An Agent Based Metaheuristic for the Travelling Tournament Problem

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Abstract

In the double round robin problem that we have studied, the main objective is to minimise the total distance travelled for the teams. A few hard constraints also need to be satisfied.
The travelling tournament problem is a complex combinatorial problem, for which it is hard to find an optimal solution. A few meta-heuristic approaches, such as tabu search and ant algorithms, have been developed. We found that the most basic algorithms required additional problem specific improvements in order to reach good quality solutions. We have compared different meta-heuristic approaches to the problem and combined them into a well-performing hybrid.

Keywords tabu search, ant algorithms, agents, sport timetabling, travelling tournament problem

1 Introduction

In a double round robin tournament, each team plays twice against each other team: one home and one away game. A tournament for n teams, n being an even number, consists of $2 * (n - 1)$ games days in which each team plays exactly one game.
We have carried out experiments on the travelling tournament problem that is introduced by Trick [9]. The data consists of a distance matrix between each pair of home cities of the teams. A few hard constraints need to be satisfied at all costs:

- no repeaters are allowed (repeaters are home and away games between two teams on two consecutive games days),
- not more than three consecutive home and three consecutive away games for each team.

The goal is to minimise the total distance travelled. We have to take into account that each team is located in its home city before it starts the first game. It also has to get back to its home city after the tournament is finished.

Solving sport timetabling problems has been a challenge for many years and it is undoubtedly a complex problem [6]. Many researchers have attempted to describe or solve the problems with exact mathematical techniques such as linear and integer programming, graph theory, etc [2]. Easton et al.[4] and Trick [8] made use of integer and constraint programming techniques to find the solution with the shortest distance. In [7], Trick decomposes the problem into two different phases. The games are scheduled

first, without considering home and away requirements. Assigning the home and away patterns happens in the second phase. Operations research techniques have generated good quality solutions for the small size problems but most larger problems seem to be too complex for exact optimisation methods.
In recent years, several attempts have been made to solve sport timetabling problems with metaheuristics. Crauwels and Van Oudheusden [1] developed an ant colony optimisation algorithm that can compete with some of the best mathematical techniques. Wright [10] has succesfully applied 'dynamic weight variation' in his metaheuristic search for scheduling a cricket competition.

2 Tabu Search

2.1 Cost function

When evaluating a solution, the cost function determines the quality by calculating the total distance travelled. We do not really distinguish feasible from infeasible solutions but we penalise the latter very highly in the cost function. In most experiments, we have set one violation of a hard constraint equal to 100 times an approximation of the total travel distance.

2.2 Neighbourhoods

We have studied the results of single neighbourhood experiments in order to come to a list of neighbourhoods that make tabu search perform well in certain situations. Fig. 1 demonstrates the different neighbourhoods that we developed for the tabu search approach.

Swapping games

The 'swapping games' neigbourhood considers each possible exchange of two games in the timetable. This may result in an infeasible schedule (with a team that has two games at one games day).

Swapping games days

The 'swapping games days' neigbourhood is only applied with feasible timetables. As a result, all the games of one games day are exchanged with the games of another games day. Test results indicate that this move highly alters the timetable. Near the end of the search, the changes are often so drastic that they destroy good quality parts of the schedule.
The following neighbourhoods turned out to produce better results in case the schedule is already of good quality.

Insert games day

This insertion neighbourhood leads to a move that takes a games day and inserts it at another place in the timetable.

Swap game with return game

For feasible solutions, we can apply a steepest descent heuristic which swaps games and return games in the timetable (exchange game A-B with B-A).

