Research on Cell Layout of Injection Workshop Based on Improved SLP-G A

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Abstract. According to the background of multi-varieties and small-batch market demands, the layout of the injection workshop is reformed by cell layout. The mathematical model of the injection workshop cell layout is constructed to minimum logistics cost, and the model is solved by using MATLAB. By using the systematic layout planning (SLP), three groups of initial solutions are generated, which are used as part of the chromosomes in the initial population of the improved genetic algorithm (GA). In this way the subjectivity and complexity of the traditional SLP method are avoided, the global and local search capability of the algorithm is enhanced, and the optimal solution can be quickly searched. Finally, the cell layout of an injection workshop is completed through the algorithm.

1. Introduction
Multispecies and small-batch production are the mainstream demands of modern manufacturing enterprises. The traditional workshop cluster layout is suitable for few-varieties and large-batch production. The cluster layout makes the manufacturing workshop have some problems, such as the confusion of logistics lines, circuitous paths, the stacking and occupying of the WIP, which greatly reduce the production efficiency of the workshop. Transforming part of rigid production lines into high flexible and high productivity cell production mode is one of the important methods to cope with the change of market demands [1-2]. The common methods of cell layout include SLP method proposed by Richard Muther in 1961 and some intelligent algorithms, and GA is more used in the intelligent algorithm. The combination of SLP and GA has become a tendency in recent years, which can not only make up for the disadvantages of manual operation tedious iteration and susceptible to subjective influence of SLP [3], but can also improve the optimization ability of GA and get more useful results [4]. In this paper, the preliminary schemes generated by SLP are used as the initial solutions of GA to make the cell layout of the injection workshop, so as to improve the productivity and market responsiveness of the workshop.

2. Mathematical model of injection workshop layout
The limitation of area should be considered in the layout of injection workshop and linear multi-row layout is used [5]. The whole workshop is rectangular, each cell can be represented as a rectangle and in the same plane. The origin of the rectangular coordinate system is in the lower left corner of the region. The length of each cell is parallel to the X-axis and the width is parallel to the Y-axis. The coordinate system and parameters are shown in figure 1.
The main objective of injection workshop layout is to minimize logistics cost, and the following objective function is constructed:

$$\min F = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} f_{ij} d_{ij}$$

(1)

$c_{ij}$ is the transportation cost of per unit material per unit distance between cell i and j, $f_{ij}$ is the material transportation amount between cell i and j, $d_{ij}$ is the distance between cell i and j.

$$d_{ij} = |x_i - x_j| + |y_i - y_j|$$

(2)

Constraints are as follows:

$$|x_i - x_j| \geq \left[ \frac{(l_i + l_j)}{2} + h_{ij} \right] z_{ik} z_{jk}, \quad i = 1, 2, \ldots, n; \quad j = 1, 2, \ldots, n$$

(3)

The cells in the same line must not overlap, $h_{ij}$ is the requirement of the minimum horizontal net spacing between cell i and j.

$$z_{ik} = \begin{cases} 1, & \text{Device i is on line k} \\ 0, & \text{others} \end{cases} \quad k = i = 1, 2, \ldots, m$$

(4)

$$\sum_{k=1}^{m} z_{ik} = 1$$

(5)

Each cell appears only once.

$$|x_i - x_j| + \frac{(l_i + l_j)}{2} \leq L$$

(6)

Lateral boundary constraint, L is the length of the workshop.

$$|y_i - y_j| + \frac{(w_i + w_j)}{2} \leq W$$

(7)

Vertical boundary constraint, W is the width of the workshop.

3. SLP-GA Algorithm design

(1) Coding: Coding with the number of cells ($m_i$) and the horizontal net spacing ($\Delta_i$), using strategy of automatic linefeed, the layout is from left to right, from down to up.

$$[[m_1, m_2, \ldots, m_n], [\Delta_1, \Delta_2, \ldots, \Delta_n]]$$

(8)

(2) Initial population: Using SLP method, based on the logistics and non-logistics relationship analysis, combined with area constraints, the preliminary layout schemes are obtained which are used for individuals of GA initial population, and other individuals are randomly generated.

