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An effective constraint-aware optimization method for university course timetabling problem

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ABSTRACT

University course timetabling is known to be hard combinatorial optimization problem. It is difficult to tackle the constraints including the classroom, course and the teacher requirement. Some optimization approaches have been proposed in order to solve this kind of problem, one of the efficient solution methods for this problem is tabu search. But these methods little take attention to the constraint relationships, mainly concern the conflict circumstances. In this paper, constraint-aware modeling method is proposed based on the fuzzy Petri net, which can respect the constraint relationships among the courses, the classrooms and the teachers. Then we locate the best legal firing sequences in the constraint model by the differential evolution (DE) method, in order to obtain the optimal course timetabling plan. The theoretical analysis and specific example show that the method is very effective.

KEYWORDS

Course timetabling problem; Fuzzy Petri net; Differential evolution; Optimization.

INTRODUCTION

Course timetabling scheduling in colleges and universities is a highly complicated task for satisfying multiple constraints including the course, the classroom and the teacher requirements. Conventional course timetabling is done mainly from the school's point of view, of a course scheduling and selecting system has been viewed as a crucial indicator of the school's service quality. In the curricular management of colleges and universities, course scheduling is a critical service item. Under the constraints of limited time, space, faculty and teaching facilities, in addition to the constraints of relevant laws and regulations and teachers requirements, the school not only has to provide the required courses, but also has to offer a variety of elective courses[1,2].

The university course timetabling problem is concerned with classroom capacity, the course arrangement and the teacher requirements. About the course timetabling problem can be found in[3], the core of the course timetable is essential as more modules and associated events have to be timetabled in such a manner as to, one is to offer students maximum flexibility of choice, second to satisfy personal requirements for the teachers as far as possible, thirdly to ensure that teaching space is used effectively. In the university course timetabling problem, it has some hard constraint and some soft constraint, so these constraints are tackled by different methods respectively[4]. For the course timetabling problem, some literature proposed lots of specific techniques and methods[5-8]. According to different case, the constraints, the three factors defining the effectiveness of each timetable are determined. These university course timetabling problems are NP-complete, as far as their computational complexity is concerned, meaning that the difficulty to find a solution rises exponentially to their size and a deterministic algorithm, giving an acceptable solution in polynomial time, cannot be found[9]. Therefore, alternative optimization methods have been used in order to implement an optimal solution for various kinds of the timetabling problem. Other methods used in order to solve the timetabling problem of educational organizations are genetic/evolutionary algorithms, case-based reasoning, heuristic orderings, local search techniques, particle swarm optimization, ant systems, tabu search, metaheuristics and hyperheuristics.

The mentioned-above methods mainly considered the heuristic optimization methods to solve the complicated course timetabling problem. few methods concerned the constraint relationships before the optimization process. So these may lead to some blindness searching process, and the computing time-cost is high. In the paper, we propose an effective constraint-aware optimization method to solve the university course timetabling problem. In our method, the course timetabling model with constraint is built by the some constraint conditions, then using the differential evolution method to locate the best firing sequences on the model. The course timetabling plan can be scheduled effectively

CONSTRAINT-AWARE MODELING OF THE UNIVERSITY COURSE TIMETABLING

Problem description

In the Chinese AUST university, the teaching time is scheduled into 5 teaching timeslot each work-day (5 work-day each week), and the set of classrooms including 50 seats, 100seats and150 seats, where the course can take place and a set of students. Every course has associated a list of students who have to attend or attend selectively, the same course cannot be assigned in the same day. Moreover, some teachers have personal requirements[4]. A feasible timetable is one in which all courses are assigned a timeslot and a room so that the following three hard constraints are satisfied:

H1: Only one course is assigned to each room at any timeslot.
H2: The classroom can accommodate all attending students.
H3: No student attends more than one course at the same time.
H4: The same teacher can be assigned 0 or 1 course at any timeslot.

In addition, a candidate timetable receives a penalty cost for violating any of the following three soft constraints:

S1: A student should not have the same course in the same day.

S2: The big classrooms should service the course which the more student number firstly.
S3: The teacher requirements should be considered as far as possible.

Constraint-aware modeling of the course timetabling based on the fuzzy Petri net

Petri net is used to model course timetabling problem because of its intuitive graphical symbol, rich theoretical analysis technology, and suitable to describe some constraint relationships. In the course timetabling, it is not only to achieve the internal arrangement of the three factors including the classroom, the course and the teacher, but also the exchange of information among the three factors. The paper uses Fuzzy Petri net (FPN) modeling methods[11].

