Research on dynamic allocation of human resources based on Improved Ant Colony Optimization

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***Abstract*— In order to solve the problems of poor balance and low efficiency of traditional dynamic allocation method of human resources, this paper proposes a new dynamic allocation method of human resources based on improved ant colony optimization. In order to improve the convergence of the traditional ant colony optimization algorithm and avoid falling into the local optimal solution, the ant colony optimization algorithm is improved from three aspects: heuristic function, state selection strategy and pheromone allocation mechanism. Based on the improved ant colony optimization algorithm, the objective function of human resource dynamic allocation is constructed on the basis of human resource workload, work efficiency and work ability index, so as to obtain the optimal allocation results and complete the dynamic allocation of human resources. The experimental results show that, compared with the traditional human resource allocation method, the distribution equilibrium and efficiency of the proposed method are higher, and the distribution equilibrium is basically consistent with the standard value, indicating that the practical application performance of the proposed method is stronger.**

Key words: Improved ant colony optimization; human resources; Dynamic allocation

I. INTRODUCTION

At present, the demand for human resources of enterprises is increasing. While increasing the number of human resources, how to allocate human resources has become a key factor to improve the work efficiency of enterprises [1]. The commonly used human resource allocation method is one person one post mode, which can lead to overtime or nothing to do to a certain extent. Both of the above two states are not ideal working state, which wastes employees' working time and increases the economic cost of the enterprise [2]. For an enterprise, the most important thing is to ensure the orderly improvement of the economy, and avoiding cost waste is also a way to improve economic efficiency. From the perspective of human resources, reasonable allocation of human resources can greatly improve the work efficiency of enterprises, thus promoting the reduction of enterprise costs. Therefore, it is necessary to study a reasonable method of enterprise human resource allocation [3-5].

Reference [6] puts forward a method of human resource allocation based on big data, which uses big data technology to deeply mine the human resource demand of enterprises, and extracts the demand characteristics of human resources of enterprises on the basis of mining. According to the results of feature extraction, the human resource allocation model is constructed. However, this method has the problem of poor distribution equilibrium. In reference [7], a method of human resource allocation based on K-means clustering algorithm is proposed. This method performs the iterative operation of allocation in the elastic space of the distributed platform, uses K-means clustering algorithm to cluster the human resource demand data, and constructs the dynamic recommendation model of human resource to complete the human resource allocation. However, the allocation efficiency of this method still can not meet the allocation needs. Reference [8] puts forward a method of human resource allocation based on demand forecasting. This method first makes a periodic analysis of the human resource demand of enterprises. Combined with the results of periodic analysis, the multiple regression algorithm is used to build the human resource allocation model. However, the allocation effect of this method is poor.

In order to improve the balance and efficiency of enterprise human resource allocation, a dynamic allocation method of enterprise human resource based on improved ant colony optimization is proposed. The basic ant colony optimization algorithm is improved to obtain dynamic allocation results and improve the rationality of allocation results.

II. IMPROVEMENT OF ANT COLONY OPTIMIZATION ALGORITHM

In the concept of basic ant colony optimization algorithm, the next moving path of ant is determined by the state transition probability P_{ij}^k, and the value of state transition probability P_{ij}^k is positively correlated with the probability of the path being selected. Suppose that the grid where the ant is at the moment is i, and the calculation formula of the possibility of moving to the next grid j is as follows:

$$P_{ij}^k(t)=\begin{cases}\dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum\limits_{s\in allowde_k}\tau_{is}^{\alpha}(t)\eta_{is}^{\beta}(t)} & ,j\in allowde_k\\ 0 & ,otherwise\end{cases} \tag{1}$$

In the formula, $allowde_k$ is the grid selected by ant k without obstacles, $\tau_{ij}(t)$ is the pheromone content on the path from grid i to grid j, $\eta_{ij}(t)$ is the heuristic function of grid i and j, and α and β are the influence factors of state transition probability [9-11].

The expression of heuristic function $\eta_{ij}(t)$ is as follows:

$$\eta_{ij}(t)=\frac{1}{d_{ij}} \tag{2}$$

In the formula, d_{ij} is the distance between i and j grids.

