Applied machine learning in game theory

Dmitrijs Rutko
Faculty of Computing
University of Latvia

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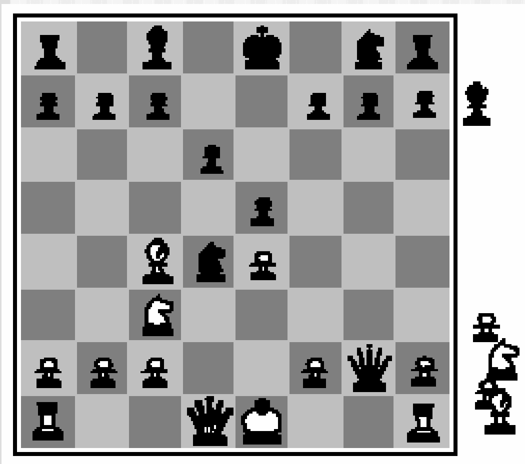
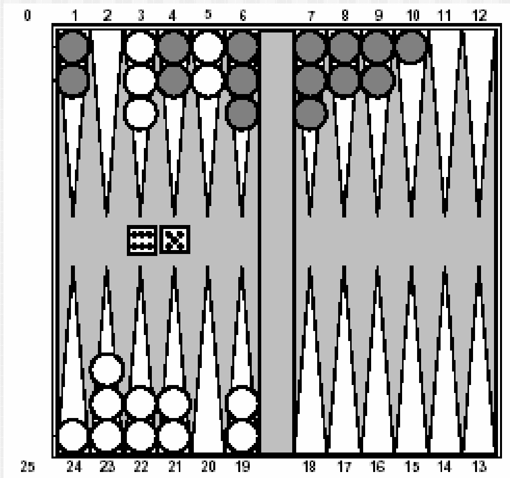
Topic outline

- Game theory
  - Game Tree Search
  - Fuzzy approach
- Machine learning
  - Heuristics
  - Neural networks
  - Adaptive / Reinforcement learning
- Card games

Research overview

- Deterministic / stochastic games
