Constructive Algorithms for the Constant Distance Traveling Tournament Problem

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Abstract. The traveling tournament problem considers scheduling round-robin tournaments that minimize traveling distance, which is an important issue in sports scheduling. Various studies on the traveling tournament problem have appeared in recent years, and there are some variants of this problem. In this paper, we deal with the constant distance traveling tournament problem, which is a special class of the traveling tournament problem. This variant is essentially equivalent to the problem of 'maximizing breaks' and that of 'minimizing breaks', which is another significant objective in sports scheduling. We propose a lower bound of the optimal value of the constant distance traveling tournament problem, and two constructive algorithms that produce feasible solutions whose objective values are close to the proposed lower bound. For some size of instances, one of our algorithms yields optimal solutions.

1 Introduction

In scheduling of round-robin tournaments, there are two major objectives [9], 'minimizing breaks' and 'minimizing traveling distance'. The former is to improve quality of a tournament by decreasing the number of breaks (consecutive games both held at away or both held at home); the latter aims to reduce traveling costs of teams by minimizing traveling distance. Many papers that concern minimizing traveling distance have been published so far. The traveling tournament problem (TTP), established by Easton et al. [3], is a well-known benchmark problem that abstracts the concept of minimizing traveling distance. The constant distance traveling tournament problem (CDTTP), introduced by Urrutia and Ribeiro [13], is a variant of TTP, in which all distance between

E.K. Burke and H. Rudová (Eds.): PATAT 2006, LNCS 3867, pp. 135–146, 2007.

pairs of teams are one. It is known that maximizing breaks gives an approximate solution for minimizing traveling distance [11]. In particular, in CDTTP maximizing breaks is not approximation but direct transformation of minimizing distance [13]. Moreover, it was also shown that the problem of maximizing breaks is essentially equivalent to that of minimizing breaks [6], which is another significant subject in sports scheduling.

Most of the best upper bounds of CDTTP (and TTP) are obtained by metaheuristic algorithms [1,12,14]. In contrast, it is difficult to obtain good lower bounds for CDTTP; a logic based Benders decomposition approach [7] was used to obtain lower bounds of instances of up to 16 teams, and lower bounds of larger instances are not known so far. In this paper, we propose a new lower bound for CDTTP, and two algorithms that produce feasible solutions whose objective values are close to the proposed lower bound. For some size of instances, one of our algorithms yields optimal solutions.

2 Problem

In this section, we introduce some terminology and definitions, and then describe the constant distance traveling tournament problem (CDTTP). For more discussions on CDTTP and its variations, see [7,13].

We are given a set of teams $T = \{1, 2, \ldots, n\}$ where n is an even number, and each team has its home venue. A game is specified by an ordered pair of teams. A double round-robin tournament is a set of games in which every team plays every other team once at its home venue and once at away (i.e., at the venue of the opponent); hence, exactly $2(n-1)$ slots are required to complete a double round-robin tournament.

Each team stays its home venue before a tournament, and then travels to play games at the chosen venues. After a tournament, each team goes back to its home venue. In a tournament, the number of trips of a team is defined by the number of moves of the team between venues. We note that, when a team plays two consecutive away games, the team goes directly from the venue of the first opponent to the other, without returning to its home. Consecutive away games for a team constitute a *road trip*; consecutive home games are a *home stand*. The length of a road trip/home stand is the number of opponents playing against in the road trip/home stand, respectively. The constant distance traveling tournament problem is defined as follows.

Constant Distance Traveling Tournament Problem
Input: the number of teams, n;
Output: a double round-robin tournament of n teams such that

1. the length of any home stand and that of any road trip are at most three;
2. no repeaters (A at B immediately followed by B at A is prohibited);
3. the total number of trips taken by teams is minimized.

In the rest of this paper, a double round-robin tournament satisfying the above conditions 1 and 2 is called a *feasible tournament*.