Research on the Optimization of Staff Allocation under the Strategy of "Strong Leads the Weak"

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Abstract. Based on the operator's competency index matrix, a two-layer mathematical model with the goal of maximizing the total competency of employees' workstations is designed. The upper layer uses the Hungarian Algorithm to achieve the configuration of "strong employees", and the lower layer uses the Hybrid Genetic Simulated Annealing Algorithm to achieve the configuration of "weak employees". The results show that: compared with the traditional undifferentiated overall configuration, the double-level configuration based on the double-level mathematical model increases the employee competency difference ratio by 5.71%, which effectively embodies the idea of "strong leads the weak".

Keywords: Strong Leads the Weak; Optimization; Hungary Algorithm; Hybrid Genetic Simulated Annealing Algorithm

1. Introduction
Under the consensus that human resources have become the first resource for the development of manufacturing companies, how to choose effective management methods and scientific management methods to achieve the best allocation of corporate human resources has become the common development of manufacturing companies in the world strategy.

Benavides A J et al.[1] established a flow shop staffing model in order to minimize the difference between the job fitness of personnel. Gen M et al.[2] established an optimal configuration model of assembly line personnel with the goal of maximizing the total job fitness of assembly line operators. Azadeh et al.[3] studied the optimization model of assembly workshop staffing with multiple people at the same workstation with the goal of minimum completion time. Majozi T et al.[4], in order to reduce the labor cost of flexible production enterprises, established a mathematical model with a reasonable manual allocation plan and optimal job sequencing as the goal.

Based on the strategy of “strength leads the weak”, this paper designs a double-level mathematical model with the goal of maximizing the total competence of operators and employees. The upper level of the model "strong employees" and workstations are configured one-to-one, and the solution is solved by the Hungarian Algorithm(HA) of the deterministic analysis algorithm. The lower level of the model to solve the "weak employee" configuration is a one-to-many type, which is more complicated, and a Hybrid Genetic Simulated Annealing Algorithm(HGSAA) with faster speed is designed to solve it.
2. Model description

2.1. Problem description and parameter definition
For an assembly line of a manufacturing enterprise, the product to be assembled passes through m stations, and n (n>m) employees complete the assembly operation. Each employee exhibits different competences when assembling at each station, and each employee can only complete one task on one station at the same time. "Strong employees" and stations are configured one-to-one.

P: Personnel set (\(\{i=1,2...N\}\))
Q: The total station set (\(\{j=1,2...M\}\))
N: Number of personnel
M: Number of stations
\(\theta_{ij}\): Competency of the \(i\)-th person at station \(j\)
\(\theta_{j}\): The competencies of the \(j\)-th station are assembled, \(\theta_{j} = \{\theta_{1j}, \theta_{2j}...\theta_{Nj}\}\)
\(\theta_{i}\): The collection of all the competences of the \(i\)-th person, \(\theta_{i} = \{\theta_{i1}, \theta_{i2}...\theta_{iM}\}\)
\(S_{j}\): The number of personnel required for the \(j\)-th station

2.2. Mathematical Model
The upper-level objective function indicates that the total competency of "strong employees" is the largest:

\[
F = \max \sum_{i=1}^{N} \sum_{j=1}^{M} \theta_{ij} X_{ij}
\]

s.t. \(\sum_{j=1}^{M} X_{ij} \leq 1, i=1,2...N\) \hspace{1cm} (1)

\[
\sum_{i=1}^{N} X_{ij} = 1, j=1,2,...M\]

(2)

\(N\geq M\)

Formula(1) indicates that one person can only be allocated to one position, or no configuration. Formula(2) indicates that only one person can be assigned to one position. Boolean variable \(X_{ij}\) indicates that when personnel \(i\) is configured on station \(j\), it is 1, otherwise it is 0.

The lower-level objective function represents that the maximum sum of "weak employees":

\[
F = \max \sum_{i=1}^{N} \sum_{j=1}^{M} \theta_{ij} Y_{ij}
\]

s.t \(\sum_{i=1}^{N} Y_{ij} = S_{j} - 1, j=1,2,...M\) \hspace{1cm} (3)

If \(X_{ij}=0\), then existence \(Y_{ij}=1\) or 0,

\[
\sum_{j=1}^{M} Y_{ij} = 1, i=1,2,...N\]

(4)

Formula(3) indicates that the number of employees for the \(j\)-th station configuration should be equal to the number of station requirements minus 1 (not including the configuration of "strong employees"). Formula(4) means that one employee can only be configured on one station. Boolean variable \(Y_{ij}\) indicates that when employee \(i\) is configured at station \(j\), it is 1, otherwise it is 0.