- Perfect / imperfect information games





Finite zero-sum games

	deterministic	chance
perfect information	chess, checkers, go, othello	backgammon, monopoly, roulette
imperfect information	battleship, kriegspiel, rock-paper-scissors	bridge, poker, scrabble

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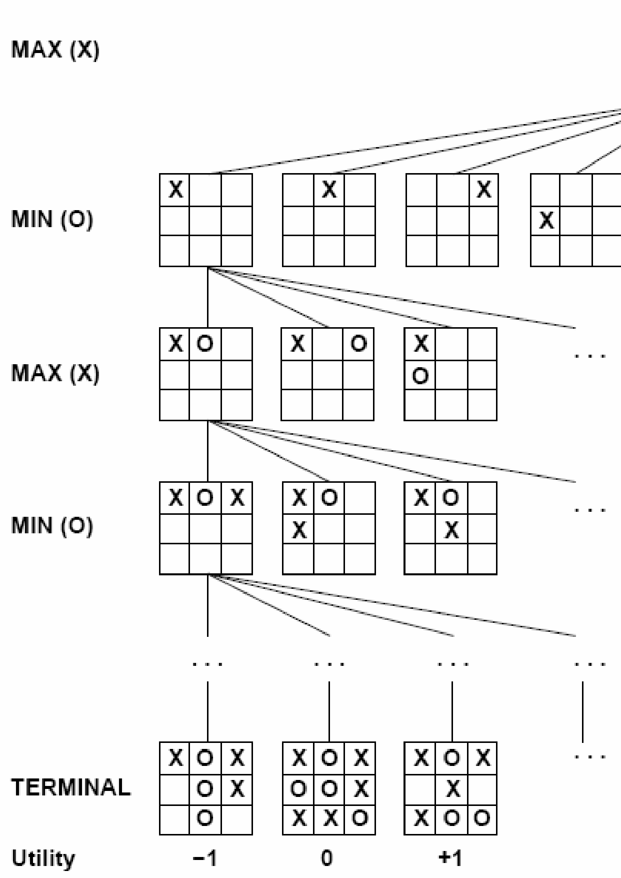
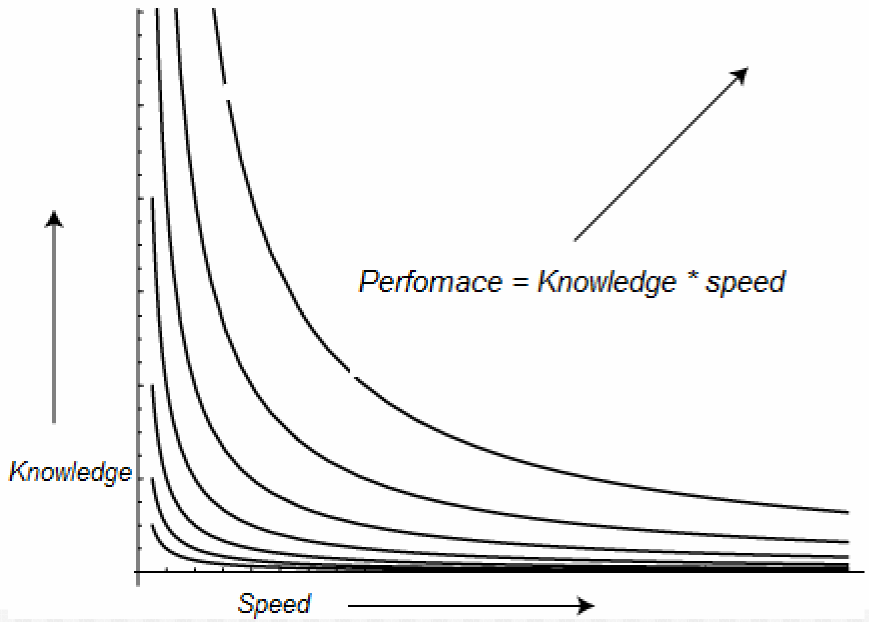
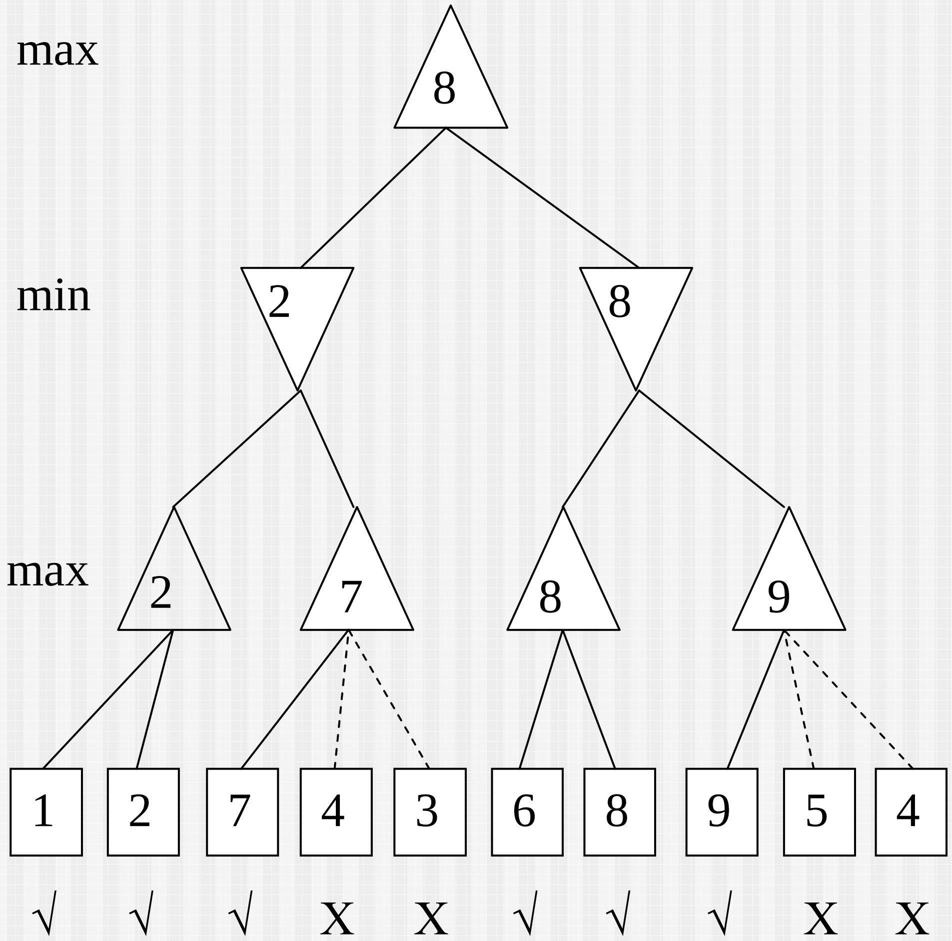
Game trees


