Checkers Solved

Schaeffer et al. 2007

Artificial Intelligence for Games

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Overview

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History

- 1950 start with Arthur Samuel's pioneering work in machine learning
- 1963 first win of a checker program
- 1989 start of the search for a champion challenging program
- 1992 peak, over 200 processors were devoted simultaneously
- 1994 defeat of a world champion (Chinook), but not solved yet

Definition Of Solving

3 States of Solving:

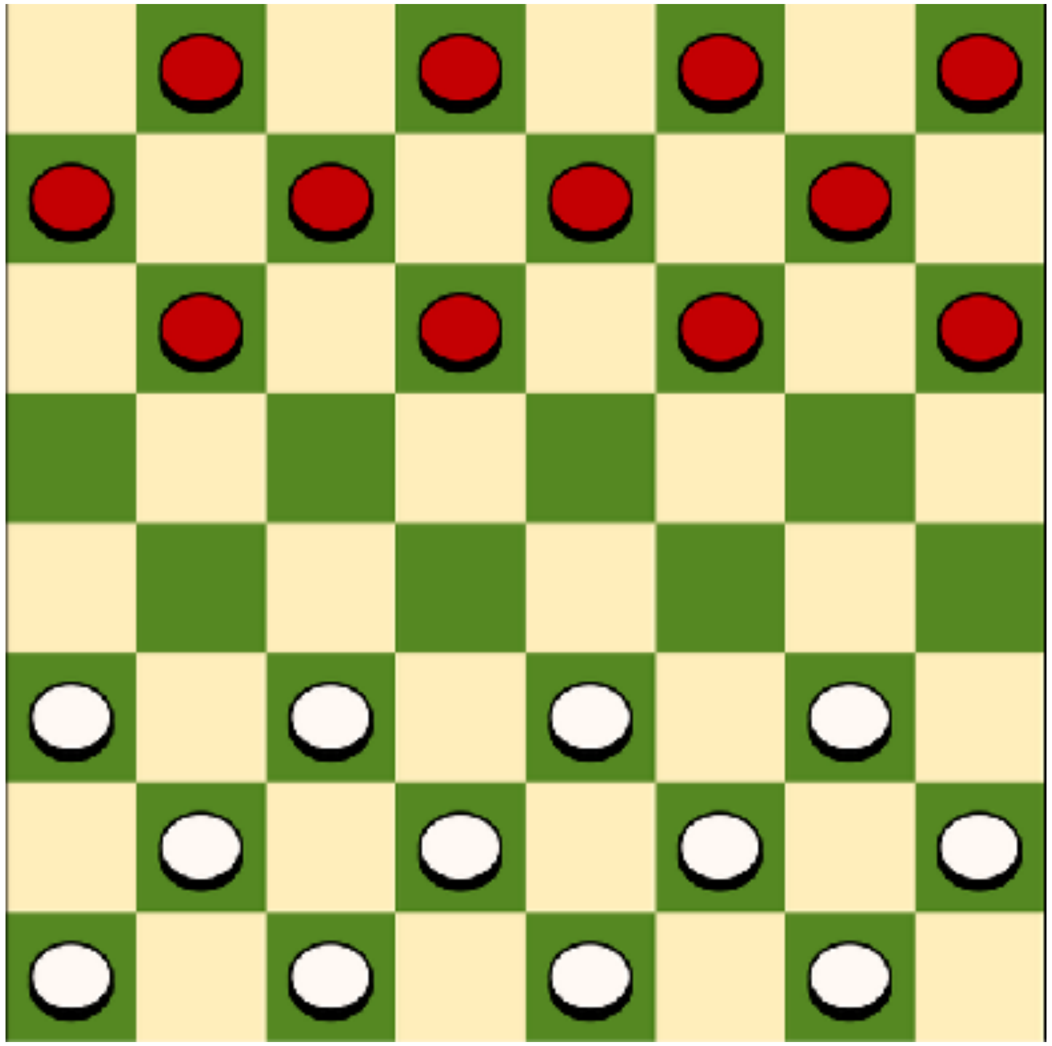
1. **ultra weakly:** Outcome known for starting position
2. **weakly:** Outcome and Strategy known for the starting position
3. **strong:** Outcome and Strategy known for the every position

Checkers

Rules:

- Kings can move one field,
  but backwards, too
- 8x8 field, but only on black played
- 2 types of figures

