Lecture slides for

Automated Planning: Theory and Practice

Chapter 23
Planning in the Game of Bridge

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Computer Programs for Games of Strategy

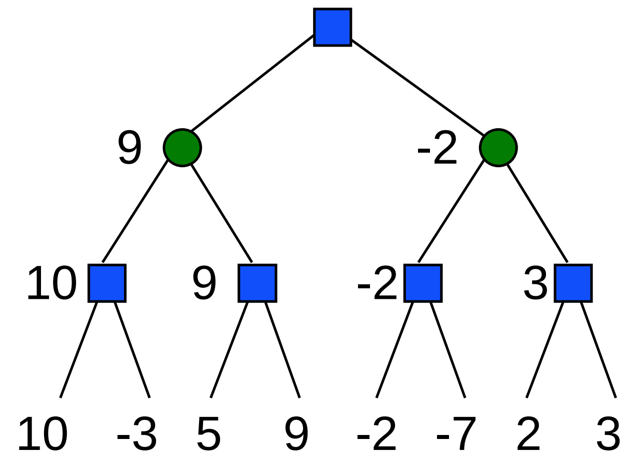
Connect Four:	solved
Go-Moku:	solved
Qubic:	solved
Nine Men's Morris:	solved
Checkers:	solved
Othello:	better than humans
Backgammon:	better than all but about 10 humans
Chess:	competitive with the best humans
⋮	
Bridge:	about as good as mid-level humans

Computer Programs for Games of Strategy

- Fundamental technique: the minimax algorithm

$$\begin{aligned}\text{minimax}(u) &= \max\{\text{minimax}(v) : v \text{ is a child of } u\} \text{ if it's Max's move at } u\\ &= \min\{\text{minimax}(v) : v \text{ is a child of } u\} \text{ if it's Min's move at } u\end{aligned}$$

- Largely "brute force"
- Can prune off portions of the tree
  - cutoff depth & static evaluation function
  - alpha-beta pruning
  - transposition tables
  - …