MAX (X)
MIN (O)
MAX (X)
MIN (O)
TERMINAL
Utility
−1
0
+1


Perfomace = Knowledge * speed
Knowledge
Speed

Classical algorithms

- MiniMax
  - $O(w^d)$
- Alpha-Beta
  - $O(w^{d/2})$

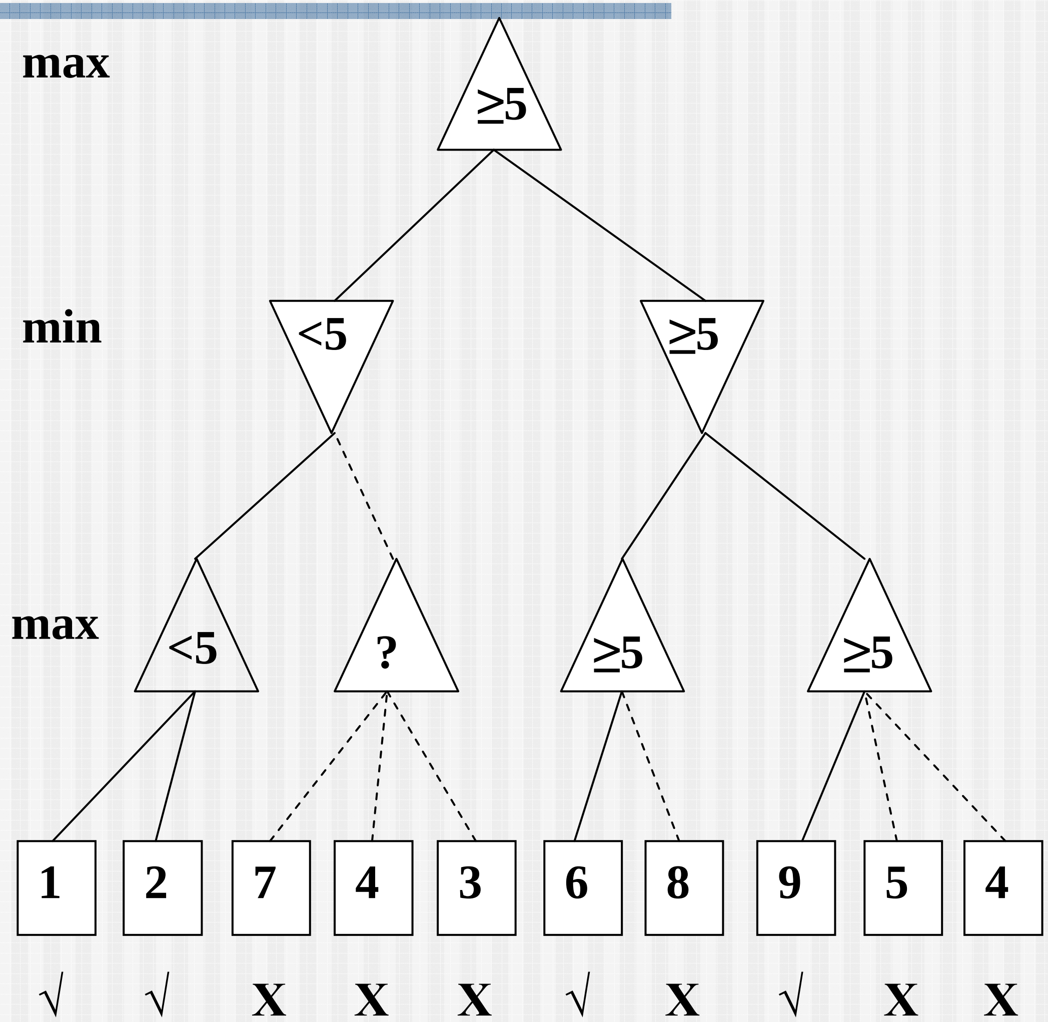


Advanced search techniques

- Transposition tables
- Time efficiency / high cost of space
  - PVS
  - Negascout
  - NegaC*
  - SSS* / DUAL*
  - MTD(f)