The initial pheromone of ant movement is defined as $\tau_{ij}(t)=C$, and the time for an ant to go through a path cycle is n. the pheromone change characteristics on the

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path are as follows:

$$\tau_{ij}(t+n)=\rho\cdot\tau_{ij}(t)+\Delta\tau_{ij}(t,t+n) \tag{3}$$

$$\Delta\tau_{ij}(t,t+n)=\sum_{k=1}^{m}\Delta\tau_{ij}^{k}(t,t+n) \tag{4}$$

In the above formula, $\Delta\tau_{ij}(t,t+n)$ is the total amount of pheromones on the path between grid i and j, $\Delta\tau_{ij}^{k}(t,t+n)$ is the pheromone content left by ant k at time $(t,t+n)$, and ρ is the attenuation coefficient of pheromones on this path, and its value range is $(0,1)$.

If there are ants passing through the path between i and j, the pheromone variation is calculated as follows:

$$\sum_{k=1}^{m}\Delta\tau_{ij}^{k}(t,t+n)=\begin{cases}\dfrac{Q}{L_k}, through\ path\ (i,j)\\ 0, else\end{cases} \tag{5}$$

In the formula, Q is the pheromone concentration influence constant, L_k is the total length of the path that ant k passes through.

According to the calculation results of the above parameters, the starting function of ant colony optimization algorithm is improved. The cost function of ant movement is constructed by using A* algorithm

$$f(n)=g(n)+h(n) \tag{6}$$

In the formula, $g(n)$ represents the cost impact function from node S to node n, and $h(n)$ represents the cost impact function from node n to the target node.

According to the construction structure of the cost function, the new heuristic function is obtained as:

$$\eta_{ij}(t)=\frac{1}{d_{ij}+d_{jE}}f(n) \tag{7}$$

In the formula, d_{jE} represents the distance between grid j and target point E.

In order to make the performance of the improved ant colony optimization algorithm stronger, the mobile path selection strategy is improved to avoid the optimization result from falling into the local optimal solution [13-15]. The improved formula of the state selection strategy is:

$$j=\begin{cases}\max\left\{\tau_{is}^{\alpha}\cdot\eta_{is}^{\beta}\right\},\ s\in allowed_k,\ if\quad q\le q_0\\ p_{ij}^{k} \qquad\qquad\qquad , otherwise\end{cases} \tag{8}$$

In the formula, q_0 is constant and q is random uniform distribution parameter.

The final improvement step is to improve the pheromone allocation mechanism. In the traditional ant colony optimization algorithm, the global pheromone is updated after the ants have completed all the paths, so this traditional update method cannot eliminate the path length The influence caused by other unrelated factors leads to poor convergence of the pheromone update algorithm. The idea of the pheromone allocation mechanism in the ant colony optimization algorithm is: sort the path lengths of all ants in ascending order, set the path retention threshold to $1/w$, and eliminate the paths that exceed the threshold. And update the optimal solution of n iterations with the pheromone in this calculation path, which can improve the convergence speed of the algorithm. The improvement process of the information distribution mechanism is as follows:

$$\Delta\tau_{ij}(t,t+n)=\begin{cases}\sum_{k=1}^{1/w}\Delta\tau_{ij}^{k}(t,t+n)\ \ Top\ 1/w\ ants\\ 0\quad otherwise\end{cases} \tag{9}$$

$$\Delta\tau_{ij}^{k}(t,t+n)=\begin{cases}\left(\left(\dfrac{1}{w}-\mu+1\right)\dfrac{Q}{L_k}\right.\quad \mu\ ants\ go\ through\ path\ (i,j)\\ 0\quad otherwise\end{cases} \tag{10}$$

$$\Delta\tau_{ij}(t,t+n)=\Delta\tau_{ij}^{B}(t,t+n)+\Delta\tau_{ij}^{S}(t,t+n) \tag{11}$$

In the formula, $\Delta\tau_{ij}^{B}(t,t+1)$ is the global optimal solution, and $\Delta\tau_{ij}^{S}(t,t+n)$ is the optimal solution of this iteration.

Through the above research, the ant colony optimization algorithm is improved from three aspects: heuristic function, state selection strategy and pheromone allocation mechanism.