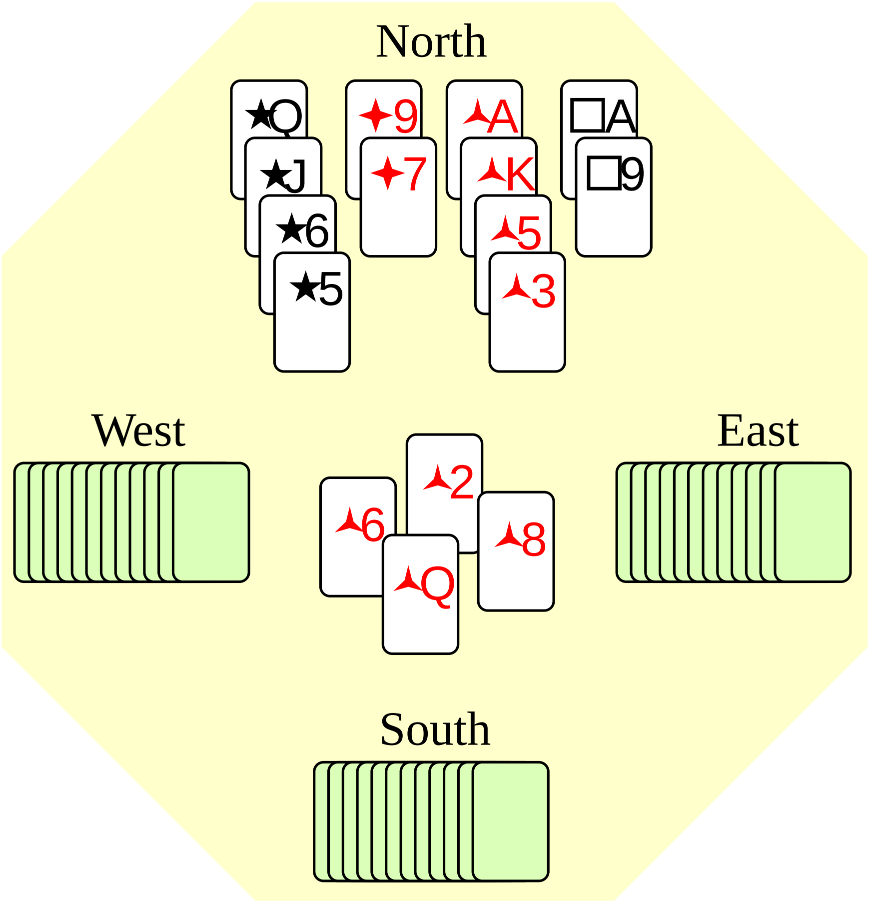


- But even then, it still examines thousands of game positions

- For bridge, this has some problems …

How Bridge Works

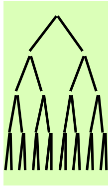
- Four players; 52 playing cards dealt equally among them
- Bidding to determine the trump suit
  - Declarer: whoever makes highest bid
  - Dummy: declarer′s partner
- The basic unit of play is the trick
  - One player leads; the others must follow suit if possible
  - Trick won by highest card of the suit led, unless someone plays a trump
  - Keep playing tricks until all cards have been played
- Scoring based on how many tricks were bid and how many were taken



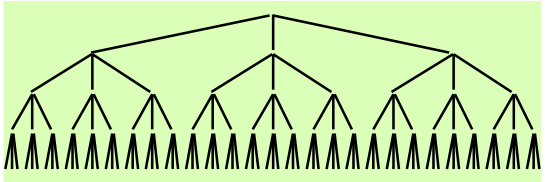
Game Tree Search in Bridge

- Bridge is an *imperfect information* game
  - Don′t know what cards the others have (except the dummy)
  - Many possible card distributions, so many possible moves
- If we encode the additional moves as additional branches in the game tree, this increases the branching factor *b*
- Number of nodes is exponential in *b*
  - worst case: about $6\text{x}10^{44}$ leaf nodes
  - average case: about 10^{24} leaf nodes

