

Discrete Optimization

Local Search: Part V

Goal of the Lecture

- ▶ Local search
 - sports scheduling
 - complex neighborhood

Sports Scheduling

- ▶ Practical applications
 - baseball, basketball, football, hockey
 - radio and television networks: \$\$\$
- ▶ The traveling tournament problem (TTP)
 - abstraction of major league baseball
 - proposed by Easton, Nemhauser, and Trick
- ▶ The TTP is complex
 - Feasibility constraints: home/away patterns
 - Objective function: total travel distance

The Traveling Tournament

► Input

- n teams
- a matrix d of distances between teams

► Output: a double round-robin schedule

- atmost constraint: no more than three consecutive games at home or away
- no repeat constraint: a game $a @ b$ cannot be followed by a game $b @ a$
- minimize travel distance

The Traveling Tournament

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	4	3	6	@4	@1	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@6	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

$$d_{12} + d_{21} + d_{15} + d_{54} + d_{43} + d_{31} + d_{16} + d_{61}$$

$$d_{12} + d_{21} + d_{15} + d_{54} + d_{43} + d_{31} + d_{16} + d_{61}$$

+ ... +

$$d_{61} + d_{14} + d_{45} + d_{56} + d_{63} + d_{36} + d_{62} + d_{26}$$

The Neighborhood

- ▶ A number of moves
 - swap homes
 - swap rounds
 - swap teams
 - partial swap rounds
 - partial swap teams

Swap Homes

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	4	3	6	@4	@1	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@6	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	@4	3	6	4	@1	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	2	1	5	@2	@6	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

Swap Rounds

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	4	3	6	@4	@1	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@6	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1



T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	@5	3	4	@4	@3	5	2	@6
2	5	1	4	@6	@3	3	6	4	@1	@5
3	@4	5	6	@1	2	@2	1	@6	@5	4
4	3	6	@2	@5	@1	1	5	@2	@6	@3
5	@2	@3	1	4	6	@6	@4	@1	3	2
6	@1	@4	@3	2	@5	5	@2	3	4	1

Swap Teams

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	4	3	6	@4	@1	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@6	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	@3	6	4	1	@6	@4	@1	3	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	2	1	5	@2	@6	@3
5	@2	1	@3	@6	4	3	6	@4	@1	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

Swap Teams

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	4	3	6	@4	@1	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@6	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	@3	6	4	1	@6	@4	@1	3	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	2	1	5	@2	@6	@3
5	@2	1	@3	@6	4	3	6	@4	@1	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

Swap Teams

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	@3	6	4	1	@6	@4	@1	3	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	2	1	5	@2	@6	@3
5	@2	1	@3	@6	4	3	6	@4	@1	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