3. Algorithm design for model solving
3.1. Upper model algorithm design

Since HA is to solve the minimum value of the objective function, the objective function of maximizing the total competence of the workstation is converted. Let $G = \max \{0_{ij}\}$, construct a new competency matrix $(G - \theta_{ij})_{M \times N}$, between employees and positions. So make the optimal solution of

$$\max \sum_{i=1}^{N} \sum_{j=1}^{M} \theta_{ij} X_{ij},$$

$$H = \min \sum_{i=1}^{N} \sum_{j=1}^{M} (G - \theta_{ij}) X_{ij}.$$

Construct a coefficient matrix, according to the competency value of each employee at each workstation, construct a competency matrix $K = (G - \theta_{ij})_{M \times N}$. Find the augmentation path, subtract the minimum value from each row, transform from matrix $K$ to matrix $K'$, so that zero elements appear in each row and column of the matrix $K'$. Finally mark configuration results.

3.2. Algorithm design of the lower model

In order to facilitate the solution, a negative value is used to convert the maximization of the underlying objective function into a minimization. The minimum value of the new objective function is the maximum value of the original objective function, namely

$$H = -\min \sum_{i=1}^{N} \sum_{j=1}^{M} \theta_{ij} Y_{ij}.$$

HGSAA adopts an optimal solution preservation strategy to avoid the reduction of fitness while ensuring the global convergence of the genetic algorithm. In the selection operation of the Genetic Algorithm, the optimal 10% of the moderate value is selected to determine the population that directly enters the next generation. Since the lower-level objective function is the maximum total competence after staffing, the fitness function is expressed as:

$$fitness = H^{v}, \quad v = 1.005$$

Using the classic roulette method, $dp$ is the probability that the $p$-th individual is selected, and $fitness(fp)$ is the fitness value of the $p$-th individual.

$$d_{p} = \frac{fitness(f_{p})}{\sum fitness(f_{p})}.$$

The crossover probability is $Pm$, and two of the parents are selected for crossover according to the selection operation. The mutation probability is $Pc$, and a random number is generated during the mutation operation. The termination condition of the inner loop of the hybrid algorithm is to reach the preset evolutionary algebra, and the termination condition of the outer loop is the cooling operation of the simulated annealing algorithm, and the corresponding staffing plan is output.

4. CASE ANALYSIS

In the case of this article, 22 employees need to be allocated to 8 positions. The competency matrix of 22 employees at 8 workstations is acquired. $Pi$ represents the employee set, $Qj$ represents the workstation set, and the corresponding value is the competency.

The configuration of the "strong employees" obtained by HA is shown in Fig. 1. For example, the personnel numbered 3 is placed on the station numbered 7, and the total competence of the 8 "strong employees" is 13.242.
The parameters of MGSAA are set as follows: the initial population is 60, the number of iterations is 100, the mutation probability is \( P_m = 0.2 \), the crossover probability \( P_c = 0.8 \), the initial temperature is 5000, the lowest temperature is 50, and the annealing coefficient is 0.9. The combined solution of HA and HGSAA results in double-level configuration of personnel as shown in Fig. 2. Red represents "strong employees" and black represents "weak employees". The total competency value is 33.877.

### 5. Result Analysis

In order to verify the effectiveness of the "strong leads the weak" strategy, HGSAA was used to model the overall configuration strategy. The staffing results are shown in Fig. 3. Blue represents "strong employees" and black represents "weak employees". The competency value is 34.002.
model can effectively achieve the idea of "Strong leads the weak". Combining the analysis in Fig. 4 and Fig. 5, in the case of little impact on the overall objective function, The double level strategy of "strong leads the weak" can effectively play the value and initiative of "strong employees", the experience and tacit knowledge of "strong employees" can be inherited and developed, it has an important contribution to the sustainable development of enterprises.

In order to verify the effectiveness of HGSAA, a single GA and SA were used to conduct a comparative analysis. Fig. 5 shows the gradual convergence of the total competency value of "weak employees" as the number of iterations increases. The results show that as the number of iterations increases, the objective function gradually decreases. When the number of iterations reaches a certain value, the objective function tends to a certain stable value, which proves that the three algorithms have good convergence. HGSAA converges when the number of iterations reaches 100, while the GA convergence threshold is 260 and the SA convergence threshold is 2200, indicating that HGSAA has better convergence.

6. Conclusion
This paper designs a double-level mathematical model with the goal of maximizing the total competence of operators and employees. The upper layer uses the HA to realize the configuration of the most skilled personnel, the upper layer solves the result as the constraint condition of the lower layer, and the lower layer uses a HGSAA realize the configuration of ordinary personnel. The simulation shows that the double-level mathematical model established in this paper and the combination of the three types of algorithms can find the approximate optimal solution, indicating that the model is effective. Compared with the traditional overall configuration, the double-level configuration based on the strategy of "strength leads the weak" has little effect on the overall objective function. At the same time, the difference in competence of employees at work stations is more obvious, which effectively embodies the idea of "strong leads the weak".

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