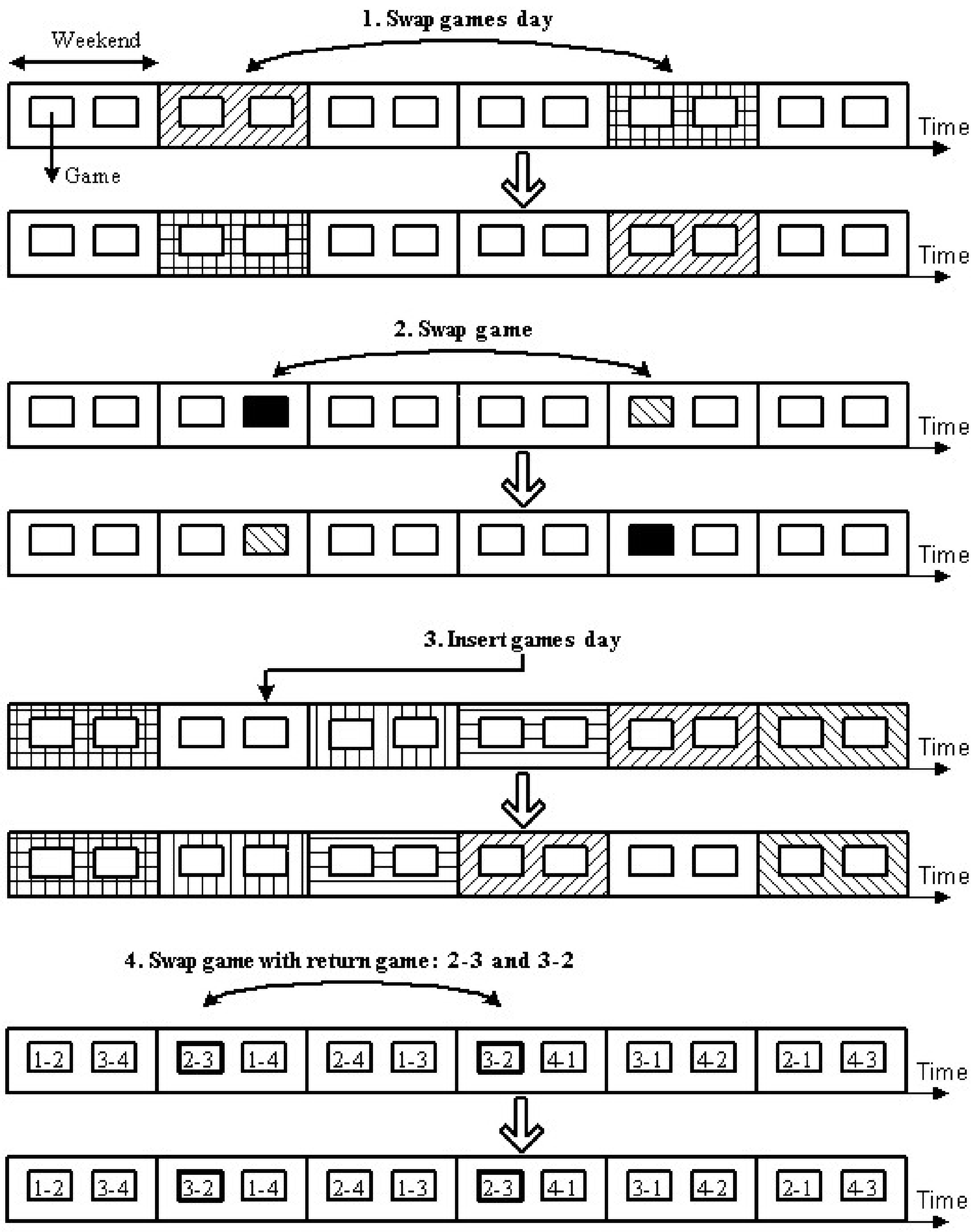

Figure 1: Different neighbourhoods for tabu search

3 Agent based heuristic inspired by ant colony optimisation

In a second heuristic for the travelling tournament problem, we use a group of agents that construct a sports schedule. This heuristic is inspired by ant colony optimisation [3]. Initially, each game in the round-robin tournament is assigned to an agent. This game becomes one of the games scheduled at the first games day. Starting from this initial game, every agent builds a timetable. Per step in the algorithm, every agent constructs a list of candidate games. The candidate list is influenced by the history of the agent. An agent remembers which games are already accepted in the timetable. It also maintains information about the teams that are already playing during the current games day. For example, in the round-robin tournament with 4 teams the agent selects in the first step the second game for the first games day; in the second step it selects the first game of the second games day, and so on.

Each agent has to choose a game from the candidate list. Therefore we maintain information about the desirability of playing a game at a certain games day. We favour the games in the candidate list that have, besides a high desirability, a low cost according to the history of the agent. This cost is influenced by the traveling costs for each team, the number of consecutive home and away games and repeaters. If a game is choosen by an agent for a certain games day, an updating rule is applied for increasing the game's desirability measure. Once all agents have terminated their timetable, a global updating rule is applied to adjust the desirability measures for the games in the best timetable. The agents can then start all over.

4 Hybrid heuristic

The agent based heuristic is a constructive heuristic while, on the other hand tabu search is an improvement heuristic. We added tabu search to the agent based heuristic in order to make it more competitive. After the agents have constructed a timetable, we apply tabu search to improve the schedule of each agent. The agent based heuristic first completes a number of iterations without tabu search. We did some experiments to find a proper time for introducing tabu search. We also experimented with the duration of the tabu search improvements.

5 Conclusion

Both the hybrid tabu search approach and the agent based technique perform very well for the travelling tournament problem.
Both techniques reached the optimal solution for the small size problems with 4 and 6 teams. We noticed that the introduction of different neighbourhoods was necessary to reduce the computation time for tabu search. Also, the parametrisation of the agent based algorithm, in which the approach swaps between exploration and exploitation techniques are efficient and create good quality solutions. In order to approach the optimal solution, a hybrid technique that combines the best of both approaches performs better.

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