According to the hard and the soft constraint, we analyze the constraint relationships, and give out the model method[11]. The modeling methods are presented as follows:

(1) According to the domain knowledge, the three key model including abstract tasks and the dependent relation between abstract tasks. Each abstract task is represented by a place and the same abstract task are put the same level.

(2) The independent global constraints are represented by transitions. If two tasks have independent global constraints, then the former place is linked with the latter place by directed arc. The confidence factor of transitions is the confidence degree of relationship between places.

(3) Taking advantage of (1) and (2), a FPN model can be obtained about independent global constraints for the course timetabling. The problem of locating instance course plan is turned into searching the legal firing sequences in the FPN model. Furthermore, the optimal course timetabling are the legal firing sequences having the largest trust value in the FPN model.

According the constraint-aware modeling method, we can build the FPN model of the university course timetabling (showed in the Figure 1).

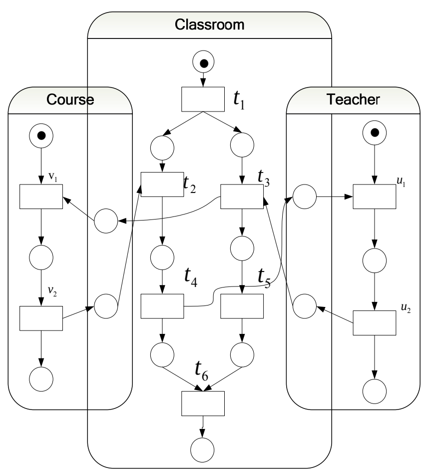

Figure 1 : The FPN model of the university course timetabling.

THE OPTIMIZATION OF THE UNIVERSITY COURSE TIMETABLING BASED ON THE DE

By making full use of FPN model, the paper uses transition elements of FPN model to encode intimidation population. Concretely, regarding firing sequences of FPN as chromosomes, every legal firing sequence in Petri Net model represent a feasible course plan. So the problem of locating instance course plan is turned into searching the legal firing sequences in the FPN model, then the best firing sequence can be found by optimizing legal sequence with DE[12]. If simply adopting Petri net to schedule course, it is very complex when the scale of course is comparatively large. If DE method is adopted only, searching has comparatively large randomness. It goes against resolving problems effectively. This method takes these two aspects into consideration simultaneously, which reduces the complication and searching randomness effectively.

The optimization methods of independent global constraints for university course timetabling based DE and FPN are as follows:

Initialization population

For a FPN, if it exists a firing sequences $\sigma = t_1 t_2 \cdots t_{n-1} t_n$, makes $M_0 \lfloor \sigma > M_f$, then σ can be regarded as a chromosome, here, M_0 is the first marking, M_f is the end marking, $t_1, t_2 \cdots t_{n-1}, t_n \in T$.

According to the requirement of scheduling process, we select fixed number (such as M) firing sequences from FPN model with constraints as the first population $x_{\mu 0}$ of the DE, here $x_{\mu 0} = rand[0,11] \cdot (x_j^{(u)} - x_j^{(L)}) + x_j^{(L)}$, $(i = 1,2,\cdots, NP; j = 13,\cdots, D)$

Mutation operator

The operation of the mutation operator as follows:

1) Appointing every transition in the firing sequences as a variation point in order.

2) For each variation point, replacing it with the new transition in its range according to the mutation probability p_m, then, generating new firing sequences.

3) Checking the new firing sequences generating in step 2 by using the legal firing sequences algorithm of Petri net, reserving legal firing sequences, excluding some illegal firing sequences.

Though the mutation operator, the mutation vector is as follows:

$$V_{i,G+1} = x_{r1,G} + F \cdot (x_{r2,G} - x_{r3,G})$$

Crossover operator

The operation of the crossover operator as follows:

(1) Putting two chromosomes randomly as a group, suppose two chromosome are σ and σ^* respectively.

(2) Swapping the same position transition of two firing sequences corresponding chromosome according to the crossover probability p_c, generating some new firing sequences.

(3) Checking the new firing sequences generating in step 2 by using the legal firing sequences algorithm of Petri net, reserving legal firing sequences, excluding some illegal firing sequences.

The test vector is as follows:

$$\mu_{i,G+1} = (\mu_{1i,G+1}, \mu_{2i,G+1}, \ldots, \mu_{Di,G+1})$$

$$\mu_{ji,G+1} = \begin{cases} V_{ji,G+1} & f(randb(j) \le CR) or\ j = rnar(i) \\ x_{ji,G+1} & if(randb(j) > CR) or\ j \ne rnar(i) \end{cases}$$

(4) Selection operator

For decide whether $\mu_{i,G+1}$ will become the next generation members, according to standard, we need compare DE greedy vector with the current population objective vector. If the objective function is to minimized, so it has a small target function value in the next generation of population will win a majority position. The next generations of all individuals are better than the current population of corresponding individual or at least as well.