=> 5*(10^20) positions

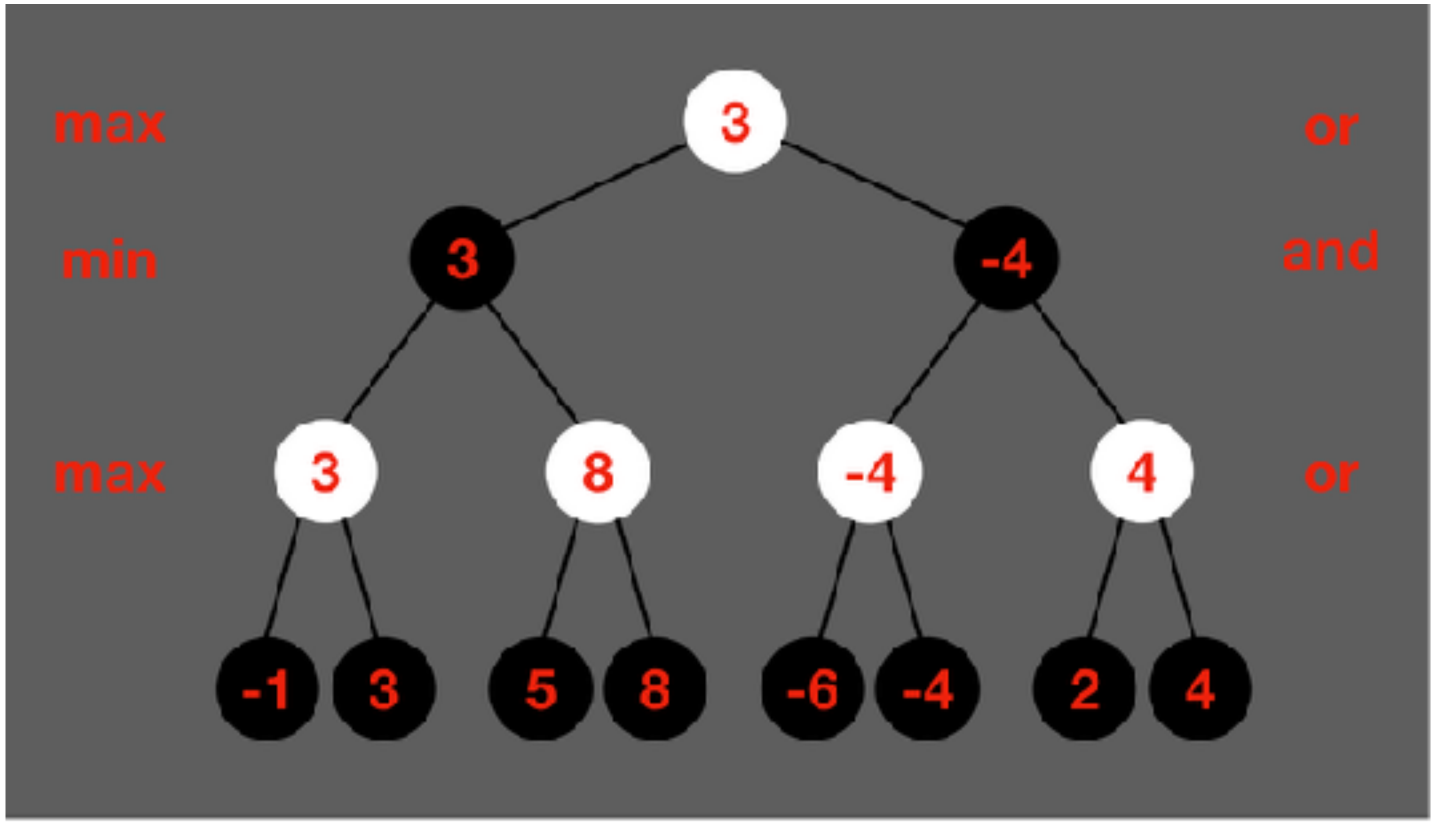


Restriction:

