Research on prefabricated component production line mold platform combination method

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Abstract—In traditional prefabricated component manufacturing enterprises, there are often problems such as low utilization rate of the platform surface due to poor production plans of the enterprise, resulting in waste of production resources and low production capacity of the enterprise. In order to solve the problem of mold platform combination allocation in the production process of prefabricated component manufacturers, a mold platform combination allocation method based on the combination of machine learning and backtracking is proposed. The backtracking method is used to search for the theoretical best fit combination result, and the improved BL is used. The positioning algorithm simulates the placement process of the mold on the platform, and uses the Apriori algorithm to train the obtained data set to obtain the association rules contained in the frequent item set. When the enterprise re-produces, the prefabricated components are combined according to the association rules for production, and the utilization rate of the platform is improved. The simulation test is carried out with the example data of the prefabricated component manufacturing enterprise, which verifies the effectiveness of the combination allocation method of mold and platform combined with the backtracking method and the Apriori algorithm to solve the problem.

1. Introduction
The production process of prefabricated building components has the characteristics of multiple varieties, small batches, and dynamic changes in production orders as the construction engineering changes. In the production process, prefabricated components are produced through corresponding molds. In the assembly line with assembly line characteristics, the platform carries the mold and passes through the processing units of each process in order to complete the entire production process. The mold required to produce the prefabricated components would be fixed on the surface of platform in the formwork erection procedure. The size of the mold corresponding to different types of prefabricated components is also different, and a fixed-size platform can carry multiple molds. Since the circulation time of the platform on the production line is relatively fixed, if more molds can be placed on the platform, the table area of the platform can be used more fully, thereby improving the
overall production efficiency of the production line. Therefore, the utilization rate of the platform has a
direct impact on the production capacity of the precast component production line. The effective
combination distribution method of mold on the platform can improve the utilization rate of the
platform and give full play to the capacity of the existing resources of the enterprise.

Compared with the production line of traditional manufacturing enterprises, the production line of
prefabricated components has many similar characteristics, but the production line of prefabricated
components also has its own unique process requirements and production operation rules. In recent
years, more and more scholars have begun to focus on the production of prefabricated components.
Wang Zhongyuan\textsuperscript{[5]} studied the mold arrangement problem in the production process of the concrete
precast component production line, and used genetic algorithms to optimize the arrangement of the
precast component production line molds on the platform. Xie Siong\textsuperscript{[6]} proposed a two-stage
prefabricated building prefabricated component production scheduling optimization based on a
multi-level coding genetic algorithm. On the one hand, it analyzes the production process of
prefabricated components, and on the other hand, he proposed a quantitative approach to the
production parameters of prefabricated component factories on this basis. The two-stage optimization
mode improves optimization performance and improves the production efficiency of prefabricated
components. Zhu Mintao\textsuperscript{[7]} proposed a new two-way expandable combined prefabricated component
digital production line. The production line can be expanded to arrange facilities and equipment, and
has the characteristics of high mechanization level and flexible equipment combination. At present,
scholars study the production line of prefabricated components, and most of them start with
optimizing the process flow and adjusting the production resources. There are few problems in the
research of the mold and platform combination distribution in the supporting mold process section of
the prefabricated component production process.

2. The Mathematical Model of the Combination and Distribution of Mold on the platform

2.1 Problem Description

The prefabricated component production workshop is a semi-automated flow workshop. The main
type of prefabricated component production is laminated board. All the processes will be carried out
on a fixed space size platform. The platform moves sequentially through the entire production process
on the assembly line. The space of the platform is limited and the size is fixed. The size of the mold
depends on the size of the prefabricated component. One platform can carry at most 3 molds. The
distribution method of the molds on the platform is shown in Figure 1.

![Figure 1 The distribution model of the mold on the platform](image)
The distribution plan is to first place the mold corresponding to the prefabricated component to be placed on the first platform, make it as full as possible, and maximize the utilization rate of the first platform, and then place it on the second platform to place the remaining molds for the prefabricated components to maximize the utilization rate of the second platform, and the molds corresponding to the remaining prefabricated components can be deduced by analogy until the components in this group are placed. By optimizing and determining the distribution results of the prefabricated components in the production process and the mold on the platform, the utilization rate of the platform is improved, and the optimized solution with the smallest number of platform is obtained.

2.2 Restrictions

Constraints that need to be met for the combination and distribution of molds on the platform:

① The sum of the area of all the molds on a single platform is less than the area of the platform.

\[ \sum_{i=1}^{n} S_i \leq M = W \times H \]  

(1)

② The sum of the areas of all the platforms is less than or equal to the sum of the areas of all the molds.

\[ \sum_{i=1}^{n} S_i \geq P \times M \]  

(2)

③ The number of molds placed on a single platform is limited, at most three.

\[ 1 \leq L \leq 3 \text{(L is integer)} \]  

(3)

Except for the above constraints, the molds must be placed orthogonally on the platform, and the molds cannot overlap each other.