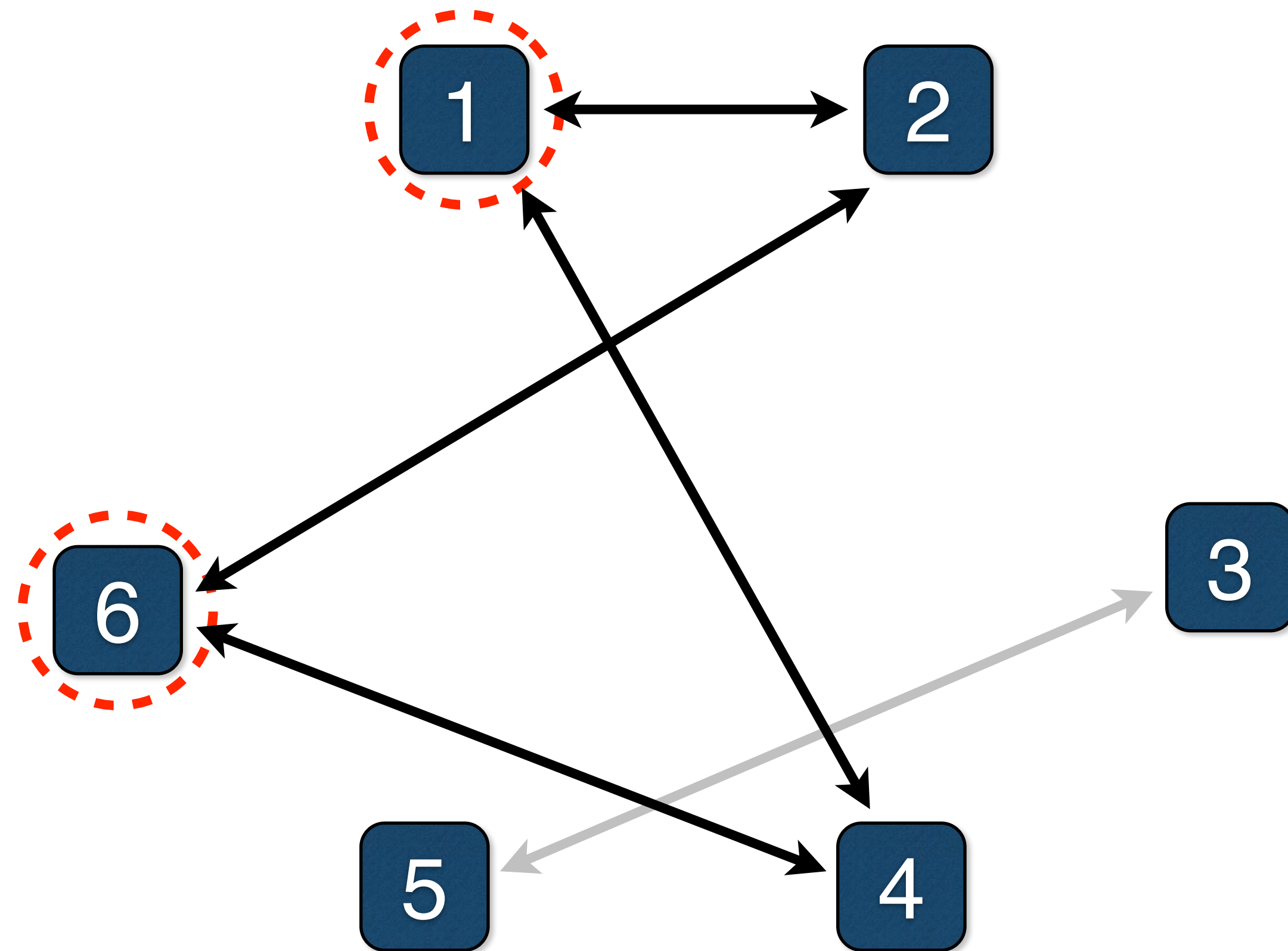
T-R	1	2	3	4	5	6	7	8	9	10
1	6	@5	4	3	@2	@4	@3	2	5	@6
2	5	@3	6	4	1	@6	@4	@1	3	@5
3	@4	2	5	@1	6	@5	1	@6	@2	4
4	3	6	@1	@2	@5	1	2	5	@6	@3
5	@2	1	@3	@6	4	3	6	@4	@1	2
6	@1	@4	@2	5	@3	2	@5	3	4	1

Swap Partial Rounds

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	2	3	@5	@4	@3	5	4	@6
2	5	1	@1	@5	4	3	6	@4	@6	@3
3	@4	5	4	@1	6	@2	1	@6	@5	2
4	3	6	@3	@6	@2	1	5	2	@1	@5
5	@2	@3	6	2	1	@6	@4	@1	3	4
6	@1	@4	@5	4	@3	5	@2	3	2	1

T-R	1	2	3	4	5	6	7	8	9	10
1	6	4	2	3	@5	@4	@3	5	@2	@6
2	5	@6	@1	@5	4	3	6	@4	1	@3
3	@4	5	4	@1	6	@2	1	@6	@5	2
4	3	@1	@3	@6	@2	1	5	2	6	@5
5	@2	@3	6	2	1	@6	@4	@1	3	4
6	@1	2	@5	4	@3	5	@2	3	@4	1

Swap Partial Rounds



Swap Partial Rounds

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	2	3	@5	@4	@3	5	4	@6
2	5	1	@1	@5	4	3	6	@4	@6	@3
3	@4	5	4	@1	6	@2	1	@6	@5	2
4	3	6	@3	@6	@2	1	5	2	@1	@5
5	@2	@3	6	2	1	@6	@4	@1	3	4
6	@1	@4	@5	4	@3	5	@2	3	2	1

T-R	1	2	3	4	5	6	7	8	9	10
1	6	4	2	3	@5	@4	@3	5	@2	@6
2	5	@6	@1	@5	4	3	6	@4	1	@3
3	@4	5	4	@1	6	@2	1	@6	@5	2
4	3	@1	@3	@6	@2	1	5	2	6	@5
5	@2	@3	6	2	1	@6	@4	@1	3	4
6	@1	2	@5	4	@3	5	@2	3	@4	1

Swap Partial Teams

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	4	3	6	@4	@1	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@6	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

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1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	4	3	6	@4	@6	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@1	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
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3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@6	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
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3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@1	@3
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6	@1	@4	@5	2	@3	5	@2	3	4	1

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3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@1	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

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3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@3	@6	@2	1	5	2	@1	@3
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3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@1	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

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3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@3	@6	@2	1	5	2	@1	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