- Forced-Capture

Solving Methods

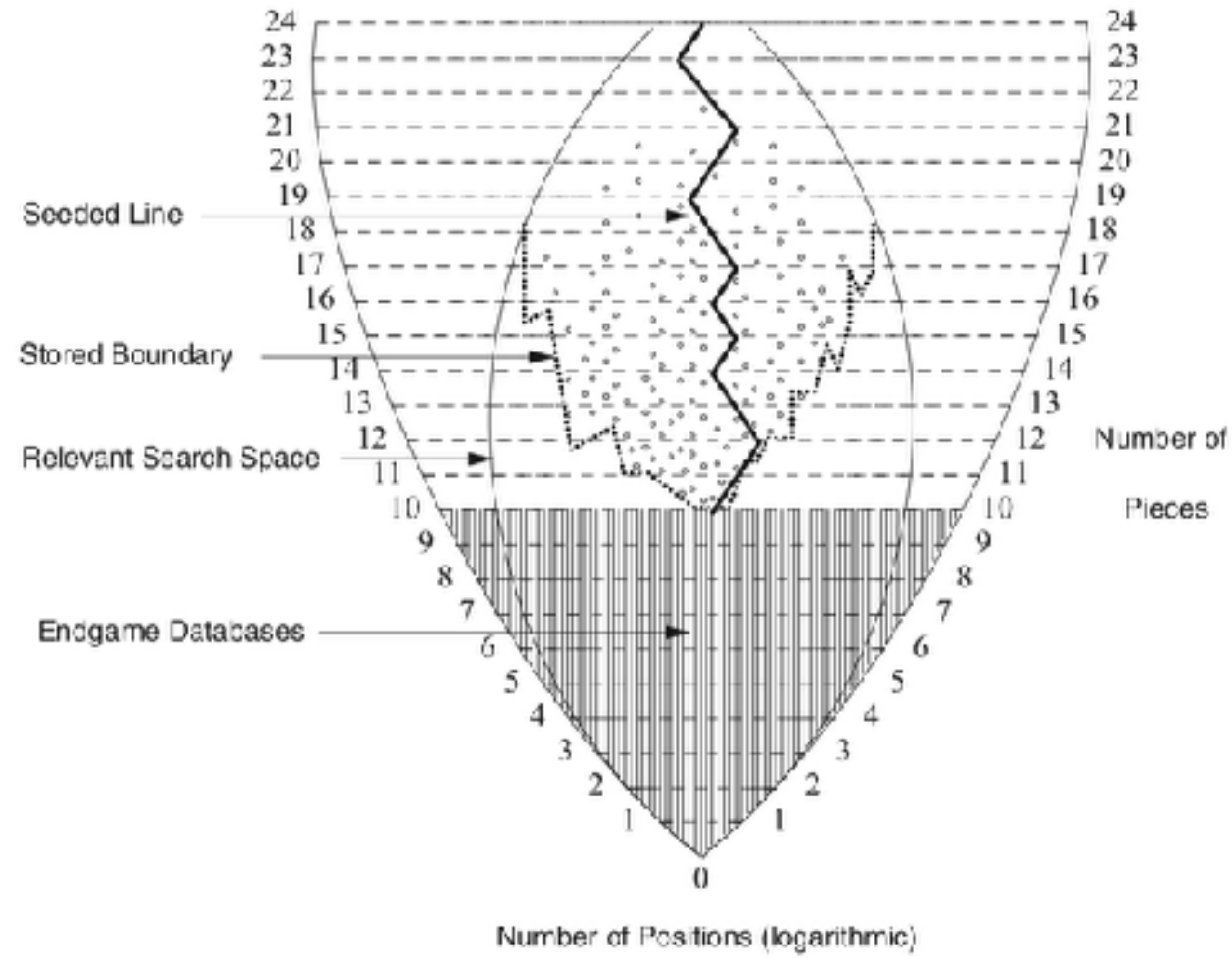
Perfect play from both players



Solving Methods

3 Components:

1. Database
2. Proof-tree manager
3. Proof-tree solver
    1. Alpha-Beta
    2. Depth first proof number (Df-Pn)



Database

- 1989-1996 8 piece
- In 2001 only 1 month for 8 piece
- 2001-2005 10 pieces

Pieces	Number of positions
1	120
2	6,972
3	261,224
4	7,092,774
5	148,688,232
6	2,503,611,964
7	34,779,531,480
8	406,309,208,481
9	4,048,627,642,976
10	34,778,882,769,216
Total 1–10	39,271,258,813,439

For 1 piece: (32+28)*2=120

forced-capture => fast reduction to 10
=> much smaller game tree

Proof-tree manager

Maintains a tree of the proof in progress
Identifies positions which are interested

