Research on the intelligent algorithm of the nurse scheduling problem

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Abstract: The nursing work is one of the most important International work contents of the hospital. The nurse scheduling problem is restricted by many constraints due to the particularity of nursing work. Good nurse scheduling method helps motivate nurses work. In this paper, the problem of nurse scheduling is analyzed, and the mathematical model of the problem is made, and the two stage algorithm is used to solve the question of nurse scheduling. First, a feasible white night shift allocation scheme is selected by branch and bound algorithm, and then the simulated annealing algorithm is used to optimize the design of the selected scheme. Through the optimization algorithm, the complex nurse scheduling problem can be effectively solved.

Keywords: nurse scheduling, branch and bound algorithm; simulated annealing algorithm.

1. Introduction

In modern society, there are many problems of scheduling in the process of production, life and study, such as the school scheduling problem, the factory scheduling problem and the nurse's scheduling problem and so on. Among them, the problem of the nurse scheduling is complicated and challenging because of the special work of hospital. It is difficult to ensure the rationality and efficiency of the scheduling of nurses in most hospitals with the possibility of long time, low efficiency, waste of human resources and personal subjective assumption.

Many researches have been done on nurses' scheduling problems. Many literatures are looking for appropriate mathematical models to solve this scheduling problem. Warner et al. First proposed a single choice algorithm, which uses two steps to solve the possible work arrangement of each nurse and optimize the selection of the target value. Burke and others chose the nurse scheduling problem in Belgian hospital as an example, and also used two stages of solution. First, a large number of local optimal solutions are obtained by multi domain search. Then tabu search is used to solve the final result. The methods of artificial intelligence have also been used in nurses' scheduling problems. Beddoe et al. Used the method of case reasoning (CBR) to introduce the constraints and repair records that are not in practice in the optimization. Dowsland et al. Is the three stage solution method, the first stage to judge the resource conditions of nursing work, the second stage using tabu search algorithm, and the third stage using the network flow model. Genetic algorithm and heuristic algorithm are also the main algorithms used by scholars to solve nurse scheduling problems.

Most of the previous nurses' scheduling problems have been solved in many stages, and the results of the final solution are remarkable. This paper studies and absorbs the achievements of predecessors, analyzes the problem of nurse scheduling, gives the mathematical model of the problem, and uses the two stage algorithm to solve the problem of nurse scheduling. First, the branch and bound algorithm is used to select the feasible white night shift allocation scheme, and then the simulated annealing algorithm is used to optimize the design of the selected scheme. Through the optimization algorithm, the complex nurse scheduling problem can be effectively solved.

2. Analysis of the nurse scheduling problems

The nurse scheduling problem is to arrange each nurse's daily work situation. According to one week's nursing work arrangement, the daily working condition is divided into three kinds, namely, the white shift, the evening shift and the vacation. Therefore, according to the permutation and combination, there are probably 2187 kinds of work arrangements for a nurse in a week. In this paper, each work arrangement is defined as a situation, using 14 bit binary number to replace the nurse scheduling problem. The first seven numbers represent the white shift and the later seven figures for the late shift, and the 1 represents the schedule, and the 0 is not scheduled for the shift.

There are many related factors affecting the effect of nurse scheduling. The joint effect of various factors makes the scheduling problem become a major problem in the work of hospital. Some hospitals even

waste a lot of manpower and financial resources on the scheduling problem, even after investing a lot of resources, they still fail to solve the problem. Among them, the main influencing factors are the number of nurses, the grade of nurses, the white evening shift and the individual needs. It is necessary to make the teaching work smoothly and orderly through the optimal arrangement according to the rules of different constraints, and then expect to improve the teaching quality.

In order to get the optimal solution of the combination, enough constraints do bring better solutions. However, the more constraints are required for the solution process, the more difficult the solution process is to be realized, which brings great computing time and waste calculation resources, so it is very important to select the appropriate conditions. In view of the factors affecting the effect of nurse scheduling, we can choose the following constraints, which can be divided into two categories: important constraints and secondary constraints. Among them, the important constraint condition is the constraint that has great and direct influence on nurse scheduling. The secondary constraint is a type of constraint that has little effect on the scheduling problem, but it can not be ignored. In this paper, several typical constraint conditions are mainly considered. There are several important constraints and minor constraints.

Table 1 .The constraint condition table

The important constraint conditions	
1	The number of nurses per day meets the needs of each week
2	On the same day, the same nurse can only be assigned one job.
The secondary constraint conditions	
1	To meet the special needs of individual nurses as far as possible
2	Limit the maximum and minimum number of working days per nurse and the number of consecutive working days.
3	There should be two days of rest after the night shift
4	Limit the number of consecutive weekends of overtime

Here, for each scenario given a weight value w to judge the popularity of the situation, there are three main factors affecting the W value: (1) the intrinsic property of the situation itself, that is, the attitude of most people to the situation; (2) the difference between the personal feelings and needs of the nurses, each person is different; (3) the influence of the arrangement of the historical work, the distribution of the night shift and the evening shift should consider the rest of the body reasonably.