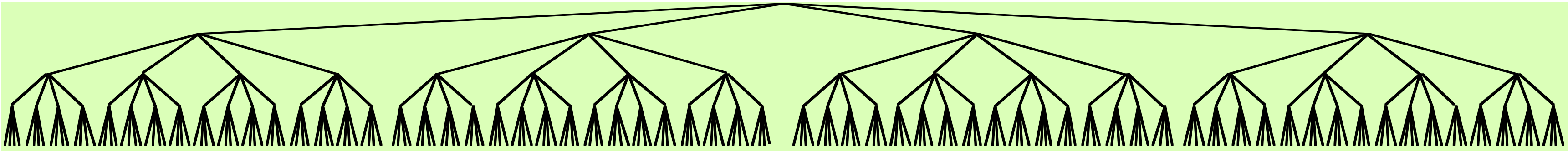
b =2



b =3



b =4



  - A chess game may take several hours
  - A bridge game takes about 1.5 minutes

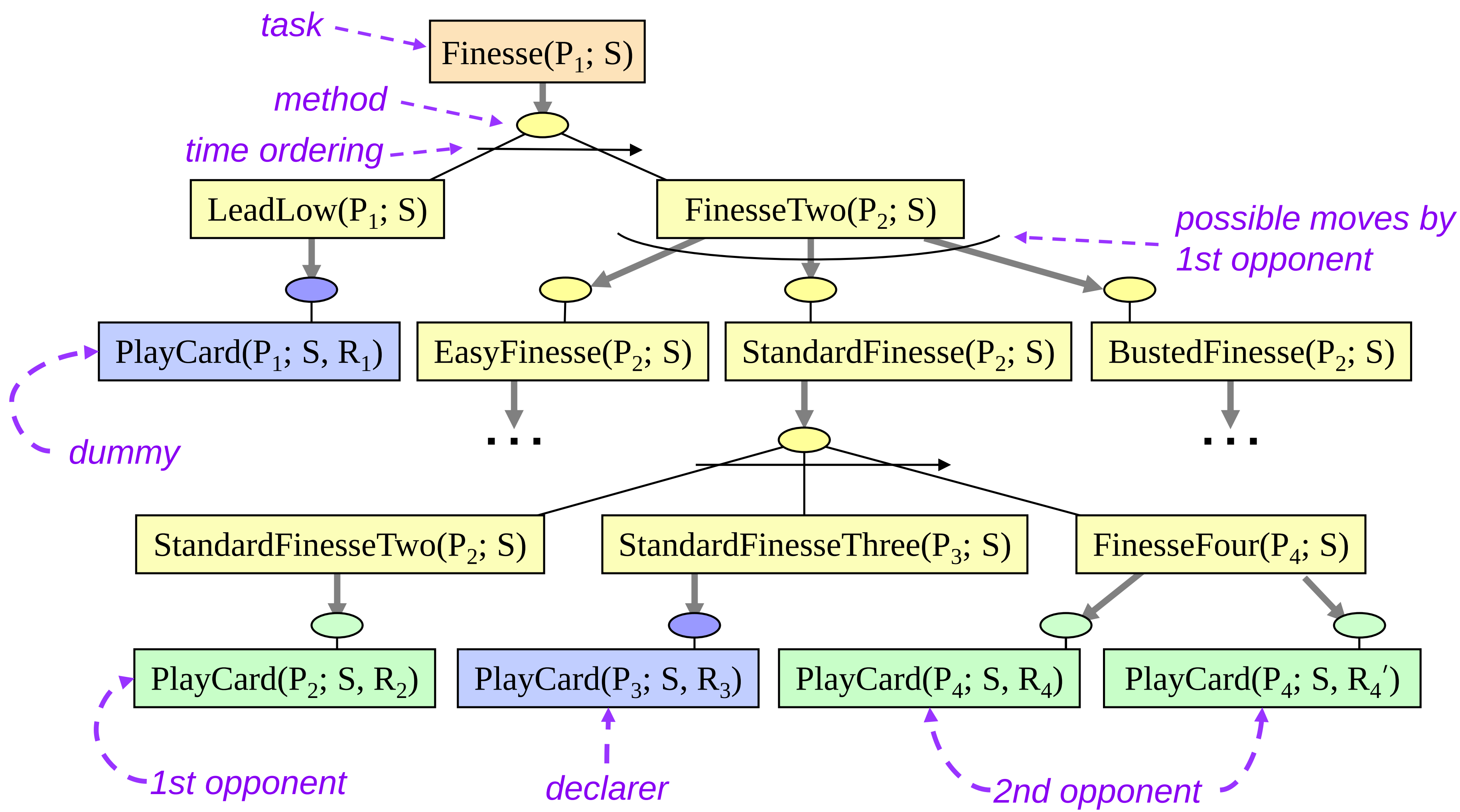
Not enough time to search the game tree

Reducing the Size of the Game Tree

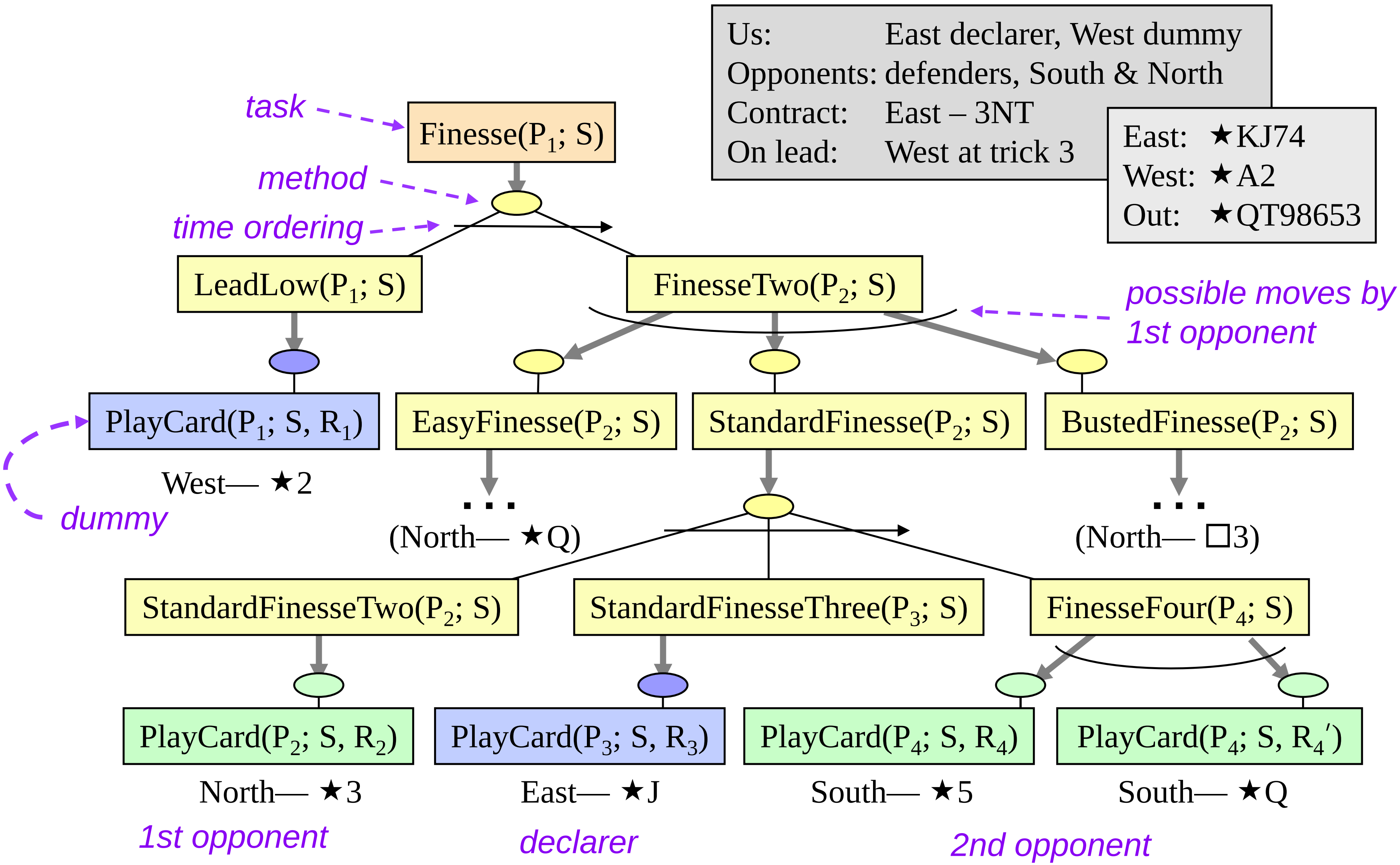
- One approach: HTN planning
  - Bridge is a game of planning
  - The declarer plans how to play the hand
  - The plan combines various strategies (ruffing, finessing, etc.)
  - If a move doesn′t fit into a sensible strategy, it probably doesn′t need to be considered
- Write a planning procedure procedure similar to TFD (see Chapter 11)
  - Modified to generate game trees instead of just paths
  - Describe standard bridge strategies as collections of methods
  - Use HTN decomposition to generate a game tree in which each move corresponds to a different *strategy*, not a different *card*

	Brute-force search	HTN-generated trees
Worst case	≈ 6×10^{44} leaf nodes	≈ 305,000 leaf nodes
Average case	≈ 10^{24} leaf nodes	≈ 26,000 leaf nodes