3. Research on Mold Combination Allocation Method Based on the Combination of Backtracking Algorithm and Machine Learning

3.1 Backtracking method to search for the best combination

The backtracking method is used to solve the problem, first accurately obtain the solution space of the entire combination. A set of production orders has n components the length of solution space is composed of 0-1 vectors of length n, and the number of vectors is one. The solution space of the combined distribution problem of the mold on the platform can be represented by a binary tree.

![Figure 2 The solution space tree of the mold's combined distribution on the platform](image-url)
These components are sorted randomly in the solution space tree. The path from the i-th layer to the i+1-th layer of the solution space tree indicates whether to place this component. The value 1 means to place this component, and the value 0 means not to place this component.

In the process of searching for the above solution space, the backtracking method is performed on the fourth layer and back to the third layer. The sum of the area of the first and second components is calculated and compared with the area of the mold base. If the sum of the areas of the first and second components is less than the area of the platform, then there may be a solution in the subtree. According to the depth-first choice, the first, second, and fourth component combinations of this path are selected, the sum of the areas is calculated and compared with the area of the platform. If the sum of the areas is less than the area of the platform, it means that the three molds can be placed on the platform without considering the shape of the components. This combination and the sum of their areas are recorded and compared with previous combinations. Combinations with larger areas were selected. If the sum of the areas is greater than the area of the platform, it means that the three molds cannot be placed on the platform together. This combination scheme is not good.

Backtrack again, and then calculate the sum of the component area again, compare and judge whether the combination is the most suitable solution, and continue to compare and iterate until the entire subtree is searched.

3.2 Apriori algorithm flow
Set the min support and confidence, and search the data set. For an optimal itemset, search for each component in the optimal combination, search for an item set with a support not less than the min support for a single component, and aggregate these itemsets into a set called frequent 1-itemsets \( L_1 \).

Combine these components in pairs, generate candidate item sets through self-calculation and statistical connection, and use the pruning function to delete the combinations that do not meet the conditions. The combination that meets the min support is retained, and the itemsets in which these retained candidate sets are located are frequent 2-itemsets \( L_2 \).

On the basis of the retained candidate item set, add another component to form a new candidate item set, and again use the pruning method to subtract the candidate item set that does not meet the conditions, and keep the combination that meets the min support. These reservations the item set where the candidate set are down is the frequent 3-item set \( L_3 \).

After the final frequent itemsets are obtained, the strong association rules can be obtained by manually setting the min confidence. Association rules are formulas of the form \([X] \Rightarrow [Y]\). The steps for generating association rules are as follows: for each frequent item set \( L \) obtained above, generate all its non-empty proper subsets; calculate \( \frac{\text{support}_{\text{count}}(S)}{\text{support}_{\text{count}}(L)} \) for each non-empty proper subset \( S \). If\( \min_{\text{conf}} \leq \frac{\text{support}_{\text{count}}(S)}{\text{support}_{\text{count}}(L)} \), indicates that the probability of the remaining components in \( L \) and the components in the \( S \) subset appearing together is greater than the min confidence, indicating that this rule can be trusted. Get the strong association rules needed by the final enterprise.
3.3 The implementation steps of the mold and platform combination allocation method combining the backtracking method and the Apriori algorithm

Figure 3 Apriori and backtracking combined algorithm flow chart
4. Simulation experiment

4.1 Simulation data and algorithm parameter settings
The data information of the prefabricated components is derived from the production line production data of a prefabricated component company. The actual data are cleaned and processed to facilitate theoretical research. This paper does not reflect the cleaning process, and the displayed data have been cleaned.

The list of laminated boards contains 42 types of laminated boards, the number of single-type laminated boards is 1-7, and the area of laminated boards is 4.3-20.4 (m²).

In the parameter setting of the backtracking method, the area parameter weight and value parameter value of the prefabricated component are set to the same value, which is the table area c of the platform. c=24 (m²); in the process of data mining on the best fit set obtained by the backtracking method using the Apriori algorithm, the minimum support is set to 0.02, and the minimum confidence is set to 0.6.