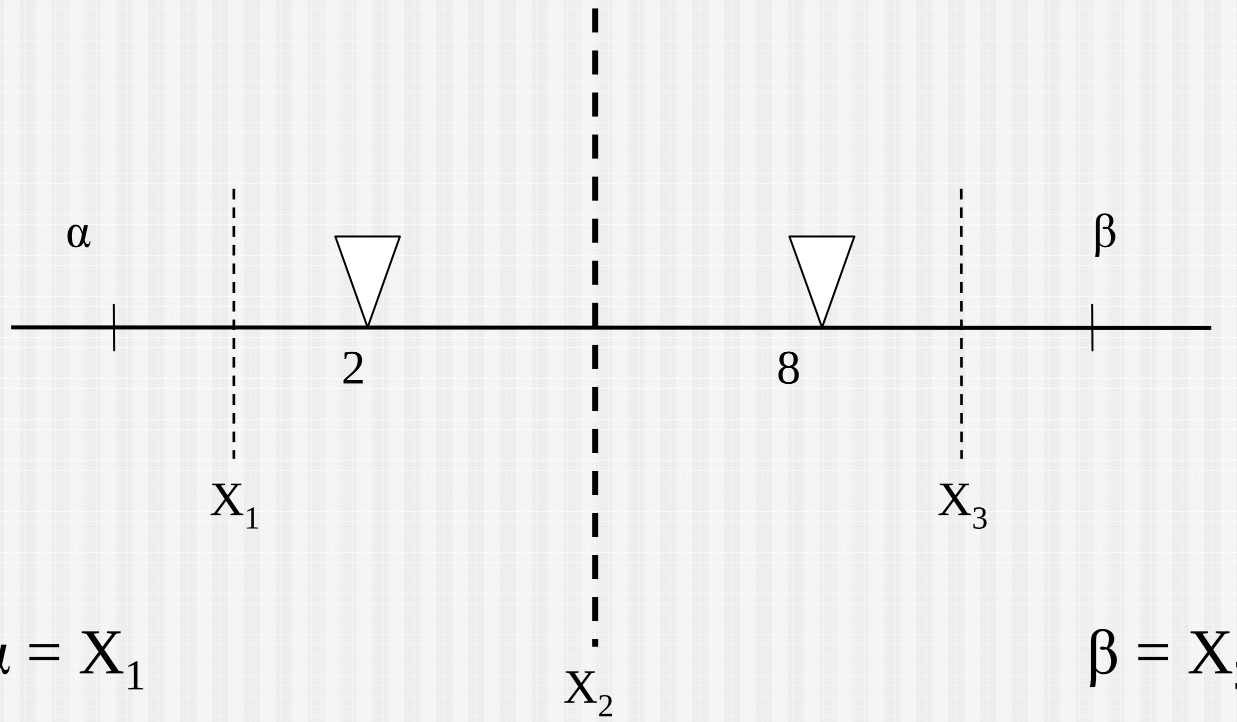
Fuzzy approach

- $O(w^{d/2})$
- More cut-offs



Geometric interpretation

- 1) X_2 - successful separation
- 2) X_1 or X_3 - reduced search window



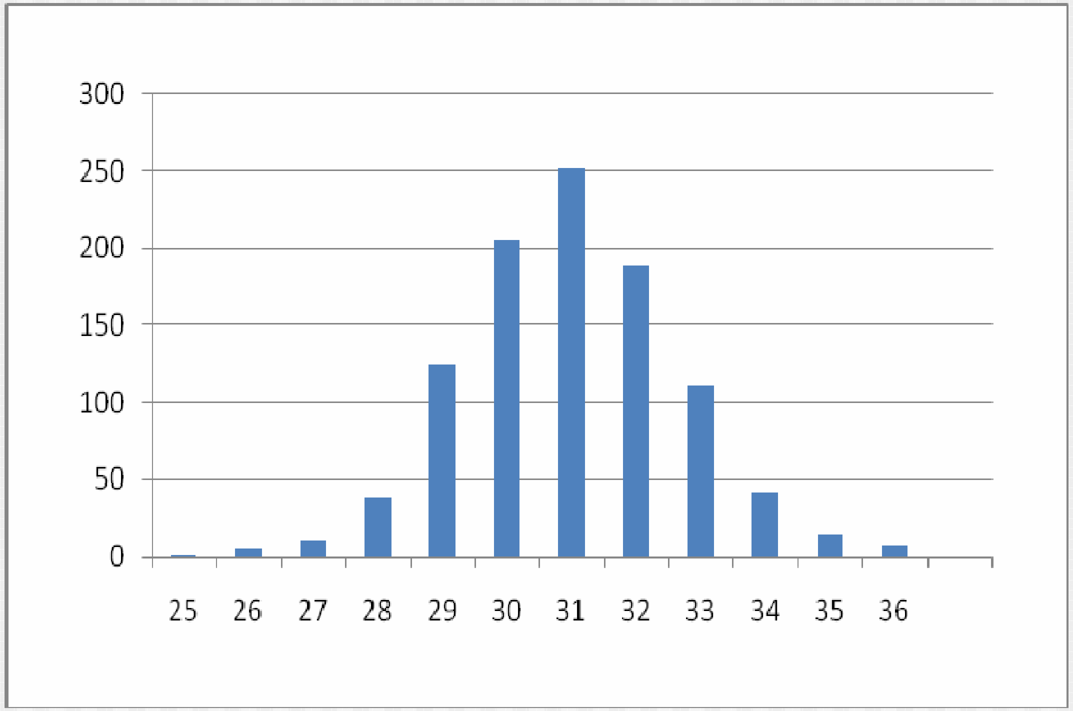
$\alpha = X_1$

$\beta = X_3$

BNS enhancement through self-training

- Traditional statistical approach

Minimax value	Tree count
25	1
26	5
27	11
28	38
29	124
30	206
31	252
32	189
33	111
34	42
35	14
36	7
	1000

