A Branch-and-Cut Algorithm for Scheduling the Highly-Constrained Chilean Soccer Tournament

Thiago F. Noronha[1], Celso C. Ribeiro[2], Guillermo Duran[3], Sebastian Souyris[3], and Andres Weintraub[3]

[1] Department of Computer Science, Catholic University of Rio de Janeiro, Rua Marquês de São Vicente 225, Rio de Janeiro, RJ 22453-900, Brazil
tfn@inf.puc-rio.br
[2] Department of Computer Science, Universidade Federal Fluminense, Rua Passo da Pátria 156, Niterói, RJ 24210-240, Brazil
celso@inf.puc-rio.br
[3] Department of Industrial Engineering, University of Chile, Republica 701, Santiago, Chile
{gduran,ssouyris,aweintra}@dii.uchile.cl

Abstract. The qualifying phase of the Chilean soccer championship follows the structure of a compact single round robin tournament. Good schedules are of major importance for the success of the tournament, making them more balanced, profitable, and attractive. The schedules were prepared by ad hoc procedures until 2004, when a rough integer programming strategy was proposed. In this work, we improve the original integer programming formulation. We derive valid inequalities for improving the linear relaxation bound and we propose a new branch-and-cut strategy for the problem. Computational results on a real-life instance illustrate the effectiveness of the approach and the improvement in solution quality.

1 Introduction

There are 20 teams in the first division of the Chilean national soccer championship, organized by the National Association of Professional Soccer (ANFP). It is organized in two phases: qualifying and playoffs. The qualifying phase follows the structure of a compact single round robin tournament, in which each team plays against every other exactly once and all teams play exactly one game in every round. The teams are evenly distributed over four groups with five teams each. The groups are formed according to the performance of each team in the last tournament. Each of the first four teams is placed in one of the four groups. The teams from the 5th to the 8th places are randomly distributed in different groups. The same happens with the teams from the 9th to the 12th places. This procedure is repeated until all teams are assigned to a group. At the end of the qualifying phase, the teams that end up in the two first positions of each group qualify for the playoffs. The qualified teams play four quarter-final matches, whose winners play the two semi-final matches. The winners of the semi-final

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matches play the final match. Playoff matches consist of two games each, each of them played at the home of one of the opponents.

The schedules of the Chilean soccer championship were prepared by ad hoc procedures until 2004. As for most European and South American soccer championships, the games were randomly assigned to slots in a predefined round sheet. Then, team representatives voted whether the schedule should be accepted or not. If the proposed schedule was not accepted, then the representatives proposed modifications and the voting process was repeated until a schedule was accepted by more then 50% of the representatives. There were several drawbacks with these schedules that made them less attractive for fans and less profitable for teams: (a) classical games at inconvenient rounds, (b) weak teams playing away all their games against strong teams, (c) teams playing too many consecutive home games or too many consecutive away games, and (d) no games between traditional teams and teams from tourist cities during summer rounds, when many people are visiting the tourist regions. Duran et al. [6] tackled the problem of scheduling the Chilean soccer championship by integer programming in 2005, handling the above issues. The model was solved by a standard branch-and-cut procedure of the CPLEX solver. However, this procedure would take up to two hours of computation time to find a feasible solution. The procedure would be interrupted at this time, the set of possible home–away patterns fixed, and the resulting simplified model solved to optimality using a limited set of decision variables. In consequence, the model becomes easy and solvable in a few seconds. Although the resulting schedules were better than those obtained by the ad hoc procedures, the duality gaps could be very large and solutions lacked of quality.

Good schedules have a major importance in the success of sports tournaments, making them more balanced, profitable, and attractive. Many authors tackled the problem of tournament scheduling optimization in different leagues and sports. Bean and Birge [2] focused on the scheduling problem for the National Basketball Association, in which the most limiting constraints concerned rest days and stadium availability. Costa [4] considered the scheduling of the National Hockey League, for which one of the objectives consisted in the minimization of the total distance traveled by all teams. Henz [8] used constraint programming to improve the processing times of the enumerative approach proposed in [10] to compute schedules for a college basketball conference. These results were later improved by Zhang [15], once again using constraint programming. We refer to Henz [9] for recent advances in constraint programming for scheduling problems in sports, as well as to Trick [13,14] for the combination of integer and constraint programming. Bartsch et al. [1] developed a branch-and-bound procedure for scheduling the professional soccer leagues of Austria and Germany. Goossens and Spieksma [7] proposed an integer programming formulation for scheduling the Belgian soccer league, whose objective function consisted in the minimization of the violations of soft constraints. Ribeiro and Urrutia [12] solved the problem of scheduling the Brazilian soccer tournament by an approach combining backtracking and integer programming, which found