1. Several hundred at a time

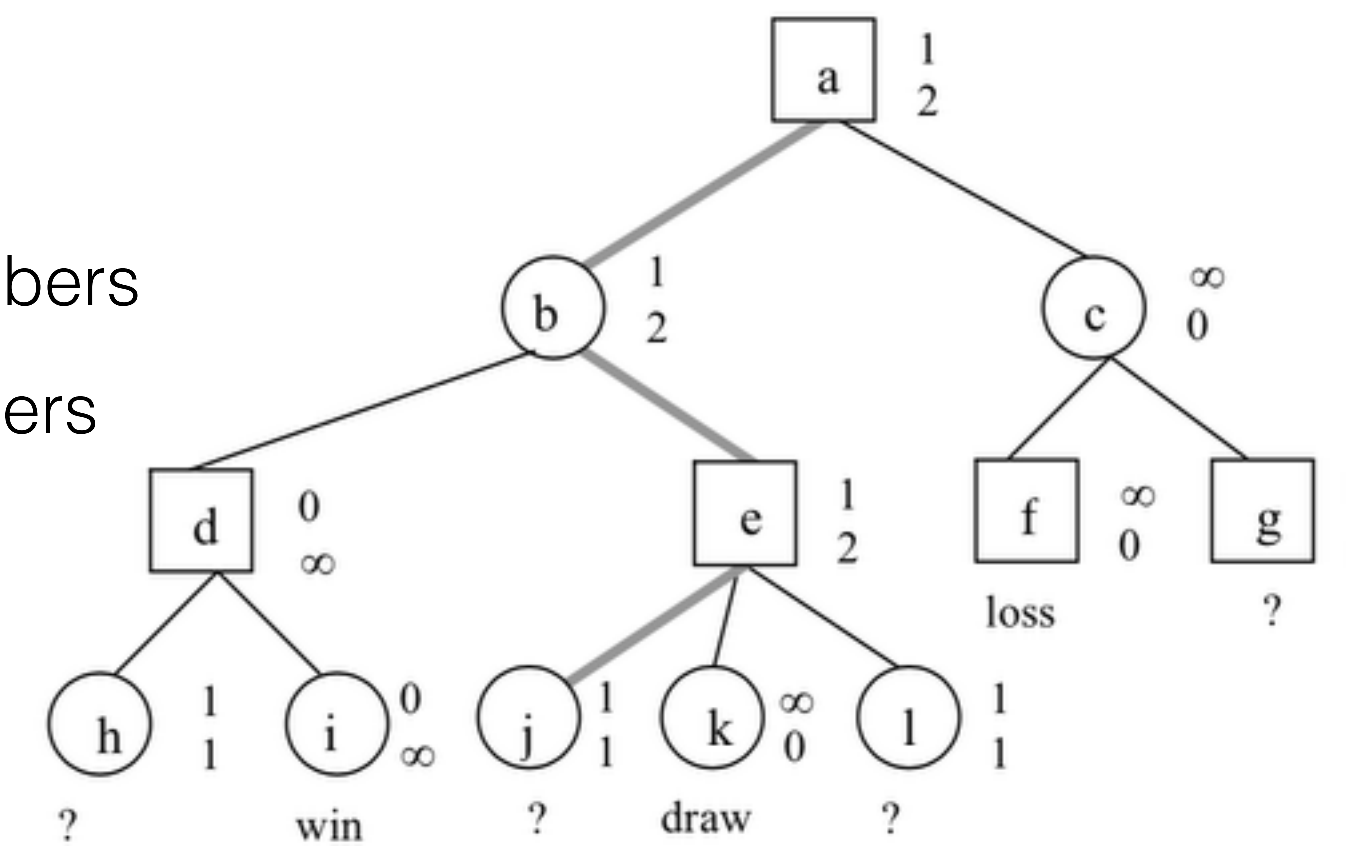
Proof number Search

1. Disprove value := minimum number of leaf nodes needed for disproof
2. Prove value := minimum number of leaf nodes needed for the proof