(5) The treatment of boundary conditions

In the problem of boundary constraints, it is necessary to ensure the new individual values for the parameters in the feasible domain of question, a simple method is to instead randomly the infeasible solution.

If $\mu_{ji,G+1} < x_j^{(L)}$ or $\mu_{ji,G+1} > x_j^{(U)}$, then $\mu_{ji,G+1} = rand_j[0,1] \cdot (x_j^{(U)} - x_j^{(L)}) + x_j^{(L)}$ $(i = 1,2,\cdots, NP; j = 1,3,\cdots, D)$

(6) If it does not satisfy terminating condition, then update $t \leftarrow t+1$, and consider the first M of the legal firing sequences generating from (7) as the next new group, then go to (4) step. If meeting the terminating conditions, then output results, the algorithm ends.

EXPERIMENT SIMULATION

The methods of university course timetabling with constraint based on DE and FPN is proposed, which not only uses FPN superiority in the description multi-attribute multi-constraint problems, but also takes fully Petri net's properties when DE locating in the FPN model into account. In the theoretical, the method is of great benefit to analyze independent global constraint question, which can avoid high complexity using Petri net methods solely and large randomness using DE only.

In order to analyze feasibility and validity of the methods, we compare DE method with Hybrid method[4] by experiment simulation.

The experiment is set as follows:

(1) Building and simulating domain ontology including class, subclass and level relations using Protégé 2000.

(2) Setting the function and constraint description of three factors, the number of the classroom is enough.

(3) Experiment environment: CPU is Intel dual 3.00GHz, Memory is 2.00GB, and operation system is Windows XP.

For a given course timetabling requirement, using the DE method, Hybrid method presented in the literature[4] respectively, the experiment result (Figure. 2) shows the execution time of DE & FPN method is less than the Hybrid method, and when the more of the service number in the service library, the better is the effect. The reason is that we uses fully FPN’s properties when DE locating in the FPN model, which makes locating space lower, and some component services which don’t satisfy constraint relations or have minor associate relation need not to match each other. So it can save execution time, and improve the time performance of service composition.

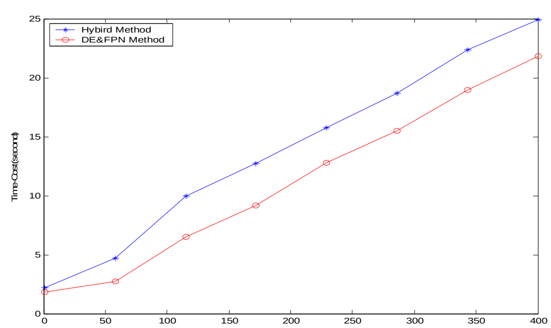

Figure 2 : The execution time of three methods.

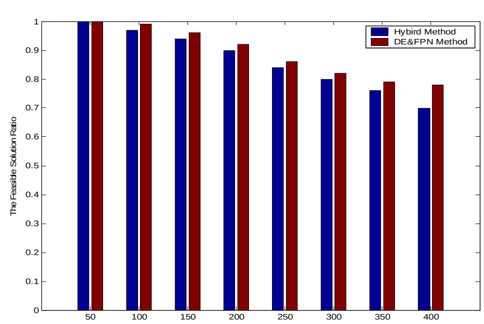

Figure 3 : The ratio of solution and web services

In Figure 3, we locate feasible candidate services from service library, and compare the relation graph between the ratio of solution and web services. The experiment result shows the ratio of solution of DE & FPN method is higher than the Hybrid method, but lower than greedy methods. With the web services number adding, the ratio of solution of DE & FPN method decrease quickly.

CONCLUSION

This work described an effective constraint-aware optimization method of the university course timetabling. Firstly, aiming to the constraint requirements, we propose the modeling method based on the fuzzy Petri net. Then we analyze the course scheduling problem, and present the optimization method based on the DE[13]. So the problem of locating instance course plan is turned into searching the legal firing sequences in the FPN model, then the best firing sequence can be found by optimizing legal sequence with DE. Finally, the experiment simulation shows the DE method is very effective.

In the future work, we plan to study the muli-object optimization of the course timetabling, and further to study the a atomic scheduling methods of the course timetabling.

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