Constraint-based Round Robin Tournament Planning

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Chonology

- November 1996, Boston, CP 96: George Nemhauser mentions ACC problem
- Summer 1997, Trick and Nemhauser solve ACC problem (published Jan 1998)
- Dec 1996 - Jan 1998, using constraint programming for ACC problem
- March - June 1998, development of sport scheduling tool Friar Tuck
- January 1999, Friar Tuck 1.1

The ACC 1997/98 Problem

- 9 teams participate in tournament
- dense double round robin:
  - there are 2 * 9 dates
  - at each date, each team plays either home, away or has a “bye”
- there should be at least 7 dates distance between first leg and return match. To achieve this, we fix a mirroring between dates: (1,8), (2,9), (3,12), (4,13), (5,14), (6,15) (7,16), (10,17), (11,18)

The ACC 1997/98 Problem (cont'd)

- No team can play away on both last dates
- No team may have more than two away matches in a row.
- No team may have more than two home matches in a row.
- No team may have more than three away matches or byes in a row.
- No team may have more than four home matches or byes in a row.

The ACC 1997/98 Problem (cont'd)

- Of the weekends, each team plays four at home, four away, and one bye.
- Each team must have home matches or byes at least on two of the first five weekends.
- Every team except FSU has a traditional rival. The rival pairs are Clem-GT, Duke-UNC, UMD-UVA and NCSt-Wake. In the last date, every team except FSU plays against its rival, unless it plays against FSU or has a bye.

The ACC 1997/98 Problem (cont'd)

- The following pairings must occur at least once in dates 11 to 18: Duke-GT, Duke-Wake, GT-UNC, UNC-Wake.
- No team plays in two consecutive dates away against Duke and UNC. No team plays in three consecutive dates against Duke UNC and Wake.

- UNC plays Duke in last date and date 11.
- UNC plays Clem in the second date.
- Duke has bye in the first date 16.

The ACC 1997/98 Problem (cont'd)

- Wake does not play home in date 17.
- Wake has a bye in the first date.
- Clem, Duke, UMD and Wake do not play away in the last date.
- Clem, FSU, GT and Wake do not play away in the fist date.
- Neither FSU nor NCSt have a bye in the last date.
- UNC does not have a bye in the first date.

Preferences

- Nemhauser and Trick give a number of additional preferences.
- However, it turns out that there are only 179 solutions to the problem above.
- If you find all 179 solutions, you can easily single out the most preferred ones.

More details on ACC 97/98 in:Nemhauser, Trick; Scheduling a Major College Basketball Conference; Operations Research, 46(1), 1998.

Nemhauser/Trick Solution

- enumerate home/away/bye patterns
  - explicit enumeration (very fast)
- compute pattern sets
  - integer programming (below 1 minute)
- compute abstract schedules
  - integer programming (several minutes)
- compute concrete schedules
  - explicit enumeration (approx. 24 hours)

Schreuder, Combinatorial Aspects of Construction of Competition Dutch Football Leagues, Discr. Appl. Math, 35:301-312, 1992.

Modeling ACC 97/97 as Constraint Satisfaction Problem

Variables:

- 9 * 9 * 2 variables taking values from {0,1} that express which team plays home when. Example: $H_{UNC,\,5}$=1 means UNC plays home on date 5.
- away, bye similar, e.g. $A_{UNC,\,5}$ or $B_{UNC,\,5}$
- 9 * 9 * 2 variables taking values from {1,...,9} that express against which team which other team plays. Example: $O_{UNC,\,5}$ =1 means UNC plays team 1 (Clem) on date 5

Modeling ACC 97/97 as Constraint Satisfaction Problem (cont'd)

Constraints:

Example: No team plays away on both last dates.

$A_{Clem,17} + A_{Clem,18} < 2$, $A_{Duke,17} + A_{Duke,18} < 2$, ...

All constraints can be easily formalized in this manner.

Constraint Programming Approach for Solving CSP

"Propagate and Distribute"

- store possible values of variables in "constraint store"
- encode constraints as computational agents that strengthen the constraint store whenever possible
- compute fixpoint over propagators
- distribute: divide and conquer, explore search tree

First Step: Back to Nemhauser/Trick!

- constraint programming for generating all patterns.
  - CSP representation straightforward.
  - computing time below 1 second (Pentium II, 233MHz)
- constraint programming for generating all pattern sets.
  - CSP representation straightforward.
  - computing time 3.1 seconds

