Design of Scheduling System Based on Improved Ant Colony Algorithm

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Abstract: In order to solve the problem of scheduling, a scheduling algorithm based on improved ant colony algorithm is proposed in this paper. In order to take into account the rules of scheduling and the requirements of the personnel, the scheduling problem is reduced to a complete matching problem with a weighted bigraph, and an improved ant colony algorithm is searched under the constraint conditions. The results show that the improved ant colony algorithm can better meet the scheduling requirements and improve the scheduling efficiency.

1. Introduction

In some companies, an assistant to the company leader, in order to coordinate with the effective operation of the company, needs to schedule work at each working time. However, due to the many constraints of scheduling, time, place and personnel situation, it can be reasonably arranged. Moreover, due to personnel changes every month, it is necessary to adjust the duty tables for many times, or even to re-schedule. In order to solve the complex scheduling problem of the company every month, a scheduling method based on improved ant colony algorithm is proposed.

2. Materials and Methods

Scheduling algorithm is a typical combinatorial optimization problem with complex constraints, but as the number of problems needed in the problem is increasing, the required amount of calculation will also show an explosive growth. Although the scheduling problem is a hot issue interiorly and at abroad, but its more research direction is the scheduling of hospital nurses or vehicles. There is less research on the duty in the company, so it is necessary to improve a scheduling algorithm based on the actual situation of the company's scheduling in order to improve the efficiency of the company's scheduling. In solving scheduling problems, the greedy algorithm of intelligent algorithm, simulated annealing algorithm, ant colony algorithm, genetic algorithm, particle swarm optimization algorithm have made great achievements in various scheduling systems.

This paper mainly chooses the ant colony algorithm, and improves it according to the crew scheduling rules, making it suitable for scheduling. Ant colony algorithm was first proposed by M.
Dorigo in 1991, and then improved ant colony system, ant colony algorithm with elite, and the
largest and smallest ant colony algorithm.

3. Discussion

Ant colony algorithm is a simulation algorithm based on ant colony to find food discovery path. In
nature, ants transmit information by secreting pheromones themselves, enabling them to
collaborate with each other to find food. Ant colony algorithm is a kind of bionic algorithm with
strong positive feedback mechanism, distributed computing and other advantages applicable to
many combinatorial scheduling problems.

3.1 The Mathematical Model of Scheduling Problem.

The problem of scheduling is influenced by three factors: personnel, time and place. The
problem of scheduling is to ensure that at least one person is on duty at each time point.
Personnel collection: P={P1, P2, P3,..., Pn} personnel are composed of new staff and old staff.
Duty time: T={T1, T2, T3,..., Tn} duty time is determined according to the actual situation. This
is mainly one day divided into five periods. In one day, there are two classes in the morning, two
classes in the afternoon and one class in the evening.
Collection of duty locations: A ={A1, A2, A3,..., An} Because of different places, duty locations
are different, so the duty locations can be filled out according to the actual situation.
The Cartesian product composed of the above three factors constitutes the solution space of the
problem, and the scheduling problem is the solution under some constraints. People need to find a
suitable duty time and location according to the situation, that is to say, a set of G1 for <P> relations.
At the beginning of each semester, the duty place and the duty time will be arranged according to
the past to form a set of G2 of <T and A>. So the scheduling problem can be simplified as <T, A>
and <T>, and the maximum matching problem of the two partite graph is [1].

3.2 Constraint Condition.

There are two kinds of constraints for scheduling problems. One is the hard constraint, the
scheduling process must be satisfied, one is the soft constraint, and the other is as far as possible in
the scheduling process.
Hard constraints are presented.
1) The same time duty personnel must have no other tasks during the duty time.
2) The same time duty personnel can only be on duty in one place.
3) Women don't value night shifts.
4) At least one person should be arranged on duty.
Soft constraint conditions:
1) New staff should be the first class on Monday or Tuesday.
2) The new employees arranged two classes at most a week.
3) Two adjacent duty personnel should not be the same person as far as possible.