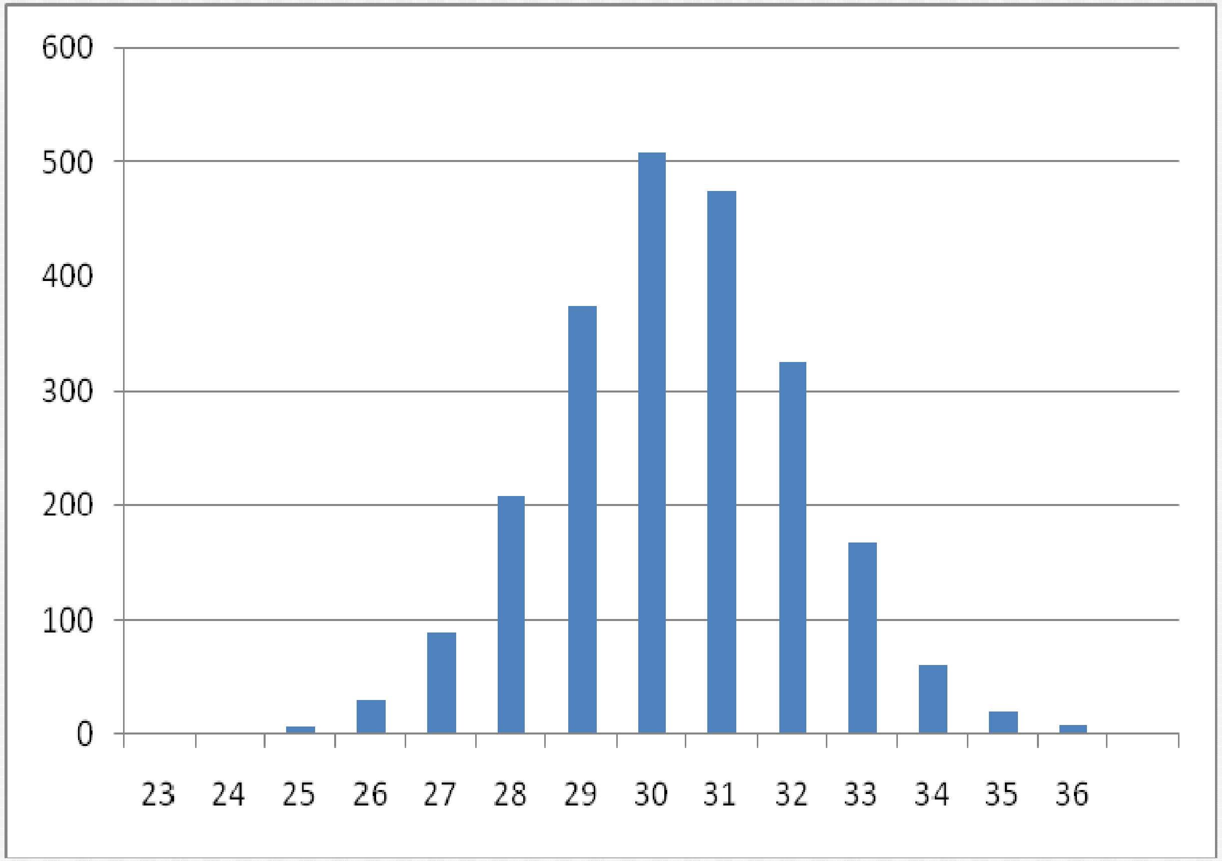


Two dimensional game sub-tree distribution

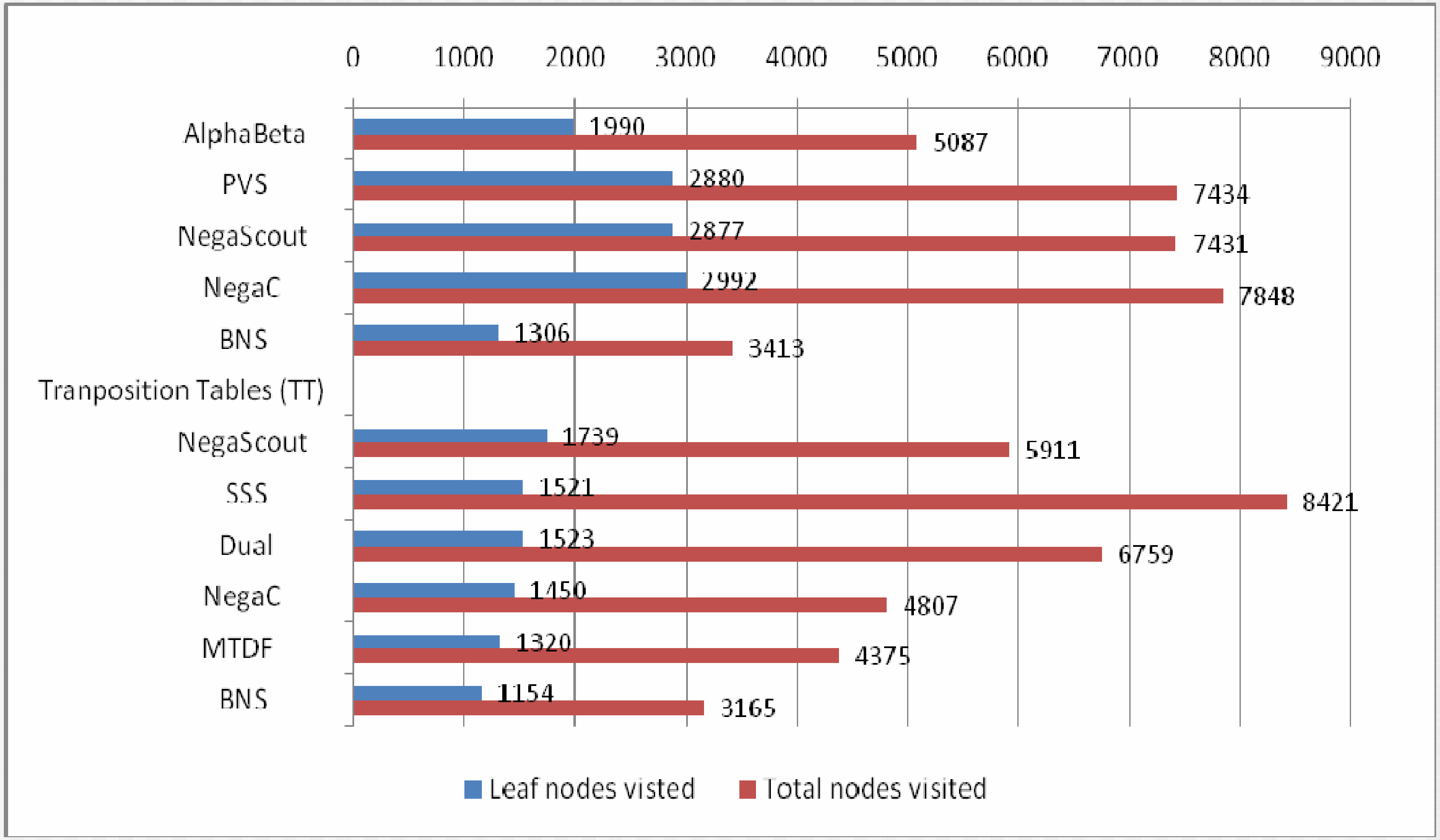
	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Tree count
23	0														0
24	0	0													0
25	0	1	0												1
26	0	0	2	3											5
27	0	0	5	3	3										11
28	0	1	0	12	12	13									38
29	0	0	2	10	35	43	34								124
30	1	2	6	9	26	58	71	33							206
31	0	0	6	10	27	41	78	57	33						252
32	0	1	3	13	17	30	32	41	38	14					189
33	0	0	1	2	8	12	26	28	21	11	2				111
34	0	0	0	1	3	5	13	8	6	2	2	2			42
35	0	0	0	0	0	2	4	3	2	3	0	0	0		14
36	0	0	0	0	0	0	1	2	2	1	1	0	0	0	7