III. Dynamic Allocation of Human Resources Based on Improved Ant Colony Optimization

Based on the improved ant colony optimization algorithm, the dynamic allocation of human resources is carried out. Suppose there are m kinds of positions in an enterprise, the number of each position is $r_i=(i=1,2,...,m)$, there are n tasks to be completed in a certain stage of work content, the time limit for completing all tasks is μ_t, and the workload required by staff i for work task j is N_{ij}, then the amount of human resources invested by staff i in work task j is R_{ij}, and the work ability index of staff i is M_{ij}, where $i=1,2,...,m; j=1,2,...,n$.

Before the dynamic allocation of human resources, the following assumptions are made on the company's human resources:

(1) Each staff member has the same work ability index for the same task;

(2) In the same work task, the amount of human resources invested by all staff can be directly proportional to the work ability index;

(3) The value of human resource ownership of enterprise staff can be accumulated.

When the value of human resource ownership of enterprise staff reaches a certain cumulative value, the greater the cumulative workload of the staff, the higher the rationality of human resource allocation. The result of the ratio of the cumulative workload of the staff to the value of human resource ownership is:

$$\frac{\sum_{j=1}^{n}R_{ij}}{x_i\mu_t}, i=1,2,...,m \tag{12}$$

During the working time μ_t, the sum of the human resources invested by the staff is less than the value of the human resources ownership. Converted into a formula form, the expression is:

$$\sum_{j=1}^{n}R_{ij}\le r_i\mu_t, i=1,2,...,m \tag{13}$$

During this working time, the total amount of work invested by the people participating in the same task is less than the total amount of human resources required for the task. The expression is:

$$\sum_{j=1}^{m} \frac{R_{ij}}{N_{ij}} \geq 1, j = 1, 2, \ldots, n \tag{14}$$

In the balanced distribution of human resources in an enterprise, it is necessary to follow the principle of efficiency first, and staff should be allowed to perform tasks with the largest work capability index as much as possible. Assuming that the sum of the product of the cumulative result of all human resource possession values of the staff and the work ability index is F, the specific expression is:

$$F = \sum_{i=1}^{m} \frac{\sum_{j=1}^{n} R_{ij} M_{ij}}{x_i \mu_t} \tag{15}$$

Therefore, the objective function of human resource dynamic allocation satisfying the above conditions is defined as:

$$\begin{aligned} & Z = \max \sum_{i=1}^{m} \frac{\sum_{j=1}^{n} R_{ij} M_{ij}}{x_i \mu_t} \\ & s.t. \\ & \sum_{j=1}^{m} R_{ij} \leq r_i \mu_t, i = 1, 2, \ldots, m \\ & \sum_{i=1}^{m} \frac{R_{ij}}{N_{ij}} \geq 1, j = 1, 2, \ldots, n \\ & R_{ij} \geq 0, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \end{aligned} \tag{16}$$

According to the objective function expression of dynamic allocation of human resources as shown in formula (16), the smaller the value of μ_t is, the larger the value of objective function Z is; The larger $\sum_{j=1}^{n} R_{ij} M_{ij}$ is, the larger Z value of objective function is; The larger the R_{ij} and $\sum_{j=1}^{n} R_{ij} M_{ij}$, the higher the work efficiency and the more reasonable the dynamic allocation of human resources.

IV. EXPERIMENTAL VERIFICATION

In order to compare the performance of the proposed dynamic allocation method of human resources based on improved ant colony optimization, the experiment is carried out.

The experimental environment parameters are shown in Table 1.

Table 1 Experimental environment parameters

Project	Parameter
Operating system	RedFlag Linux DC5.0
Database	Oracle 10g
Application server	Tongweb, Weblogic
ESB Middleware	TongIntegrator
Client side	Windows 7
Browser	IE 12.0

The overall experimental scheme is set as follows: Taking the balance and efficiency of human resource allocation as the experimental indicators, the method of this paper is compared with the methods of reference [7] and reference [8].

Distribution equilibrium: distribution equilibrium refers to the consistency between the distribution equilibrium parameters of different methods and the standard values. The higher the distribution equilibrium is, the more reasonable the distribution results of distribution methods are.