Proof number

Rules

1. Or: sum up child disproof numbers
2. And: sum up child proof numbers

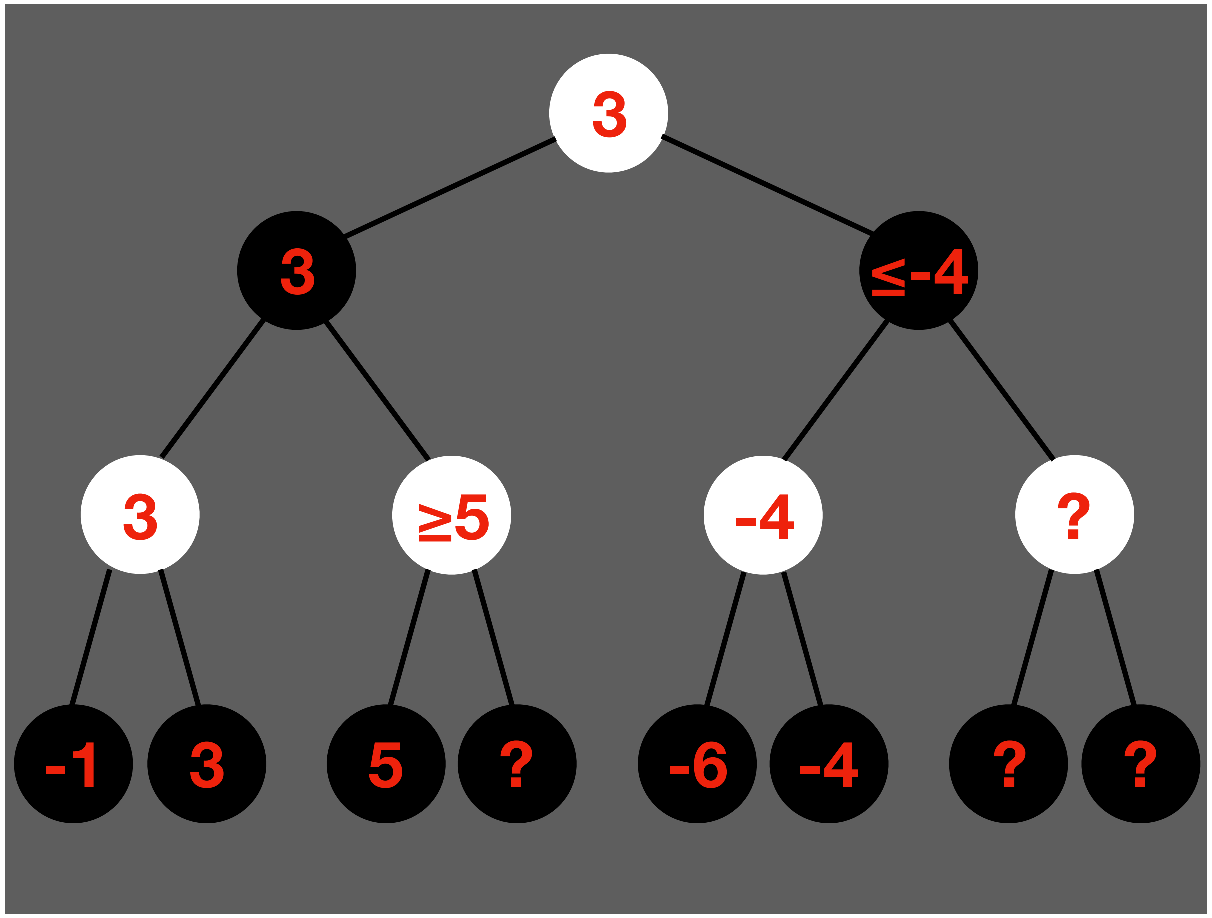


Alpha-Beta-Pruning

Thresholds for pruning trees

1. Alpha := lower threshold
2. Beta := upper threshold
3. initialized with +/- „infinity“

b^d => b^(d/2)



