A Heuristic Approach for the Travelling Tournament Problem using Optimal Travelling Salesman Tours

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1 Introduction

The travelling tournament problem (TTP) was introduced as a challenging sports timetabling problem (Easton et al., 2001). Its objective is to minimise the total distance travelled in a double round robin tournament. A solution must satisfy the following constraints: home and away games between two teams should not be scheduled on consecutive game days, and teams should not play more than three consecutive home/away games. Test data and results are presented on the TTP website[4]. In this abstract, we present the results of a metaheuristic approach for the NL instances of the TTP website. The algorithm consists of a constructive and an improvement heuristic. Many examples of successful constructive heuristics have been reported, including:

- 1 Factorization (Di Gaspero and Schaerf, 2007),
- the Polygon Method (Biajoli and Lorena, 2006), (Ribeiro and Urrutia, 2004),
- Tiling (Bar-Noy and Moody, 2006), (Kendall et al., 2006).

The first phase of the metaheuristic builds upon the tiling approach of (Kendall et al., 2006), as it explicitly addresses the problem of minimising the travelling distance. It assigns as many tiles as possible to an initially empty schedule, after which a metaheuristic algorithm turns the schedule into a feasible solution.

Apart from integer programming and constraint programming based techniques (Easton et al., 2002) to solve the problem, metaheuristic approaches have recently appeared to be quite successful. Examples include simulated annealing (Van Hentenryck and Vergados, 2006; Anagnostopoulos et al., 2006), tabu search (Di Gaspero and Schaerf, 2007), evolutionary algorithms (Biajoli and Lorena, 2006)), ant algorithms (Crauwels and Van Oudheusden, 2002; Chen et al., 2007). We applied a composite neighbourhood tabu search algorithm to improve the solutions that result from the first phase.

The two-phase metaheuristic introduced in this paper leads to optimal solutions for the smallest test instances, i.e. up to 8 teams.

[4] http://mat.gsia.cmu.edu/TOURN/

2 Constructive heuristic

2.1 TSP tiling, feasible patterns and partial solution

We have concentrated on minimising the total distance travelled by solving a travelling salesman problem (TSP) that corresponds to the TTP. We further assume that parts of the optimal TSP solution are likely to form good quality road trips, provided that their length does not exceed three away fixtures. The technique to derive a set of road trips (or tiles) from the TSP tours is based on a heuristic that creates feasible patterns. The entire TSP-related technique was first introduced by (Kendall et al., 2006)).

A first partial solution is created by assigning tiles to an initially empty tournament schedule, while respecting the TTP constraints. The basic assignment algorithm is parameterisable in that it allows us to

- define the order in which to pick tiles from the set created in Section 2.1 (e.g. random, order of increasing/decreasing distance, etc),
- define the position of the tile in the tournament schedule (e.g. random, first possible, etc),
- choose the orientation of the tile by reversing the order of teams to visit or not (e.g. 1-2-3 or 3-2-1).

The basic assignment algorithm stops when it is impossible to add extra tiles to the schedule. It results in a partial, and thus infeasible, schedule. The next algorithm attempts to put 'semi tiles' into the schedule. A semi tile is derived from a tile by rearranging the order of the teams such that the result is no longer a tile. The figure below shows an example of two semi tiles that are derived from a basic tile. Obviously, semi tiles are no longer optimal but they can overcome feasibility problems that cannot be solved with any full tiles.

$$\boxed{1\ 2\ 3} \quad \Longrightarrow \quad \boxed{2\ 1\ 3} \ \text{ and } \ \boxed{1\ 3\ 2}$$

2.2 Initial feasible solution

It is not possible to create complete schedules by placing tiles and semi tiles only. The initial assignment algorithms lead to a tournament schedule in which some games are missing. The schedule is completed using a composite neighbourhood tabu search algorithm. The neighbourhoods applied are presented below. The tabu search method halts as soon as it reaches a solution without empty game slots. That solution will be used as the initial solution for the improvement heuristic.

1. **InsertGame**(t, r, m): insert game m for team t in round r.
   Preconditions: Team t does not play a game in round r.
   Game m is not played in round r.
   Game m is not played by team t in any round.
2. **RotateGameInRound**(t, r, m): move game m to team t in round r.
   Preconditions: Game m is played in round r.
   Team t does not play a game in round r.
   Game m is not played by team t in any round.
3. **RotateGameInTeam**(t, r, m): move game m to round r for team t.
   Preconditions: Game m is played by team t.
   Team t does not play a game in round r.
   Game m is not played in round r.

3 Improvement heuristic

The improvement heuristic is a composite neighbourhood tabu search heuristic that is mainly based on neighbourhoods described in the literature. The neighbourhoods involve swapping homes and teams as in (Di Gaspero and Schaerf, 2007; Van Hentenryck and Vergados, 2006; Biajoli and Lorena, 2006; Ribeiro and Urrutia, 2004; Chen et al., 2007), swapping rounds (Di Gaspero and Schaerf, 2007; Chen et al., 2007), shifting rounds (Chen et al., 2007), swapping games (Di Gaspero and Schaerf, 2007; Biajoli and Lorena, 2006), swapping the games of a team in different rounds (Di Gaspero and Schaerf, 2007). An ejection chain is required for the last two moves in order to maintain feasible round robin tournaments.

4 Results

Table 1 presents the results obtained by the two-step approach in terms of the solution quality, the computation time and the difference between the solution found and the optimal/best solution known at this date. The constructive heuristic only has a moderate influence on the quality of the result and on the computation time. The constructive phase could thus be omitted, in which case the improvement heuristic would start from a randomly generated solution. We found, however, that the combined method is much more robust than the improvement approach alone. Although robustness is not an issue for solving static instances of the TTP, it would become important when the algorithms were applied to real world problems.

Table 1. Test results (computation time, result and % difference with the best published results)

	Constructive			Constructive + Improvement			Improvement		
	time	distance	% difference	time	distance	% difference	time	distance	% difference
NL4	58ms	8276	0,00	33ms	8276	0,00	23ms	8276	0,00
NL6	110ms	25027	4,65	50s	23916	0,00	2m	23916	0,00
NL8	365ms	43633	9,85	30m	39721	0,00	30m	39721	0,00
NL10	1143ms	68579	15,38	2h	61364	3,24	2h	62530	5,21
NL12	5,44s	130589	17,94	3h	119275	7,22	3h	120246	8,09
NL14	11,92s	242051	28,25	3h	216138	14,52	3h	216138	14,52
NL16	25,3s	336060	28,42	3h	319915	21,28	3h	314117	19,09

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