Statistical sub-tree separation

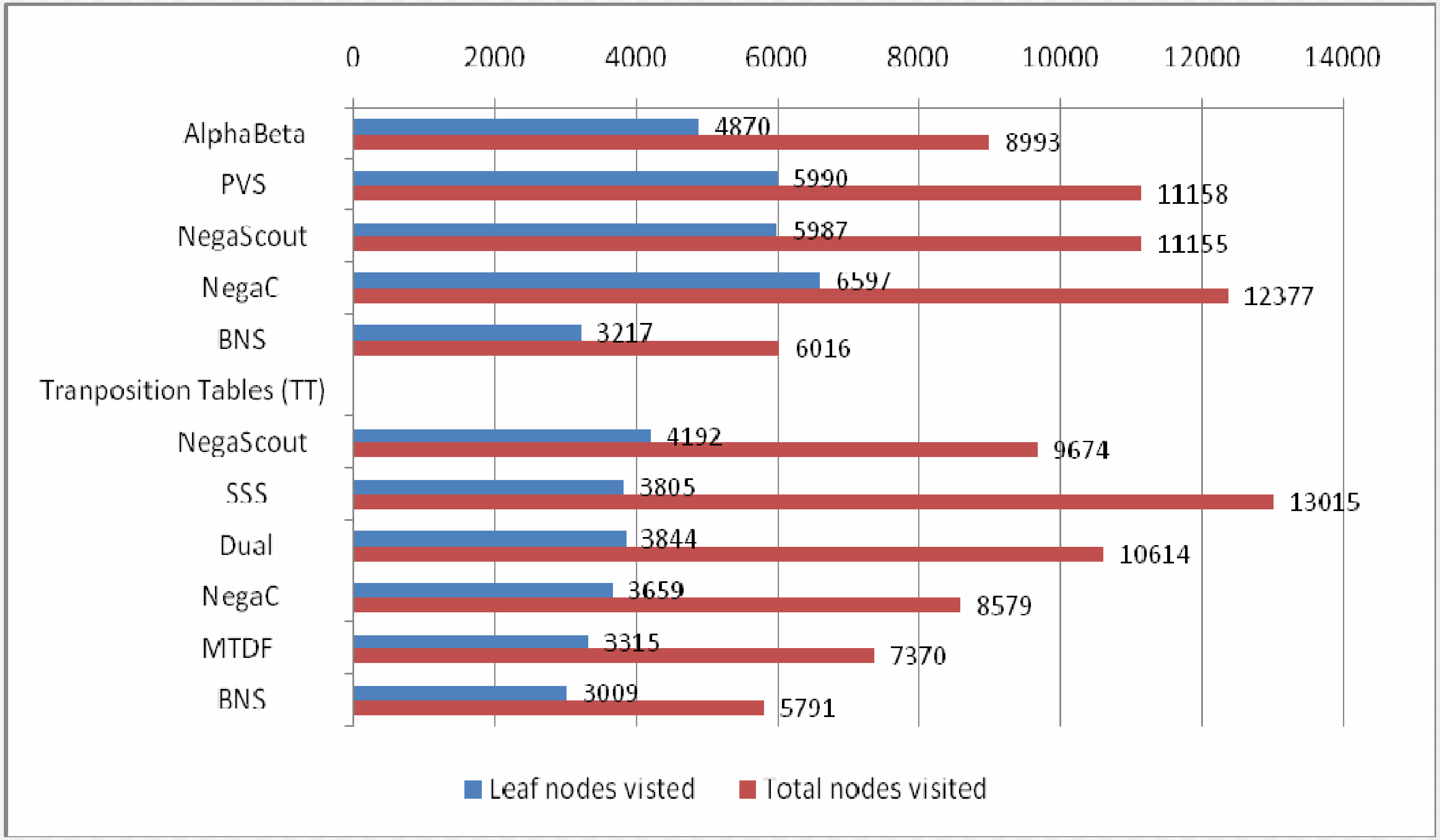
Separation value	Tree count
23	0
24	1
25	6
26	30
27	88
28	208
29	374
30	509
31	475
32	325
33	167
34	61
35	21
36	7
	2272