Allocation efficiency: allocation efficiency refers to the ratio of the amount of human resource data allocated by different methods to the total amount of data in the experimental time. The higher the allocation efficiency, the stronger the allocation performance of the method.

A. Comparison of distribution equilibrium

As the most fundamental index of dynamic allocation of human resources, the results of distribution equilibrium can show the distribution performance of distribution methods very intuitively. Therefore, we choose distribution equilibrium as the experimental index, and compare the method in this paper with reference [7] and reference [8], and compare the distribution equilibrium coefficient of the three methods with the standard value. The comparative results of the three methods are shown in Figure 1.

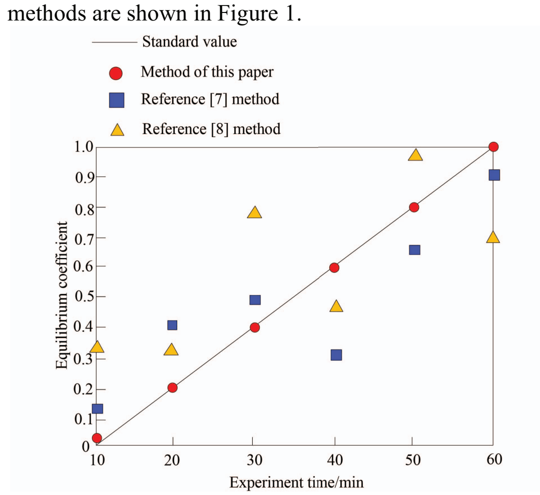

Figure 1 Comparison results of distribution equilibrium of different methods

It can be seen from the comparison results of distribution equilibrium shown in Fig. 1 that the distribution equilibrium coefficient of the method in this paper is basically consistent with the standard coefficient within the experimental time of 60min, while the difference between the distribution equilibrium coefficient of the method in reference [7] and reference [8] is too large, which leads to the poor distribution equilibrium of the two literature comparison methods. Therefore, this method can effectively improve the balance of dynamic allocation of human resources.

B. Distribution efficiency comparison results

Due to the huge demand for human resources, enterprises have higher requirements for the efficiency of dynamic allocation of human resources. Therefore, the allocation efficiency is selected as the experimental comparison index, and the method in this paper is verified with two traditional literature comparison methods. Table 2 shows the comparison results of the allocation efficiency of this method with reference [7] and reference [8].

Table 2 Comparison results of allocation efficiency of different methods

Experiment times / time	Distribution efficiency/%		
	Method of this paper	Reference [7] method	Reference [8] method
1	98.8	84.5	66.8
2	98.5	81.3	69.7
3	98.1	82.1	65.8
4	97.9	80.9	77.2
5	98.2	78.5	78.4
6	99.1	77.3	61.2
7	97.8	81.4	64.9
8	98.6	76.1	66.4
9	99.3	77.9	67.6
10	98.4	75.1	60.9
Mean value	98.47	79.51	67.89

According to the comparison results of distribution efficiency shown in Table 2, the distribution efficiency of this method is always higher than that of the two literature comparison methods. When the number of experiments is 1, the allocation efficiency of this method is 98.8%, that of reference [7] is 84.5%, and that of reference [8] is 66.8%. The distribution efficiency of this method is 98.2%, that of reference [7] is 78.5%, and that of reference [8] is 78.4%. When the number of experiments is 10, the allocation efficiency of this method is 98.4%, that of reference [7] is 75.1%, and that of reference [8] is 60.9%. Therefore, this method can effectively improve the efficiency of the balanced distribution of human resources.

V. CONCLUSION

In order to improve the balance and efficiency of dynamic human resource allocation, a dynamic human resource allocation method based on improved ant colony algorithm is proposed. The performance of the method is verified theoretically and experimentally. This method has high equilibrium and efficiency in dynamic allocation of human resources. Specifically, compared with the method based on K-means clustering algorithm, the distribution equilibrium is significantly improved, which is basically consistent with the standard distribution equilibrium coefficient; Compared with the method based on demand forecasting, the allocation efficiency is significantly improved, and the average allocation efficiency reaches 98.47%. Therefore, it fully shows that the proposed allocation method based on improved ant colony optimization can better meet the requirements of enterprise human resource dynamic allocation.

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