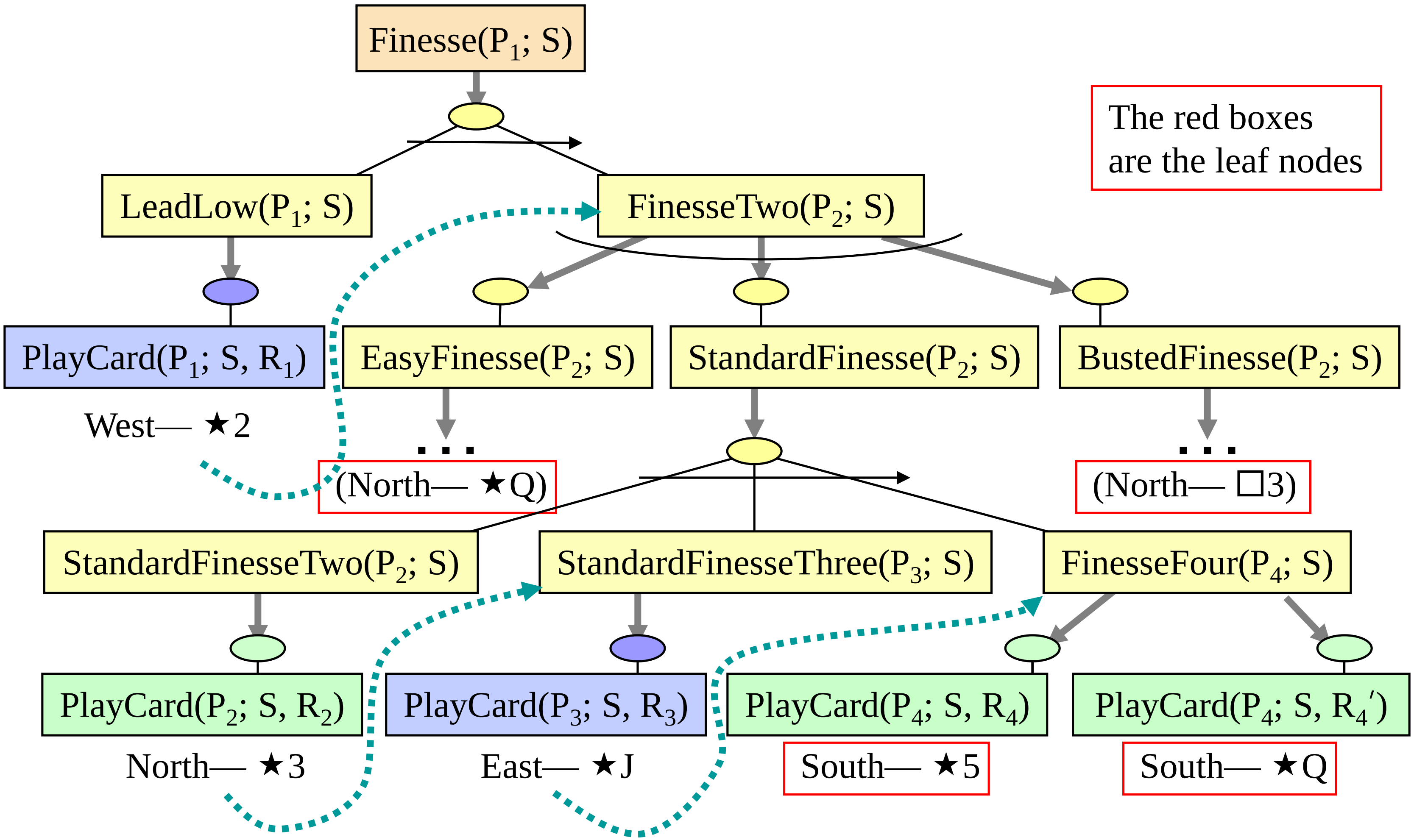
Methods for Finessing



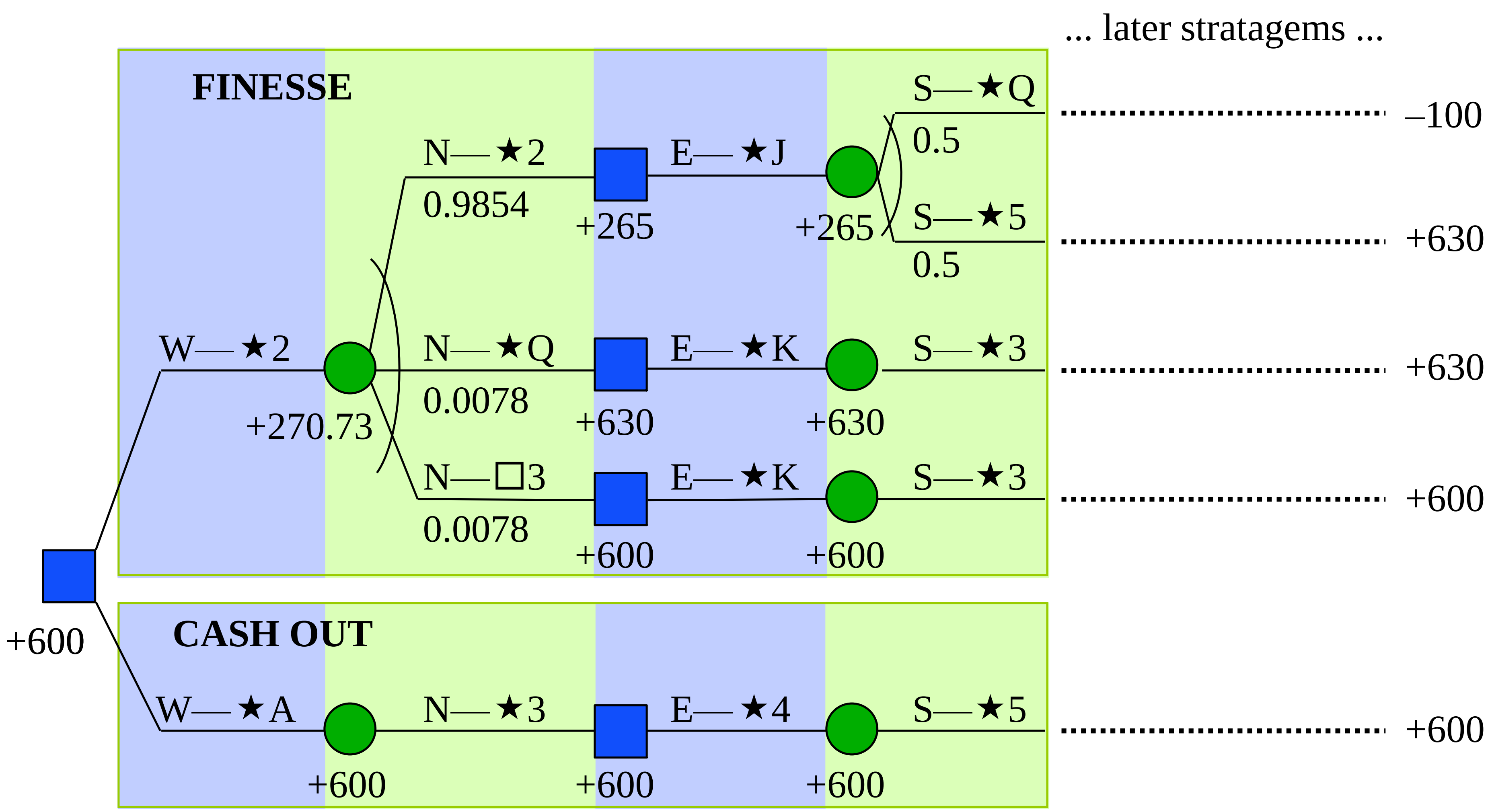
Instantiating the Methods



Generating Part of a Game Tree



Game Tree Generated using the Methods



Implementation

- Stephen J. Smith, then a PhD student at U. of Maryland
  - Wrote a procedure to plan declarer play
- Incorporated it into *Bridge Baron*, an existing commercial product
  - This significantly improved *Bridge Baron*′s declarer play
  - Won the 1997 world championship of computer bridge
- Since then:
  - Stephen Smith is now Great Game Products′ lead programmer
  - He has made many improvements to *Bridge Baron*
    - » Proprietary, I don′t know what they are
  - *Bridge Baron* was a finalist in the 2003 and 2004 computer bridge championships
    - » I haven′t kept track since then

Other Approaches

- Monte Carlo simulation:
  - Generate many random hypotheses for how the cards might be distributed
  - Generate and search the game trees
    - Average the results

  - This can divide the size of the game tree by as much as $5.2\text{x}10^6$
    - $(6\text{x}10^{44})/(5.2\text{x}10^6) = 1.1\text{x}10^{38}$
      - still quite large
    - Thus this method by itself is not enough

