Scheduling the Argentine volleyball league: A real-world application of the Traveling Tournament Problem with couples of teams

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Outline

Traveling Tournament Problem

Motivation:

- The TTP is the most important benchmark on sports scheduling (Easton, Nemhauser, Trick, 2001)

Objective:

- Schedule a *Double Round Robin* tournament minimizing the total travel distance

Restrictions:

- No team can play more than *k* consecutive home or away matches
- No pair of teams can play against each other in two consecutive rounds

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Example

Example. A schedule for 4 teams:

Rnd	A	B	C	D
1	B	@A	D	@C
2	C	D	@A	@B
3	@D	C	@B	A
4	@B	A	@D	C
5	@C	@D	A	B
6	D	@C	B	@A

- Team A plays an away match on round 3 against D.
- Team B plays a home match on round 3 against C.

Argentine Volleyball League 2007/2008

Regular Phase 2007/2008

- 12 Teams
- Mirrored *Double Round Robin* tournament
- Teams are grouped into 6 couples (defined before the tournament)
- Each couple is composed by two teams located close to each other
- Games take place on Thursday and Saturday (Weekend)

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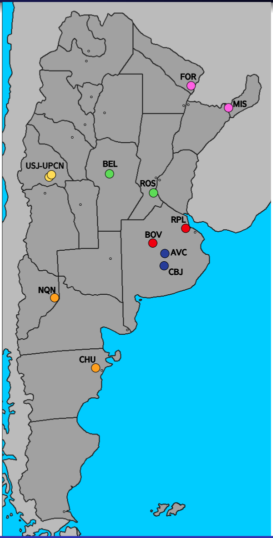
Argentine Volleyball League

Regular Phase 2007/2008

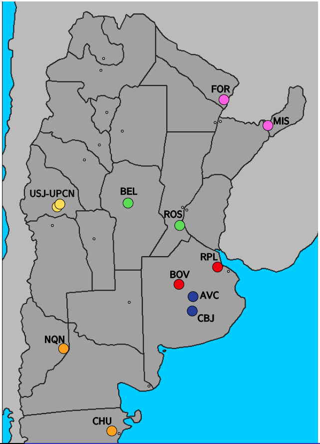
- Team Locations



Argentine Volleyball League

Regular Phase 2007/2008

- Team Locations
- Max Distance: 2,365Km (Formosa-Chubut)



Argentine Volleyball League 2007/2008

Regular Phase 2007/2008

- The regular phase spans 12 weekends
- In each weekend, a couple "plays against" another couple (2 games take place on Thursdays and the other 2 games on Saturday)
- During weekends 1 and 7, the two teams of each couple play against each other (on Saturdays)

Argentine Volleyball League 2007/2008

Objective:

- Schedule a mirrored *Double Round Robin* tournament minimizing the total travel distance.
- It is assumed (as in the TTP) that no team returns home between consecutive away weekends.

Restrictions:

- No team can play more than 2 consecutive home or away weekends
- Home and away restrictions for some teams on particular dates

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Comparing both formats

TTP	Argentine volleyball
Single teams	Couples of teams
Single matches	Two-match weekends
No repeaters	Mirrored
No more than 3 home or away matches	No more than 2 home or away weekends

Integer Programming Approach

- The scheduling of the league is composed by two key decisions: (a) how to couple the teams and (b) how to schedule the matches among the couples of teams.
- One possible way to tackle these decisions is to set up an integer programming model simultaneously addressing both issues. However, the resulting model performs very poorly with *Cplex*, and quite often *Cplex* even fails to find feasible solutions after several hours.
- Due to this fact, we concentrated in a natural two-phase process instead: we design the couples of teams first, and then we schedule the matches using the obtained couples.
- This approach is computationally feasible in the sense that each phase can be reasonably solved.