Swap Partial Teams

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1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@3	@6	4	3	6	@4	@6	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@1	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@1	@5	4	3	6	@4	@6	@3
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@3	@6	@2	1	5	2	@1	@5
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

Swap Partial Teams

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2	5	1	@3	@6	4	3	6	@4	@6	@5
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@1	@5	@2	1	5	2	@1	@3
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@1	@5	4	3	6	@4	@6	@3
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@3	@6	@2	1	5	2	@1	@5
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

Swap Partial Teams

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	4	3	@5	@4	@3	5	2	@6
2	5	1	@1	@5	4	3	6	@4	@6	@3
3	@4	5	2	@1	6	@2	1	@6	@5	4
4	3	6	@3	@6	@2	1	5	2	@1	@5
5	@2	@3	6	4	1	@6	@4	@1	3	2
6	@1	@4	@5	2	@3	5	@2	3	4	1

T-R	1	2	3	4	5	6	7	8	9	10
1	6	@2	2	3	@5	@4	@3	5	4	@6
2	5	1	@1	@5	4	3	6	@4	@6	@3
3	@4	5	4	@1	6	@2	1	@6	@5	2
4	3	6	@3	@6	@2	1	5	2	@1	@5
5	@2	@3	6	2	1	@6	@4	@1	3	4
6	@1	@4	@5	4	@3	5	@2	3	2	1

TTP results

NL12. 12 teams [Data set](#)

Feasible Solution: 143655 (Rottembourg and Laburthe May 2001), 125803 (Cardemil, July 2 2002), 119990 (Dorrepaal July 16, 2002), 119012 (Zhang, August 19 2002), 118955 (Cardemil, November 1 2002), 114153 (Anagnostopoulos, Michel, Van Hentenryck and Vergados January 14, 2003), 113090 (Anagnostopoulos, Michel, Van Hentenryck and Vergados February 26, 2003), 112800 (Anagnostopoulos, Michel, Van Hentenryck and Vergados June 26, 2003), 112684 (Langford February 16, 2004), 112549 (Langford February 27, 2004), 112298 (Langford March 12, 2004), 111248 (Anagnostopoulos, Michel, Van Hentenryck and Vergados May 13, 2004), 110729 (Van Hentenryck and Vergados, May 30 2007).

Lower Bound: 107483 (Waalewign August 2001), 107494 (Melo, Ribeiro, and Urrutia July 15 2006), 107548 (Mitchell, Trick and Waterer July 31 2008), 108244 (Uthus, Riddle, and Guesgen, Feb 11 2009), 108629 (Uthus, Riddle, and Guesgen January 6, 2010)

NL14. 14 teams [Data set](#)

Feasible Solution: 301113 (Rottembourg and Laburthe June 2001), 262010 (Larichi, Lapierre, Laport July 8 2002), 216108 (Cardemil, July 2 2002), 207075 (Zhang, August 28 2002), 205894 (Cardemil, November 20 2002), 195555 (Anagnostopoulos, Michel, Van Hentenryck and Vergados January 14, 2003), 190368 (Van Hentenryck February 26, 2003), 190056 (Langford April 22, 2004), 189766 (Anagnostopoulos, Michel, Van Hentenryck and Vergados May 13, 2004), 189759 (Dorrepaal and Chackman, April 13, 2005), 188728 (Van Hentenryck and Vergados, May 18 2006).

Lower Bound: 182797 (Waalewign August 2001), 183354 (Uthus, Riddle, and Guesgen January 29 2010)

NL16. 16 teams. [Data set](#).

Feasible Solution: 312623 (Easton January 2002), 308413 (Cardemil, July 2 2002), 301256 (Zhang August 6 2002), 293175 (Zhang, August 28 2002), 284235 (Shen, October 16 2002), 281660 (Shen, January 6 2003) 277766 (Anagnostopoulos, Michel, Van Hentenryck and Vergados January 14, 2003), 273802 (Anagnostopoulos, Michel, Van Hentenryck and Vergados February 26 2003), 267,194 (Van Hentenryck, June 26, 2003), 263772 (Van Hentenryck and Vergados, May 18 2006), 261687 (Van Hentenryck and Vergados, May 30 2007).

Lower Bound: 248852 (Easton January 2002), 249477 (Melo, Ribeiro, and Urrutia July 15 2006) [Note: Until December 30, 2000, the instance was slightly incorrect: The NY-ARI distance did not match the ARI-NY distance. This has been corrected.]

Until Next Time

Citations

NL12, NL14, NL16 from Trick, Michael. "Challenge Traveling Tournament Instances." Challenge Traveling Tournament Problems. 17 Nov. 2012. Web. 28 Apr. 2013. <<http://mat.tepper.cmu.edu/TOURN/>>.