Experimental results. 2-width trees



Experimental results. 3-width trees



Future research directions in game tree search

- Multi-dimensional self-training
- Wider trees
- Real domain games

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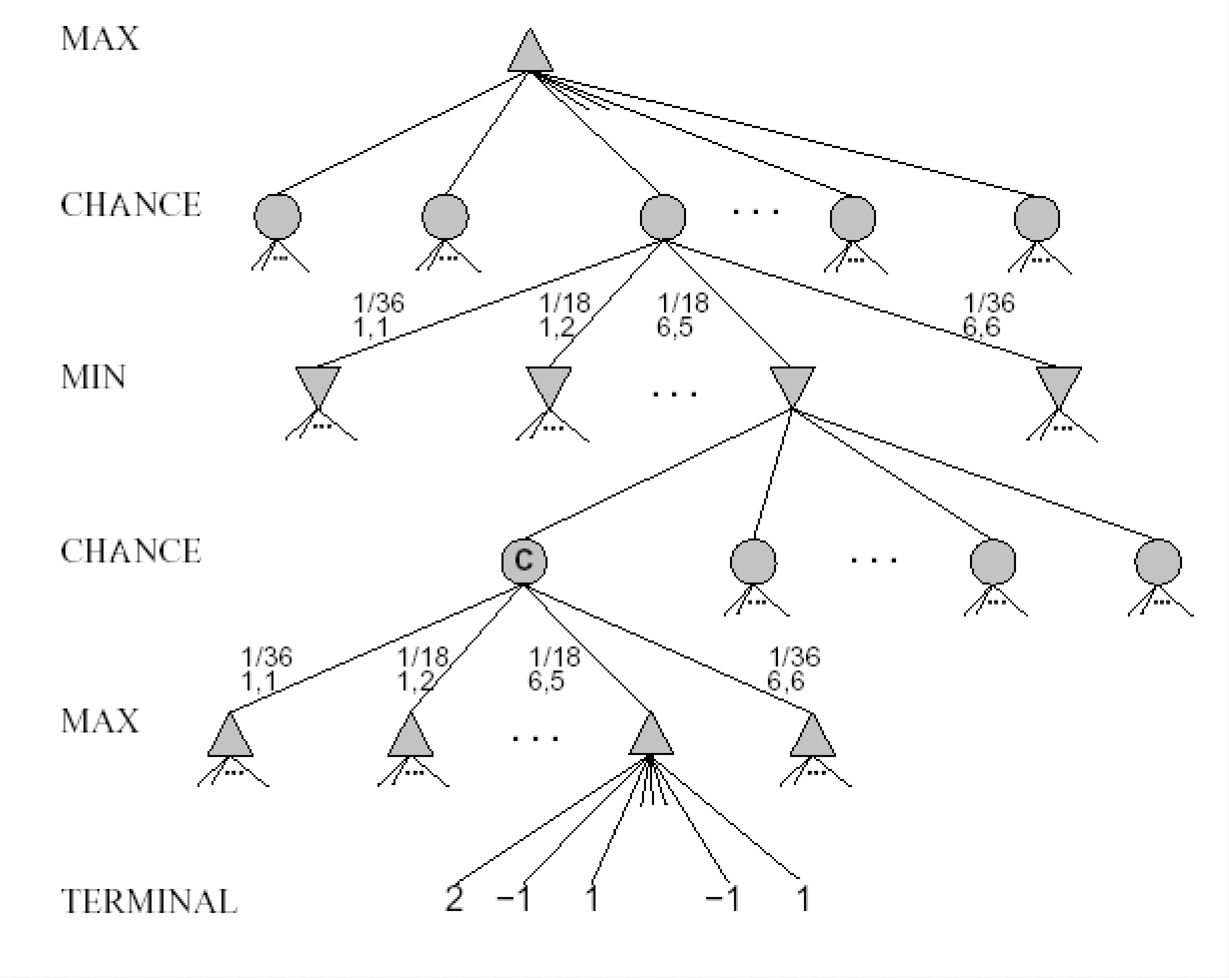
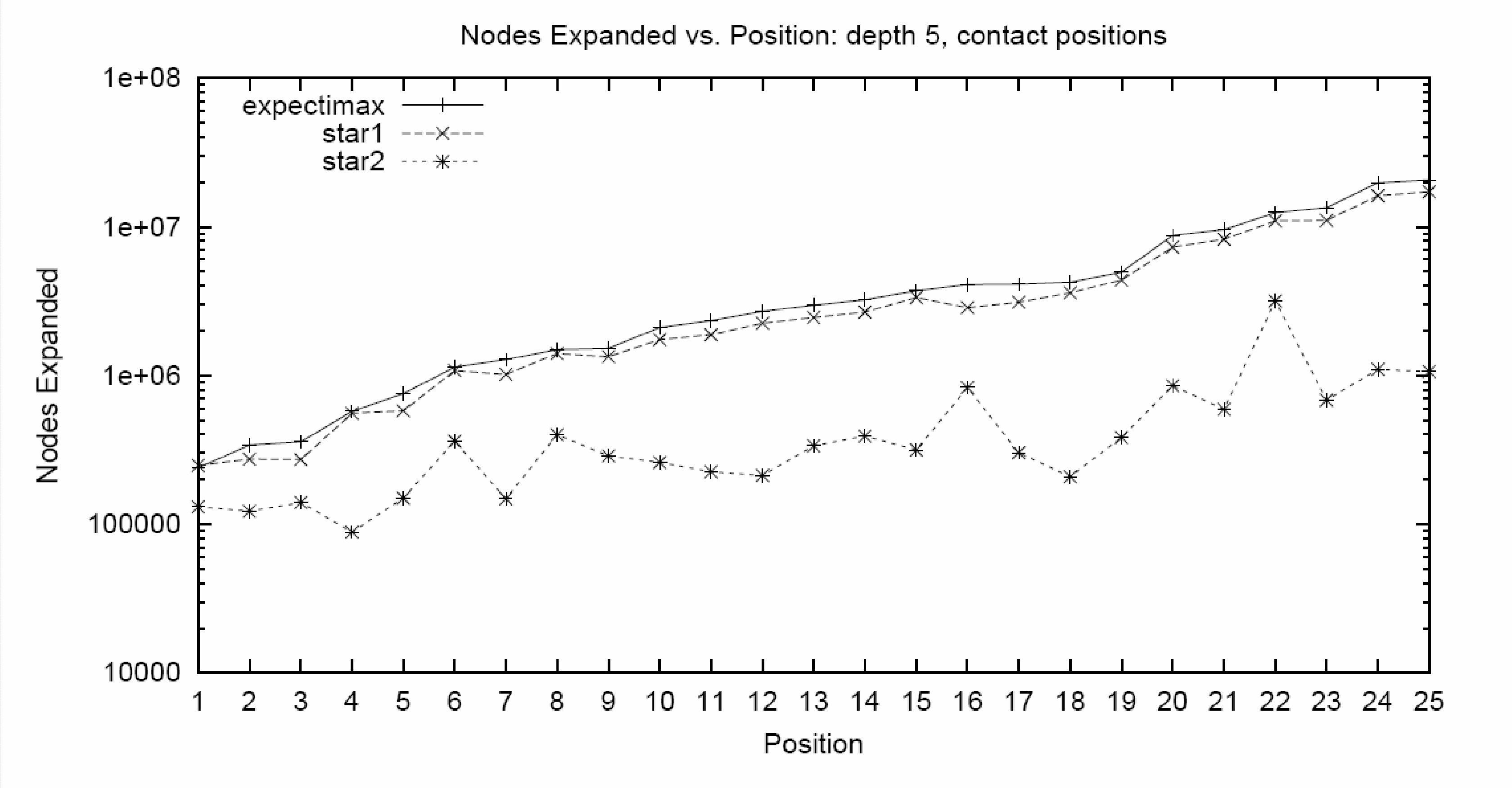
Games with element of chance



Expectiminimax algorithm

- *Expectiminimax(n) =*
  - *Utility(n)*
    - If n is a terminal state
  - *Max s ∈ Successors(n) Expectiminimax(s)*
    - if n is a max node
  - *Min s ∈ Successors(n) Expectiminimax(s)*
    - if n is a min node
  - *Σ s ∈ Successors(n) P(s) * Expectiminimax(s)*
    - if n is a chance node
- $O(w^d c^d)$