Other Approaches (continued)

- AJS hashing - Applegate, Jacobson, and Sleator, 1991
  - Modified version of transposition tables
    - Each hash-table entry represents a set of positions that are considered to be equivalent
    - Example: suppose we have ♠AQ532
      - View the three small cards as equivalent: ♠Aqxxx
  - Before searching, first look for a hash-table entry
    - Reduces the branching factor of the game tree
    - Value calculated for one branch will be stored in the table and used as the value for similar branches
- GIB (1998-99 computer bridge champion) used
  a combination of Monte Carlo simulation and AJS hashing
- Several current bridge programs do something similar

Top contenders in computer bridge championships, 1997–2004

Year	#1	#2	#3	#4
1997	Bridge Baron	Q-Plus	Micro Bridge	Meadowlark
1998	GIB	Q-Plus	Micro Bridge	Bridge Baron
1999	GIB	WBridge5	Micro Bridge	Bridge Buff
2000	Meadowlark	Q-Plus	Jack	WBridge5
2001	Jack	Micro Bridge	WBridge5	Q-Plus
2002	Jack	Wbridge5	Micro Bridge	?
2003	Jack	Bridge Baron	WBridge5	Micro Bridge
2004	Jack	Bridge Baron	WBridge5	Micro Bridge

I haven′t kept track since 2004

For more information see http://www.jackbridge.com/ewkprt.htm