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Tabu Search Approach

- Tabu Search Algorithm (based on our previous work on the TTP in 2002, which allowed us to get good results at that time)
- Cost Function: Sum of travel distances
- Search Space: Only valid solutions (mirrored)
- Multiple neighborhoods (one at a time)

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Neighborhoods

- Swap Teams
- Swap Rounds
- Swap Home/Away
- Partial Swap Rounds (main neighborhood)

Partial Swap Rounds Example

Rnd	A	B	C	D	E	F	Rnd	A	B	C	D	E	F
1	E	@F	@D	C	@A	B	1	F	@E	@D	C	B	@A
2	B	@A	E	@F	@C	D	2	B	@A	E	@F	@C	D
3	F	@E	D	@C	B	@A	3	E	@F	D	@C	@A	B
4	@C	D	A	@B	F	@E	4	@C	D	A	@B	F	@E
5	.	.	.	.	.	.	5	.	.	.	.	.	.

- The swap involves teams A, B, E, F and rounds 1 and 3

Cost Function

- We use the following function to evaluate a valid solution:

$$f(x) = \sum_{t=1}^{n} C_t$$

- where C_t is the total travel distance for team t along the tournament and is calculated as:

$$C_t = \sum_{r=1}^{R+1} T_{t,r}$$

$(t = 1...n)$

- and $T_{t,r}$ is the distance team k has to travel between rounds $r - 1$ and r

The coupled format

- To the best of our knowledge, this coupled format is only in use in the Argentine volleyball and basketball leagues (both first and second division leagues).
- With some minor modifications it is also applied in the highly professional Brazilian volleyball league and in the Czech national basketball league.

The coupled format has some interesting properties

- Reduces the manual/computational burden of generating a schedule: if we manage some minor issues, the task of generating a schedule for n teams is equivalent to generate a double round-robin schedule for $n/2$ teams (by considering each couple as a single team).
- Introduces a simple but effective evenness criterion: if no two strong teams belong to the same couple, then the coupled format ensures that no team will play against two strong teams in the same weekend.
- Contributes to a proper handling of the travel distances: if each couple groups two geographically close teams, then the coupled format helps to keep the travel distances under control, in particular for manually generated schedules.

Results

- This is the first application of the Traveling Tournament Problem to a real-world league reported in the optimization literature (M. Trick, personal communication).
- The schedules generated by our models have been successfully used in the 2007/2008 (mirrored), 2008/2009 (mirrored), and 2009/2010 (non-mirrored).
- In the mirrored cases, the IP model obtains the optimum value in a solution time which ranges from 2 minutes to 1 hour.
- In the non-mirrored case, our best solution is obtained by the Tabu Search heuristic in a running time of 5 minutes.

Results

- We run the Integer Programming model on a Pentium IV (2GHz) using CPLEX.
- The tabu search heuristic was coded in C++ with the *Microsoft Visual C++* environment.

Several objective functions have been considered:

- *Minimizing the total travel distances.* This objective function has been applied in the 2007/2008 and the 2008/2009 leagues.
- *Minimizing the distance of the most traveller team.* This objective attempts to evenly distribute the travel distances of the teams at the expense of the total travel distance. The resulting schedules are not usually acceptable, since the total travel distances tend to be larger.
- *Minimizing the gap between the most traveller team and the least traveller team.* This objective function also seeks to evenly distribute the travel distances.
- *Minimizing a combination of total travel distances and the distance of the most traveller team.* This objective function was used for the construction of the 2009/2010 schedule.

Reducing the total travel distances

- We made a comparison between the manually-designed schedules (effectively used) and the automatic schedules (generated by our methods) for the 2005/2006 and 2006/2007 leagues.
- The automatically-generated schedule for the 2005/2006 league attains a 22.34% reduction in the total travel distances, and this reduction amounts to a 15.41% for the 2006/2007 league.
- It must be noted that the set of teams varies from each league to the following one, due to promotions/demotions from/to the second division league.

Argentine Volleyball League Champion

Bolivar Team celebrating

Questions?

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