4.2 Example test
Perform algorithm test on the first group of data after grouping, enter the corresponding number of components, the corresponding prefabricated component number name, the area of the mold, and the largest area of the entire platform to obtain the optimal allocation result.

| Platform | The theoretical utilization area of the platform | Build a combination model |
|----------|-----------------------------------------------|--------------------------|
| 1        | 22.59                                         | YB3-4、YB7-1F、YB7-2      |
| 2        | 22.6                                          | YDB7、YZB-4               |
| 3        | 21.0                                          | YZB4、YB9                |
| 4        | 20.4                                          | YB7                      |
| 5        | 16.1                                          | DB5-1、YB2F              |

As shown in Table 1, the minimum support degrees in the three sets of data are different, and different maximum frequent itemsets, association rules, and actual confidence levels are obtained.
Table 2 Apriori algorithm training combination results table according to different min support

| Min support, min confidence | Largest frequent itemset | Association rules | Actual confidence |
|-----------------------------|--------------------------|-------------------|------------------|
| (0.03, 0.6)                | YB14 YDB6F YB12          | [YB14]>>>[YDB6F]  | 0.7610           |
|                             | YDB6F YB12 YDB1          | [YB2]>>>[YDB1]    | 0.6169           |
|                             | YB6F YB14 YB12           | [YB2]>>>[YB8]     | 0.6162           |
|                             | YB2 YB1 YB8              | [YB7F]>>>[YB7F]   | 0.6162           |
|                             | YB7F YB1 YDB6F           | [YB7F]>>>[YB7F]   | 0.7853           |
|                             | YDB6F YB1 YB7F           | [YB14, YB12]>>>[YDB6F] | 1.0000       |
|                             | YZB7F YB7F YB8           | [YB12, YDB1]>>>[YDB6F] | 0.9638       |
|                             |                         | [YB14, YB12]>>>[YDB6F] | 1.0000       |
|                             |                         | [YB2, YB1]>>>[YB8] | 0.9457           |
|                             |                         | [YB2, YB8]>>>[YB1] | 1.0000           |
|                             |                         | [YB1, YB8]>>>[YB2] | 1.0000           |
|                             |                         | [YB7F, YB1]>>>[YDB6F] | 1.0000       |
|                             |                         | [YB7F, YDB6F]>>>[YB1] | 1.0000       |
|                             |                         | [YB6F, YB7F]>>>[YB1] | 1.0000           |
|                             |                         | [YB1, YB7F]>>>[YDB6F] | 1.0000       |
|                             |                         | [YZB7F]>>>[YB7F, YB8] | 0.6162       |
|                             |                         | [YB7F, YB7F]>>>[YB8] | 1.0000           |
|                             |                         | [YB7F, YB8]>>>[YB7F] | 1.0000           |
|                             |                         | [YB7F, YB8]>>>[YZB7F] | 1.0000       |

Analysis of Table 2 shows that when the min confidence is set to 0.03, the max frequent item set that can be combined is 7 items, and the confidence level of the association rule between multiple frequent item sets reaches 1.000. This means that the association between the two components is unique. For example, in the association rule [YB14, YB12]>>>[YDB6F], when the YDB6F component is selected, the probability of selecting components YB14 and YB12 and its combination is 100%. With the gradual increase of the min support, the max frequent itemset of the component combination result becomes smaller. When the min confidence is set to 0.04, the max frequent itemset of the combined result is 6 items, but there are only 2 association rules that reach the min confidence. The reason is that although the components appear more frequently, the combination results between the components are also more, which is not enough to achieve the optimal combination result with the min confidence.

Through continuous training of 20 sets of daily production order data, a best-fit collection library is obtained, the database size is 5000, and the Apriori algorithm is used to conduct data mining on the database to obtain strong association rules.
Analyzing Figure 4 shows that the combined allocation method combining the backtracking method and the Apriori algorithm has a significant improvement in the average utilization rate of the platform with the other three allocation methods. There is a significant improvement in the utilization rate. The combined distribution method combining the backtracking method and the Apriori algorithm has an average utilization rate of above 0.65 and the highest value of 0.74 in the 5 experiments. The distribution method corresponding to the PSO algorithm is the mold set the average utilization rate is between 0.63 and 0.69. The average utilization rate of the mold set corresponding to the WPA algorithm distribution method is between 0.6 and 0.68. The average utilization rate of the mold set corresponding to the Greedy algorithm distribution method is 0.63, which shows that the backtracking method and Apriori algorithm-combined combination allocation method has a significant improvement in improving the utilization rate of the platform, and can effectively solve the problem of platform combination allocation in the production of prefabricated components.

5. Conclusion
This paper takes as the research object the combination and distribution of molds on the platform in the production process of concrete precast components, and proposes a mold combination distribution method based on the combination of machine learning and backtracking. First, the production orders of a single day are grouped according to the production quantity of the component type. Second, the best combination result was found by backtracking method, and the improved BL positioning algorithm was used to simulate the placement process of the mold on the platform. Finally, the Apriori algorithm is used to obtain the association rules between the prefabricated components. When the enterprise produces again, it combines the prefabricated components according to the association rules for production, and continuously trains and strengthens the association rules. The test results show that the combined distribution method combining the backtracking method and the Apriori algorithm can effectively solve the problem of combined distribution of molds on the platform in the production process of concrete precast components.

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