Improvement of Column Generation Method for Railway Crew Scheduling Problems

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The railway crew scheduling problem is to determine an optimal crew assignment to minimize the number of crews required to cover all of railway assignment satisfying several crew working constraints. The problem can be formulated as a huge set covering problem. Column generation method is commonly used to solve the railway crew scheduling problem. Conventional column generation method has a shortcoming that the convergence for deriving a lower bound is very slow because of the degeneracy or the excess oscillation of simplex multipliers. In this paper, we propose the dual inequalities for the railway crew scheduling problem to reduce the oscillation for simplex multipliers. The objective is to propose the dual inequalities for improving slow convergence of the column generation method. The dual inequalities are generated from railway timetable information. Break time constraints are incorporated in the model. Computational experiments are demonstrated to compare the performance with that of the conventional column generation method. Column generation method is one of the techniques for deriving good lower bound for combinatorial optimization problems. In the column generation algorithm, the continuous relaxation problem for the set covering formulation of the original problem is decomposed into the restricted master linear programming problem and the pricing problem. For the railway crew scheduling problem, each column represents a candidate of the crew path. In the pricing problem, a column is generated to minimize the reduced cost using the simplex multiplier vector. If the reduced cost is negative, the derived column is added to the restricted master problem. The pricing problem can be reformulated as a longest path problem with several crew working constraints. Because the path does not include any cycle, the pricing problem can be solved by dynamic programming. We have developed three types of dual inequalities that can be added to the dual problem of the restricted master problem. These dual inequalities are expected to reduce the oscillation for simplex multipliers and to accelerate the column generation method. We provide a proof that the dual inequalities do not eliminate the optimal solution of the dual problem of the continuous relaxation problem. Computational experiments are demonstrated to compare the performance between the proposed method and the conventional column generation method. The number of tasks is 216, and the number of time steps is 240 as shown in Fig. 1. Computational results for the number of replications, number of columns, and total computation time are shown in Table 1 when the break time limit $R$ is changed into 70, 80, and 90. A Pentium4 3.2GHz processor with 2GB memory is used for computation. The performance of the proposed method is improved 12%, 17%, and 10% when the break limit is 70, 80, and 90, respectively. The total computation time is also reduced by the proposed method. The results demonstrate that the proposed method is effective for solving the railway crew scheduling problems.

References