3. The problem model
In fact, the problem of nurse scheduling is to assign every day to each nurse, and make the defaults of each constraint as small as possible. Because the constraints of the scheduling problem are very complex and numerous, this paper transforms it into a single objective problem to simplify the solution to the multi-objective problem. The given problem model is shown as follows:

$$\min(f(\chi)) = \min\left(\sum_{S=1}^{S} \sum_{i=1}^{18} w_{s,i}, f_{s,i} \right)$$

$$s,t \begin{cases} \text{the number of nurses on every day meets the needs} \\ \text{The same nurse can only work in one class every day} \end{cases}$$

Among them, the w_{si} is the weight of the i constraint condition of the s nurses, and the f_{si} is the fitness value of the i constraint condition of the s nurses.

4. The optimal solution algorithm
4.1. The overall overview of the algorithm
In this paper, the technical route of the optimization algorithm is to determine the total workload of each nurse in one cycle, that is, to determine the allocation scheme for the white and late classes. This step will get many feasible allocation schemes and need to find the best one in these feasible schemes, so it is necessary to further optimize the selection process. These two stages can be separated step by step, or the two stages can be combined. When an optimal selection is carried out in a white and late class assignment scheme, the method is beneficial to find the optimal solution more quickly, reduce the unnecessary process of solving and improve the efficiency of calculation. It can be said that these two stages are mutual auxiliary relations, the branch boundary algorithm can reduce the use of simulated annealing algorithm, the simulated annealing algorithm can provide a lower upper limit of the branch boundary algorithm. The steps for solving the two stage nurse scheduling problem in this paper are shown in the following diagram:
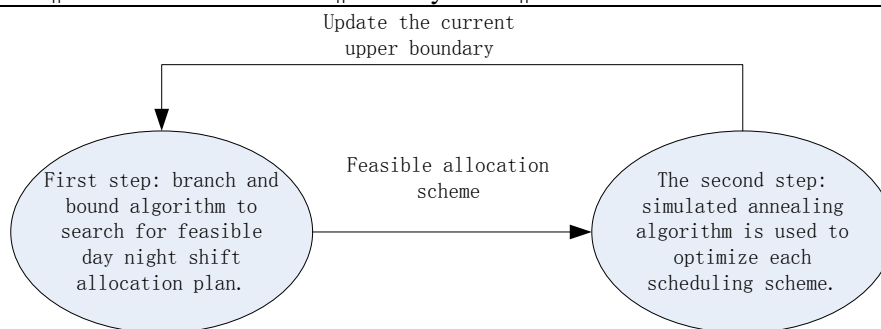
Fig. 1.The Schematic diagram of the algorithm for solving the nurse scheduling problem in the two stage

4.2 The branch and bound algorithm

Branch and bound algorithm is a widely used optimization problem search method. This method takes the current optimal solution as the upper bound, and finds the lower bounds of the problem by the relaxation method. If the lower bound is greater than the upper bound of the current setting, then prune the branch of the subtree which is the root of the node, and through such a process the efficiency of the search is realized. The two factors that affect the efficiency of the branch and limiting algorithm are the method and strategy of branching and pruning. The branch strategy uses the method of depth optimization, and the pruning strategy uses the method of feasibility pruning.

4.3. The simulated annealing algorithm

The simulated annealing algorithm was first proposed by Mr. Metropolis, and Kirkpatrick applied it to solve the optimal solution problem. It is an algorithm based on the principle of physical annealing. When the metal is heated, the molecule is in a free motion state. At this time the temperature can be lowered to make the metal molecules stay in different states. The simulated annealing method is analogous to the process of optimization as the annealing process of metal, and the optimal solution is regarded as a state of the lowest energy. The simulated annealing algorithm mainly determines the initial temperature, the drop temperature function, the stopping criterion and termination rule at a certain temperature.

5. Conclusion

Nursing is one of the most important tasks in hospital. The nurse scheduling problem is restricted by many constraints due to the particularity of nursing work. Many scholars have done many research results onnurse scheduling problems, and many literatures are seeking suitable mathematical models to solve this scheduling problem. Most of the previous nurses' scheduling problems were solved by multi-stage solutions, and the final solution was effective.

This paper studies and absorbs the research results of the predecessors, analyzes the nurse scheduling problem deeply, gives the mathematical model of the problem, and uses the two stage algorithm to solve the nurse scheduling problem. First, a feasible white night shift allocation scheme is selected by branch and bound algorithm, and then the simulated annealing algorithm is used to optimize the design of the selected scheme. Through the optimization algorithm, the complex nurse scheduling problem can be effectively solved. Good nurse scheduling can not only help motivate nurses' work, but also improve the quality of nursing work to ensure patients' life and health.

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