THE COLLEGE OF WOOSTER
Department of Mathematical and Computational Sciences

APPLICATIONS OF CONSTRAINT PROGRAMMING IN SPORTS SCHEDULING

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PURPOSE

As a student-athlete in multiple sports here at the College of Wooster, and from personal experience over most of my life as a part of many travel sports teams for football and baseball, I have often wondered about the many variables that must be considered when scheduling a sports tournament or season, i.e., what constraints are in play, and how to incorporate them to minimize team travel distances and maximize breaks. My goal was to find an optimal solution to the sports scheduling problem to get the best performance out of the players on any team.

METHODS

Several individual types, as well as some combinations of constraint programming were examined to determine if an optimal schedule could be achieved as both the number of teams and number of constraints increased.

TYPES OF CONSTRAINT PROGRAMMING

INTEGER PROGRAMMING: A class of problems that can be expressed as the optimizations of a linear function subject to a set of linear constraints over integer variables.

NP-hard

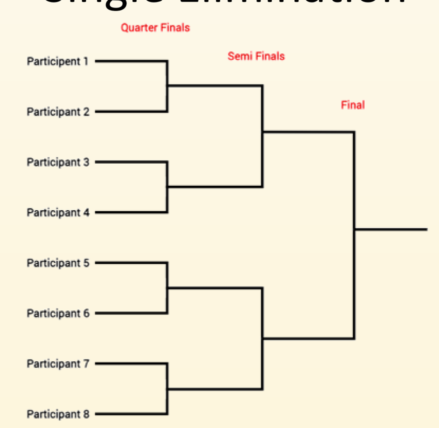
GOAL PROGRAMMING: An extension of linear programming in which targets are specified for a set of constraints.
2 Methods:
- Weights – subjective in nature
- Preemptive – constraints and goals are represented at different levels of importance

(*not examined)

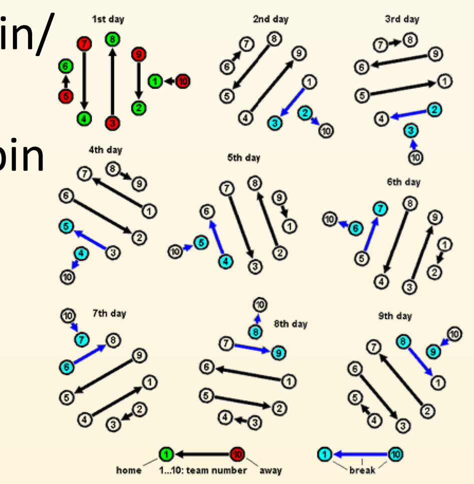
DYNAMIC PROGRAMMING: An algorithmic technique that obtains solutions by working backward from the end of a problem toward the beginning by breaking up a large problem into a series of smaller, more tractable sub-problem.

TOURNAMENT TYPES

Single Elimination



Round Robin/ Double Round Robin (DRRT)