(3) Fitness function: 

$$Fit = 1/\text{(min}F + P)$$

(9)

$$P = \{0, S_0 + (m - 1)S \leq T, \text{others} \}$$

(10)

T is a large number for penalty

(4) Genetic Selection: Roulette selection is used, the probability of individual being selected is

$$P_i = \frac{Fit_i}{\sum_{i=1}^{n} Fit_i}$$

(11)

(5) Cross and Mutation: PMX method is used for cell sequence, arithmetic cross is used to cell net spacing. Generate new net spacing at random within the range of cell net spacing, do mutation operation according to mutation probability point which has been appointed.
4. Case study

Q enterprise’s injection workshop covers an area of 62m×66m, which is divided into 8 functional areas and using traditional cluster layout. In order to adapt to the market changes and efficiency improvement needs changes its layout to cell model. it is planned to arrange 10 production cells in the workshop after preliminary cell construction, and each cell size is shown in Table 1. The distance from the centre coordinate of the first row to the lower boundary $S_0$ is 10m, and the distance between each row $S$ is 21m. The transportation cost of per unit material per unit distance $c_{ij}$ is ¥1, the logistics volume between each cell $f_{ij}$ is shown in formula (12), the minimum distance requirement between each cell in the x-axis direction $h_{ij}$ is 2m, and the minimum distance requirement between each cell and the workshop horizontal boundary $h_{i0}$is shown in formula (13).

$$[f_{ij}] = \begin{bmatrix} 
0 & 800 & 150 & 0 & 540 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 480 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 120 & 0 & 0 & 0 & 0 \\
320 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 400 & 0 \\
0 & 0 & 240 & 0 & 0 & 0 & 0 & 0 & 0 \\
150 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 120 & 0 & 0 & 0 & 0 & 0 & 0.300 \\
0 & 600 & 0 & 0 & 0 & 0 & 0 & 0 & 0 
\end{bmatrix}$$ (12)

$$h_{i0} = [2.5, 2.5, 2.5, 2.5, 2.5, 2.5, 2.5, 2.5]$$ (13)

SLP method is applied to the preliminary layout planning of the workshop, and three schemes are obtained: [10 9 6 1 2 8 5 3 4 7], [10 2 6 1 4 9 3 8 7], [8 4 5 1 2 3 9 10 7 6]. Use them to replace the sequence segments of the three chromosomes in the initial population.

The operating parameters of GA: population number is 50, termination algebra is 200, crossover probability is 0.6, mutation probability is 0.1, penalty function is 5000, and the value range of cell net spacing is $[U_{min}, U_{max}] = [0, 2.5]$. MATLAB is used to run the program for several times to obtain the optimal solution [10, 9, 6, 1, 2, 8, 5, 3, 4, 7, 8, 1.0675, 0.3519, 2.3789, 0.7278, 0.4000, 0.7316, 0.9731, 0.4578, 0.1325, 0.7672]. The evolution process is shown in figure 2, and the device layout result is shown in figure 3.

Figure 2. Evolution chart of algorithm
5. Conclusions
(1) Changing the traditional injection workshop cluster layout to cell layout can effectively cope with the market demands of multiple varieties and small batches, and improve the responsiveness.

(2) On the basis of defining the relevant parameters, the workshop cell layout model is constructed with the goal of minimizing logistics cost. The combination of the classical SLP with GA not only ensures the comprehensiveness of the factors, but also ensures the objectivity of the solution process, and can converge to the optimal solution quickly.

(3) The improved SLP-GA is used in the cell layout of an injection workshop, and the ideal layout result is obtained, the minimum logistics cost is achieved. The effectiveness of the algorithm is verified.

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