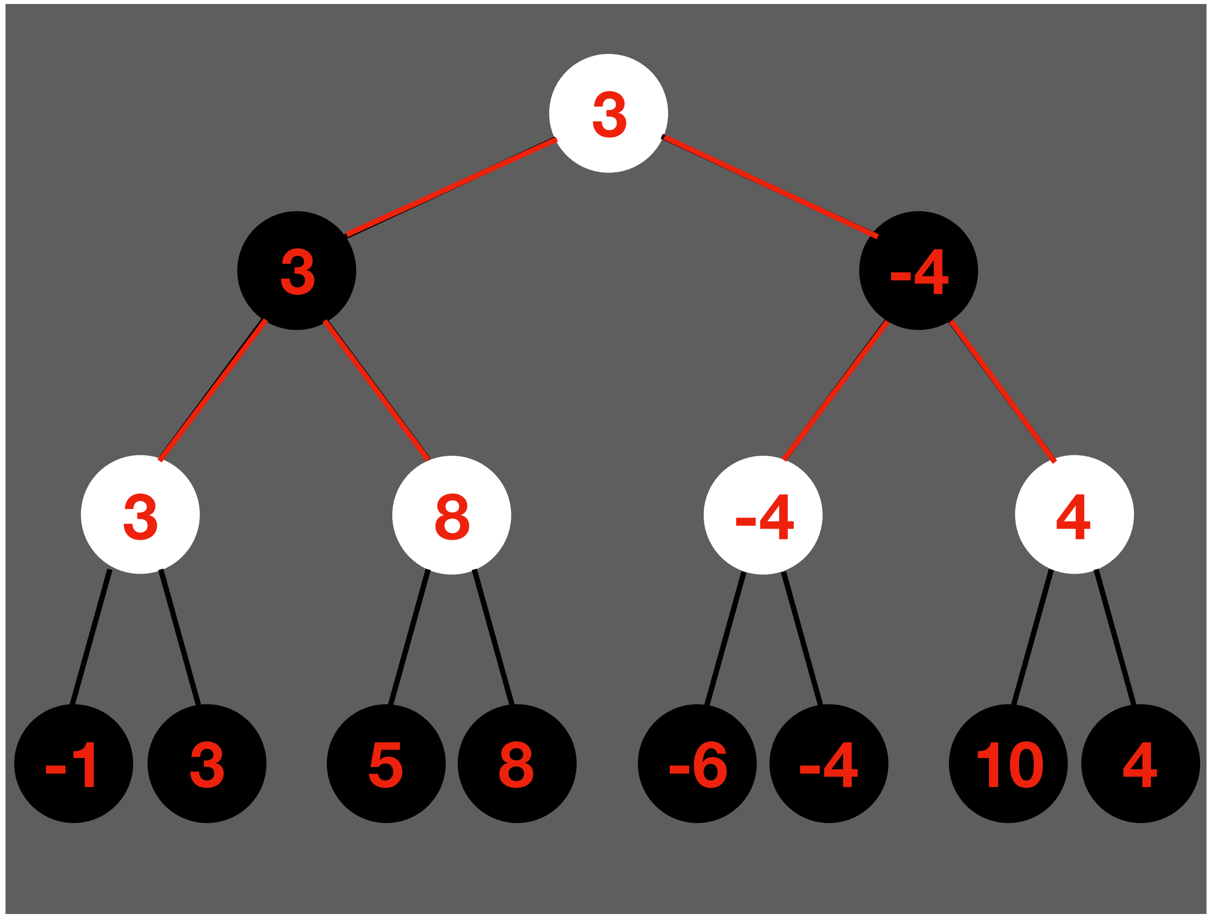
Depth-First Proofing Number

- Similar to Alpha-Beta
- Creates threshold for disproof/proof number
- follows best children until a proof is found

=> if no proof is found a heuristics value is calculated (Chinook)