Back to Schreuder

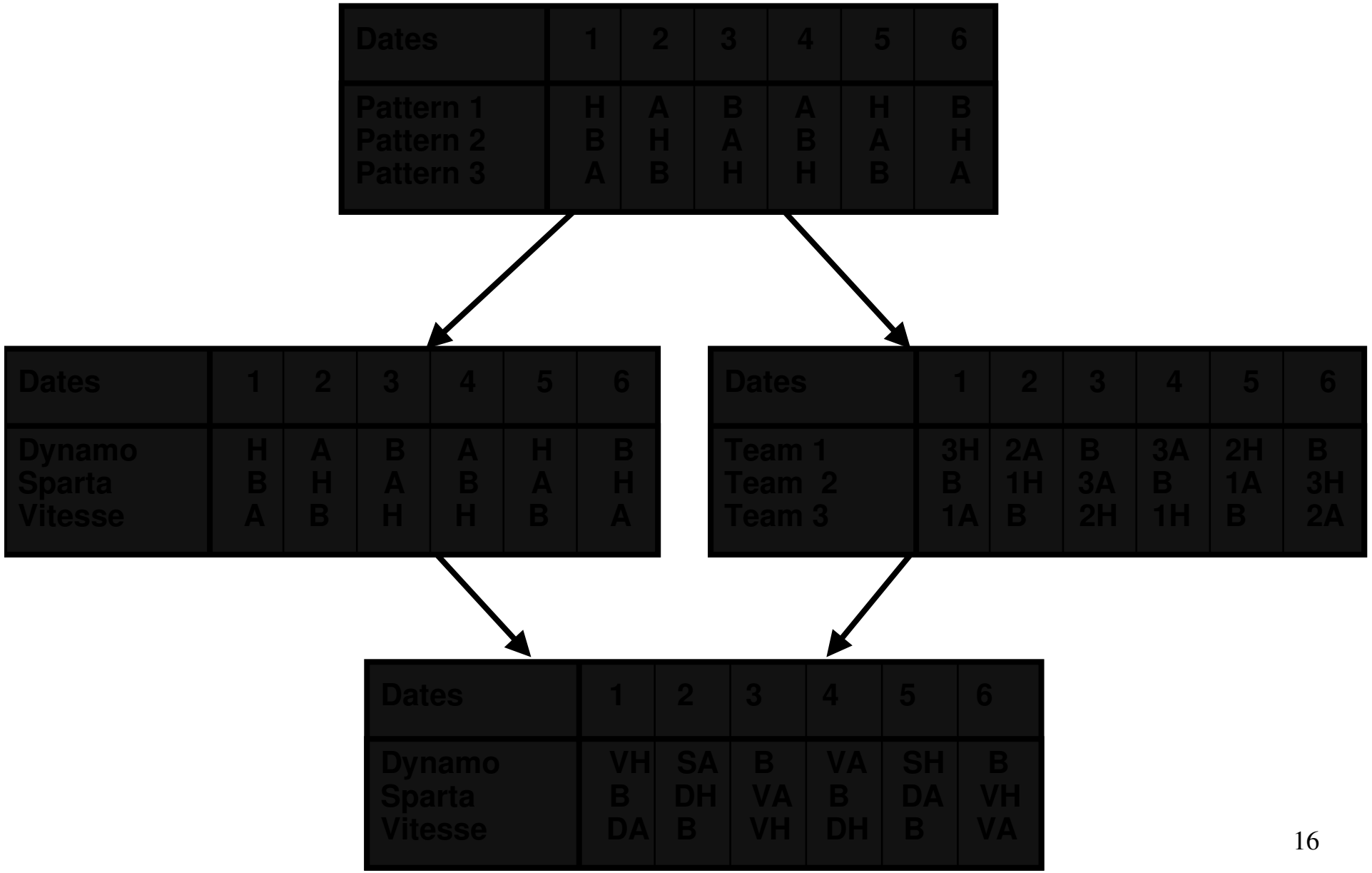
- constraint programming for abstract schedules
  - Introduce variable matrix OA similar to O in naïve model
  - there are many abstract schedules
  - runtime several minutes
- constraint programming for concrete schedules
  - model somewhat complicated, using two levels of the “element” constraint
  - runtime several minutes

Cain's Model

- Alternative to last two phases of Nemhauser/Trick
- assign teams to patterns in a given pattern set.
- assign opponent teams for each team and date.

W.O. Cain, Jr, The computer-assisted heuristic approach used to schedule the major league baseball clubs, Optimal Strategies in Sports, North-Holland, 1977

Cain 1977 Schreuder 1992



Using Cain's Model in CP

- CP model simpler than CP model for Schreuder
- runtimes:
  - patterns to teams: 33 seconds
  - opponent team assignment: 20.7 seconds
  - overall runtime for all 179 solutions: 57.1 seconds

Details in:

Martin Henz, Scheduling a Major College Basketball Conference - Revisited, Operations Research, 2000, to appear

Idea for Friar Tuck

- constraint programming tool for sport scheduling
- convenient entry of constraints through GUI
- open source, GPL
- implementation language: Oz using Mozart see www.mozart-oz.org

Implementation of Friar Tuck

- special purpose editors for constraint entry
- access to all phases of the solution process
- choice between Schreuder and Cain's methods
- computes schedules for over 30 teams
- some new results on number of schedules

Martin Henz, Constraint-based Round Robin Tournament Planning, International Conference on Logic Programming, 1999

Future Work

- application specific “constraint language” for sport scheduling
- re-implementation using Figaro library (under development)
- using local search for sport scheduling