4. Solving Process

4.1 Memory Function of Ants.

Each ant has a taboo list assigned to it. It walks in two diagrams composed of G1 and G2 and
records the nodes that walk each time. The table will be emptied before the next traversal. In order
to compare the results of every ant after every traversing, each ant will allocate a temporary scheduling table. Information on personnel, time, and location is recorded on the temporary schedule. In order to search for the optimal solution, the weight of the G1 node set to the edge of the G2 node set is set to facilitate the ant to search, to record the tightness of the G1 to G2 node and establish a weight information table.

4.2 Probability Transfer Strategy.

The probability of transferring ant K from G1 I node to G2 J node is shown in Equation (1)-(3).

\[
p^K_y(t) = \arg \max \{[\tau_{ij}(t)]^{\alpha} \cdot [\eta_{ij}(t)]^{\beta}, q \leq q_0 \} \quad (1)
\]

\[
p^K_y(t) = \sum_{u \in \text{allowed}} \frac{[\tau_{iu}(t)]^{\alpha} \cdot [\eta_{iu}(t)]^{\beta}}{[\tau_{iu}(t)]^{\alpha} \cdot [\eta_{iu}(t)]^{\beta}}, f \in \text{allowed}, q > q_0
\]

\[
p^K_y(t) = 0, \text{ Else} \quad (3)
\]

In Equation (1)-(3), “allowed” is the next node that ants can choose. \( \alpha \) is the constant weighting value of pheromone, and is the important degree of representing the residual information. \( \beta \) is the constant weighted value of the heuristic function and represents the importance of the heuristic function. \( \tau_{ij}(t) \) is the pheromone on the current time path (I, J), and \( \eta_{ij} \) is the heuristic information between ants from node i to node j. \( q_0 \) is the initial set number and the value is between (0,1), and \( q \) is the random number between values (0,1). \( \eta_{ij} \) is heuristic information, that is, the weights assigned to all sides of nodes in G1 from two nodes to G2 according to the actual situation. Heuristic information can enlighten ant’s transcendental ability, so that ants can quickly find the optimal solution of the problem. When \( q < q_0 \) is used, the ant chooses the search method and chooses the path with shorter distances and more pheromones according to Equation (1). When \( q > q_0 \) is used, it is a random search method, according to Equation  (2) to calculate probability and select a larger path. The probability transfer strategy combines deterministic search with random search, which not only ensures good convergence, but also avoids prematurity.

4.3 Update Strategy of Pheromone.

After the ant moves to the next node, it not only needs to modify the tabu table but also needs to update the pheromone. The pheromone update formula is shown in Equation (4).

\[
\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) - \rho \frac{Q}{L_k}, \tau \in [\tau_{min}, \tau_{max}] \quad (4)
\]

In Equation (4), \( L_k \) is the length of the ant K from the starting node to the current node, \( \tau_{min} \) and \( \tau_{max} \) are the minimum and maximum values representing pheromones. By setting the upper and lower limits of pheromone concentration, the problem of thread stagnation or diffusion in application process can be avoided.

4.4 The Steps of the Algorithm.

Step 1: Sorts the duty staff according to working years.

Step 2: Initialization parameter, the ant number is m, the iteration number is N=0, the maximum iteration number is Nmax, initialization pheromone \( R_{ij}(0) = R_{max} \).
Step 3: N++;
Step 4: When it is N<Nmax, ant K can access G2 according to Formula 1 under the taboo table constraint, and j element of A element.
Step 5: Selects the element J of the maximum state transition probability and modifies the taboo list of ant K according to element J.
Step 6: If the duty table is not filled, it will jump to the fourth step, or jump to the seventh step.
Step 7: Updates the pheromone according to the formula.
Step 8: When N=Nmax, iteration ends, otherwise empty taboo table, jump to the third step.