Iteration

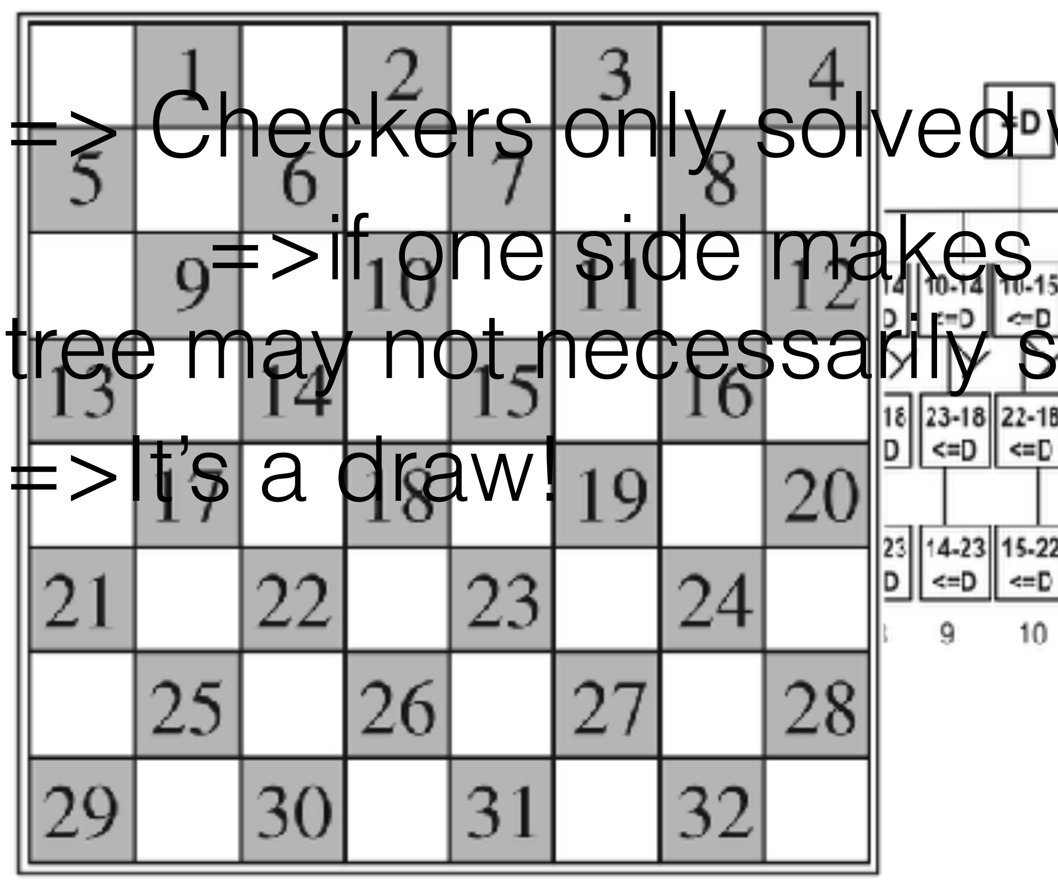
- Most iterate on search depth
- Manager uses threshold t:
  - scores ≤-t are losses
  - scores ≥t are wins
  - increase t



Results

Only 19 starting positions have to be considered:

1. 300 three-move openings, more than 100 are duplicates
2. rest can be proven to be irrelevant by an alpha-beta search



No.	Opening	Proof	Searches	Max ply
1	09-13 22-17 13-22	Draw	736,984	56
2	[illegible] 21-17 05-09	Draw	1,987,856	154
3	09-13 22-18 10-15	Draw	715,280	103
4	09-13 23-18 05-09	Draw	671,948	119
5	[illegible]	[illegible]	[illegible]	85
6	[illegible] 11-15	[illegible]	[illegible]	53
7	09-13 24-20 11-15	Draw	1,058,328	59
8	[illegible]	[illegible]	2,202,533	77
9	10-14 23-18 14-23	≤Draw	1,296,790	58
10	10-15 22-18 15-22	≤Draw	543,603	60
11	11-15 22-18 15-22	≤Draw	919,594	67
12	11-16 23-19 16-23	≤Draw	1,969,641	69
13	12-16 24-19 09-13	Loss	205,385	44
14	12-16 24-19 09-14	≤Draw	61,279	45
15	12-16 24-19 10-14	≤Draw	21,328	31
16	12-16 24-19 10-15	<Draw	31,473	35
17	12-16 24-19 11-15	≤Draw	23,803	34
18	12-16 24-19 16-20	≤Draw	283,353	49
19	12-16 24-19 08-12	<Draw	266,924	49
Overall		Draw	Total	Max
			15,123,711	154

=> Checkers only solved weakly!

=>if one side makes a losing mistake, the proof tree may not necessarily show how to win.

=>It’s a draw!

Results

- search effort: 10^14 (with only alpha beta 10^24)
- 10 pieces database is 237 Gb large (154 positions per byte)
- 50 computers simultaneously for search tree for 3 years

Conclusion

Correctness:

- many potential sources of errors (algorithm bugs, data transmission errors)
- computations have been independently verified
- outcome manually checked
- Chance of error propagation is small

Sources

- Checkers Is Solved, Schaeffer et al.2007
- An Analysis of Alpha-Beta, Priming Donald E. Knuth and Ronald W. Moore
- Searching for Solutions in Games and Articial Intelligence, L. Allis
- Parallel Depth First Proof Number Search, Tomoyuki Kaneko
- Proof-Number Search and its Variants, H. Jaap van den Herik and Mark H.M. Winands