Mass Customization

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Abstract. To solve the problem of versatile sizes and irregular number in cut order planning (COP) for apparel mass customization, the mathematical model was built and optimization method based on probability search was proposed. Several cutting table layout plans were generated randomly with the production constriction. The optimized sizes combination plan was accordingly obtained using probability search algorithm. The optimization method could rapidly get the apparel cutting plan and decrease the number of cutting table.

Keywords: Mass customization, apparel, cut order planning, optimization, probability search.

1 Introduction

In current market circumstances, orders apparel enterprises received are generally versatile, middle or small batch [1]. Apparel enterprises are faced with a major challenge of quick response to customers' needs such as figure type, style and color priority, sizes, number and so on [2]. Apparel cut order planning(COP) mainly determines the number of cutting table, the sizes combination and the lay according to production capacity. COP can not only give the cutting solution but also make use of the production capacity, save fabric and labor and increase profit.

In current studies, part of the research methods in essence was based on artificial experience which was more convenient to solve problems with less sizes and numbers [3]. However the algorithms were difficult to expand to mass customization apparel production with more sizes and numbers. In addition, part of the above studies was constructive and difficult to deal with the above situation[4]. Furthermore some algorithms yielded bigger searching space leading to low efficiency and long calculating time [5].

In response to these problems, this paper proposes optimization method based on probability search. Several initial cutting table layout plans were generated randomly with the production constriction. The optimized sizes combination plan was accordingly obtained using probability search algorithm. The optimization method could rapidly get the apparel cutting plan and decrease the number of cutting table.

H. Deng et al. (Eds.): AICI 2011, CCIS 237, pp. 267–271, 2011.

2 Optimization Model of COP

Apparel orders varies according to market or customer needs including style, color, size, quantity, material, brand and other attributes and at least color, size, number these three attributes. Take the simplest case for example, an apparel company received the order of single style, single fabric, the same color and multiple sizes, such as official's uniform. The order was shown in Table 1.

Table 1. Apparel Order for mass customization

size	*1*	*2*	...	i	...	m
number	Y_1	Y_2	···	Y_i	···	Y_m

In certain production circumstance, the largest layer of the fabric is constant $P_{\max}$ and the maximum pieces of clothes each cutting table can cut is constant c. The constant $P_{\max}$ is mainly decided by the length of cut blade and the thickness of fabric. The constant c is decided by the size of the clothes and cutting table. It is assumed that n cutting tables should be needed to complete the order. Denote the i size are cut in the j cutting tables, the pieces of clothes is a_{ij}, layers of cloth cut on the j cutting table is X_j, where $0 \le a_{ij} \le c$.

The objective are $\min(n)$. It means in actual production the total number of pieces and cutting table should be minimum to meet customer's demand.

Constrictions are

$$0 \le \sum_{i=1}^{m} a_{ij} \le c \,. \tag{1}$$

$$X_j \le P\max \,. \tag{2}$$

$$Y_i \le \sum_{j=1}^{n} a_{ij} X_j \,, \; j = 1, 2 \ldots n \,. \tag{3}$$

Formula (1) means that cut the number of clothes cut on each cutting table could not exceed the maximum number. Formula (2) expresses that the number of spreading layer could not exceed the maximum number. Formula (3) shows that the number of clothes cut for each size must exceed the number of orders for the same size. The formulas would be transformed into matrix as shown in formula (4).

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_i \\ \vdots \\ Y_m \end{bmatrix} \le \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2j} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mj} & \cdots & a_{mn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_j \\ \vdots \\ x_n \end{bmatrix}. \tag{4}$$

In formula (4) matrix X means spreading layers on each cutting table. Matrix a means the sizes on each cutting table. So a COP solution could be obtained with the matrix X and a. Since both matrix X and a are unknown, what's more, matrix X and a are matched, inversion matrix method could not be used to get results. The problem is essentially an integer programming problem, but also a NP problem. There is no tool with excellent performance to support the solution. Therefore, the paper proposed two stage optimization method based on probability search and genetic algorithm to solve it.

3 Optimization Method Based on Probability Search for COP

The optimization method based on probability search means a number of initial spreading solutions are randomly generated within certain constraints. Accordingly the sizes combination solution could be obtained using searching algorithm combined with probability.

3.1 Searching for the Spreading Solution on Cutting Tables

Spreading solution on cutting tables means to determine the number of cutting tables and the spreading layers on each table. For an apparel order these two values interact. When the number of cutting table changes, the spreading layers on each table will change accordingly. These two variables have multiple sets of feasible solutions, and in the initial algorithm stage it is difficult to get the exact value. Therefore, random searching method was used to solve the problem.

1、The number of cutting tables n

The number of cutting tables could be searched in the natural number range. Considering reducing the searching space and improving the efficiency of the algorithm in the actual calculation process, the number of cutting tables was defined a range of values. The range was jointly determined by the number of apparel order and the maximum cutting capacity of the cutting table.

2、The spreading layers on each cutting table X_j

Randomly generate spreading layers X_j on each cutting table of totally n, and in accordance with formula (2).

3.2 Sizes Combination Solution Optimization Based on Probability Search

Size combination solution could be obtained by search algorithm with probability. Based on the maximum number of clothes and the spreading solution, the size combination solution could be randomly generated to meet the apparel order. The detailed calculation method was the following.

Step 1. Calculate $\max a_{ij} = \dfrac{Y_i - \sum_{j=1}^{k-1} a_{ij} x_j}{x_j}$, if $\max a_{ij} \le c$, the clothes of size i arranged on cutting table j was a_{ij}, which was randomly generated between the integer of 0 and $\max a_{ij}$ with the same probability. If $\max a_{ij} > c$, a_{ij} was randomly generated between the integer of 0 and c.

Step 2. Calculate $\sum_{j=1}^{n} a_{ij} X_j$, if $\sum_{j=1}^{n} a_{ij} X_j < Y_i$, reduce i units from the current cutting table number, then re-run step 1, generate a new a_{ij}, and the initial value of i was 1.

Step 3. If the regenerated a_{ij} up to i cutting tables would still be unable to meet the constraints of formula (1), add 1 to i, re-run step 3, and generate new a_{ij}.

Step 4. Until $i = m$, get matrix a.

Several cut table spreading solutions and sizes combination solutions were obtained. Additional clothes would be produced according to the spreading and sizes matching solution obtained in the first stage. These additional clothes would increase the inventory, fabric and labor cost. It could not meet the actual production demand. Therefore, it is necessary to optimize the solution. The number of the clothes of over production could be controlled to the extent permitted in the enterprise.

4 Conclusion

The paper researched the COP problem with versatile sizes and irregular number of clothes for apparel mass customization. The mathematical model of the problem was built and optimization method based on probability search was proposed. Subsequent research could focus on how to solve the COP problem of more customized apparel order, as well as overall optimization of production plans combined with other aspects of clothing production[6]. In addition, other optimization methods could be used for further research in apparel production plan[7].

Acknowledgments. This work is supported by the National Key Technology R&D Program, China(No. 2011BAB02B01) and Science Foundation of Zhejiang Sci-Tech University (ZSTU) under Grant No.111329A4Y10810.

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