5. Design of Scheduling System

The scheduling system is based on the number of new employees on duty, the number of new employees on duty and the number of old employees as well as personal wishes and needs, combined with improved ant colony algorithm. In scheduling, the system needs to obey the hard constraints first, and then conform to the soft constraints according to the situation. After completing the scheduling, the administrator can communicate with the staff on duty. If the on-duty personnel need to apply for modification, they can consult with other on-duty personnel and submit the application for modification of the schedule as soon as possible. After completing the modification of the shift schedule, the schedule should be examined and passed by the superior. In the design of the scheduling system, it is divided into several functional modules according to the system implementation process for the design and development, shown in Figure 1.

![Figure 1. Function diagram of scheduling system based on ant colony algorithm.](image-url)

User rights allocation

Different users have different permissions and do not allow access to each other. If mandatory access is forced out of the system, it prompts permission to cross the boundary and requires re-login.

1) Data management
   This module mainly stores information on duty, information on duty, and information on duty time. Administrators can modify and manage scheduling information through the function of this module.

2) Management of scheduling constraints
   In addition to hard constraints and soft constraints, different personnel may have special needs during scheduling. Taboo list is formed according to these constraints and used in subsequent ant colony algorithm.

3) Shift function
Because of the different scheduling constraints of the new employees and the old employees, in order to facilitate the search for the most effective results of the fast ant colony search, the staff are sorted, so that the new employees are first searched and the old employees search after. The improved ant colony algorithm process is described in the previous article.

4) Scheduling query
The main purpose of this module is to facilitate the duty personnel to view duty time and location at any time, so as to prepare for the subsequent duty tasks. The realization of this module is to traverse the relevant information in the database and present it in the form. Finally, the table can be exported by POI technology.

5) System usage description
This module is designed to facilitate new users to quickly use the design of the system. Its functions are mainly the introduction of pictures and words to users.

6) Simulation test
In order to verify the algorithm better, set the following data. There are two duty areas, thirteen employees and eighteen new employees. A duty area A needs five people on duty every day. In the morning, two people are required to be on duty in the morning, two in the afternoon, and one at night. Another duty area, B, requires two people on duty from Monday to Friday every week. In the morning, one person is required to be on duty and one person is required to be on duty in the afternoon. The duty area B requires a new employee and an old employee on duty every day. According to the algorithm, the result of the following table is shown. To be able to distinguish between new and old employees, set \{a, b, c, d,..., l, m\} for old employees and set \{1, 2, 3, 4,..., 17, 18\} for new employees.

<table>
<thead>
<tr>
<th>Table1. A area duty table.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
</tr>
<tr>
<td>1 section</td>
</tr>
<tr>
<td>2 section</td>
</tr>
<tr>
<td>3 section</td>
</tr>
<tr>
<td>4 section</td>
</tr>
<tr>
<td>5 section</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table2. B area duty table.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
</tr>
<tr>
<td>Monday</td>
</tr>
<tr>
<td>Afternoon</td>
</tr>
</tbody>
</table>

Combined with hard constraints and soft constraints, Table 1 and Table 2 can see that the improved ant colony algorithm can well compile the scheduling table that meets the requirements. Finally, according to the ant colony algorithm, the scheduling table needs to be adjusted according to the actual situation of the employees, but the implementation of the scheduling system can solve most of the scheduling problems.

6. Conclusion

The scheduling system based on improved ant colony algorithm can improve the efficiency of company scheduling. Among them, the scheduling algorithm at the core of the system is a combinatorial optimization problem with complex constraints. According to the analysis of the problem, it can be simplified as the maximum matching problem with two graphs with weight. The
system applies ant colony algorithm based on demand improvement, so ants can search as far as possible in order to improve efficiency. The system can reduce the time of multiple schedules and the problem of unsatisfactory schedules, and can meet the needs of the staff on duty as much as possible. When the company's scheduling changes constantly, the system also needs to be improved with change control.

References