UNIVERSAL CONSTRAINTS IN SPORTS

VENUE: Avoiding double-booking conflicts

Rivalries: Scheduling for intensity and driving anticipation

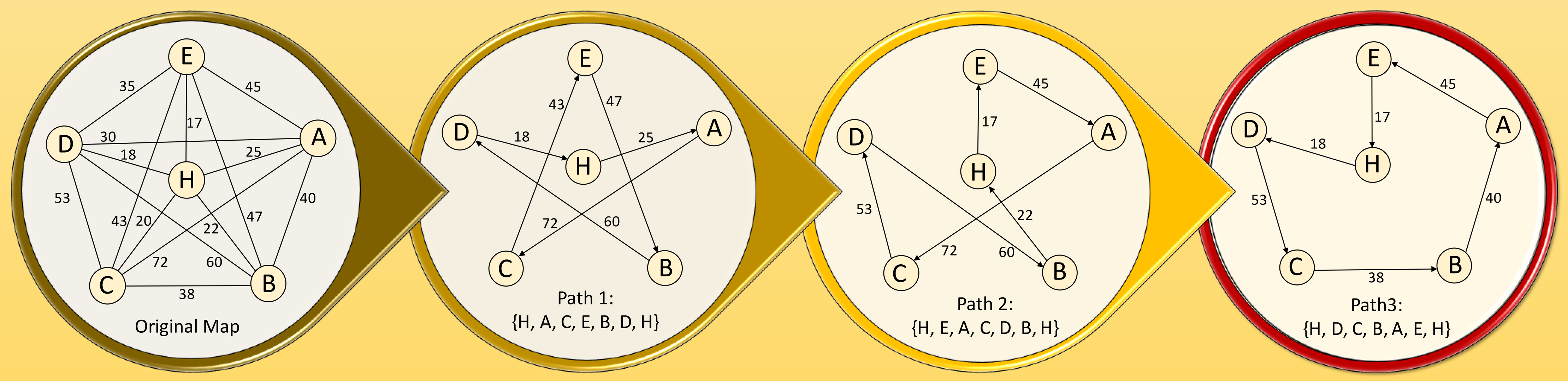
Breaks: Balancing Home / Away Games

DISTANCE TRAVELED: Minimizing maximum distance traveled for all teams

Carry-over Effects: Balancing player efforts for competition readiness

TSP

Traveling Salesman Problem: Assuming distance corresponds with travel cost, we want to minimize travel distance with only one visit to each stop starting and ending at home (H).



STP

Single Team Problem: minimizing travel distance of a single team, Team 1 (t_1) maintaining consistency of home versus away games to create a balanced schedule. NP-hard with similar characteristics to TTP but with a different optimized schedule output based on the specific constraints.

Input: n = number of teams; k = total travel distance;
L = length of each home stand and road trip;
d = individual teams' travel distance

Output: Is there an optimal schedule for a team t such that,
$L \geq 2$, and d_t must = a total distance traveled k

If distance from t_1 to t_2 = 20 miles, t_1 to t_3 = 27 miles, t_1 to t_4 = 25 miles, t_2 to t_3 = 12 miles, t_2 to t_4 = 33 miles, and t_3 to t_4 = 8 miles, and if k = 125 miles;

Multiple solutions for t_1 with n = 4 teams:

(a)	n = 4	1	2	1	3	4	1
(b)	n = 4	4	1	3	1	2	1
(c)	n = 4	1	2	1	3	4	1

Option ***B is <u>not feasible</u>*** with d_1 = 144 which is > 125. ***Option <u>A is feasible</u>*** with d_1 = 100, but ***<u>C is the optimal solution</u>*** with d_1 = 68 miles.

TTP

Traveling Tournament Problem: expands STP by minimizing the output for all teams as opposed to just one team.

Given the following:
1. Each team, t must start and finish at their home venue
2. Each team plays once at home and once away
3. Each team plays precisely once in each slot
4. Next competition follows until every team plays in all slots
5. Distances are given by an n x n matrix D minimized.

Input: n = number teams,
A road trip is defined as 2 consecutive (home or away) games, $g \geq 2$

Output: A (DRRT) with n number teams such that,
1. The length of every home stand or road trip L, must be $L \geq 2$,
2. The travel distance by n number of teams must be

If teams were to visit every other team before returning home, this would closely resemble a traveling salesman tour.

CONCLUSION

The constraints investigated were only a small sample of the number that play a key role in sports scheduling today. We found that while each method is useful under confined restraints or smaller number of teams competing, the Bipartite Traveling Tournament Problem (BTTP), as well as a combination of goal and integer programming yields the best opportunity at reaching as close to an optimal solution available when examining larger scale sports scheduling problems. Given the vast array of constraints to be considered across the plethora of sporting activities and events, no one defined method has been proven able to optimize the sheer number of variables and constraints possible. As concluded in my research, continued work in this arena provides a wealth of opportunity for scholars and enthusiasts alike.