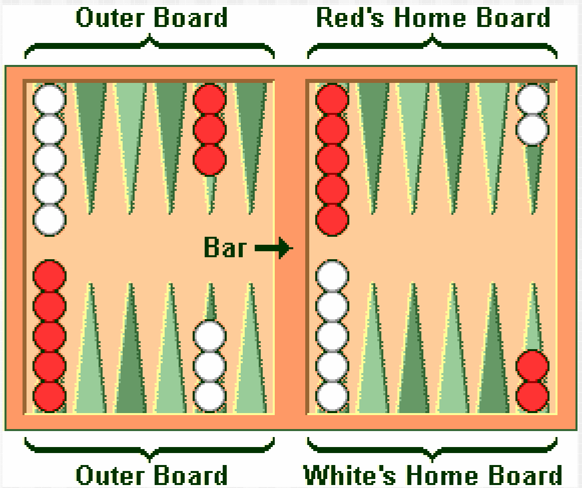
Perfomance in Backgammon

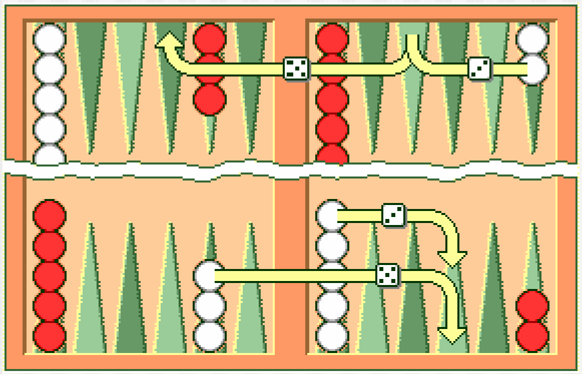


*-Minimax Performance in Backgammon,
Thomas Hauk, Michael Buro, and Jonathan Schaeer

Backgammon

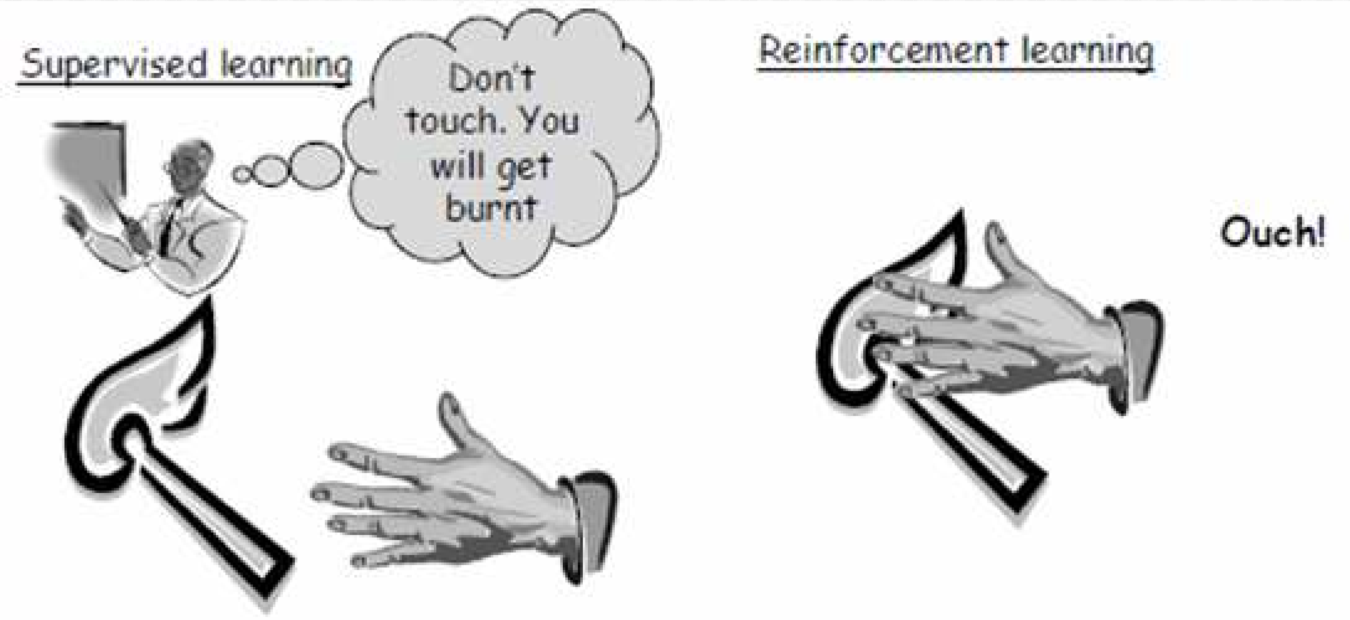
- Evaluation methods
  - Static – pip count
  - Heuristic – key points
  - Neural Networks





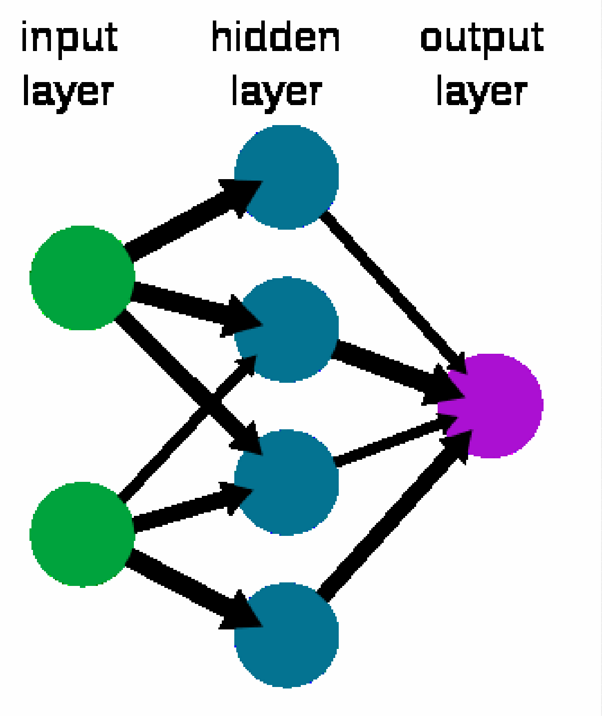
Temporal difference (TD) learning

- Reinforcement learning
- Prediction method

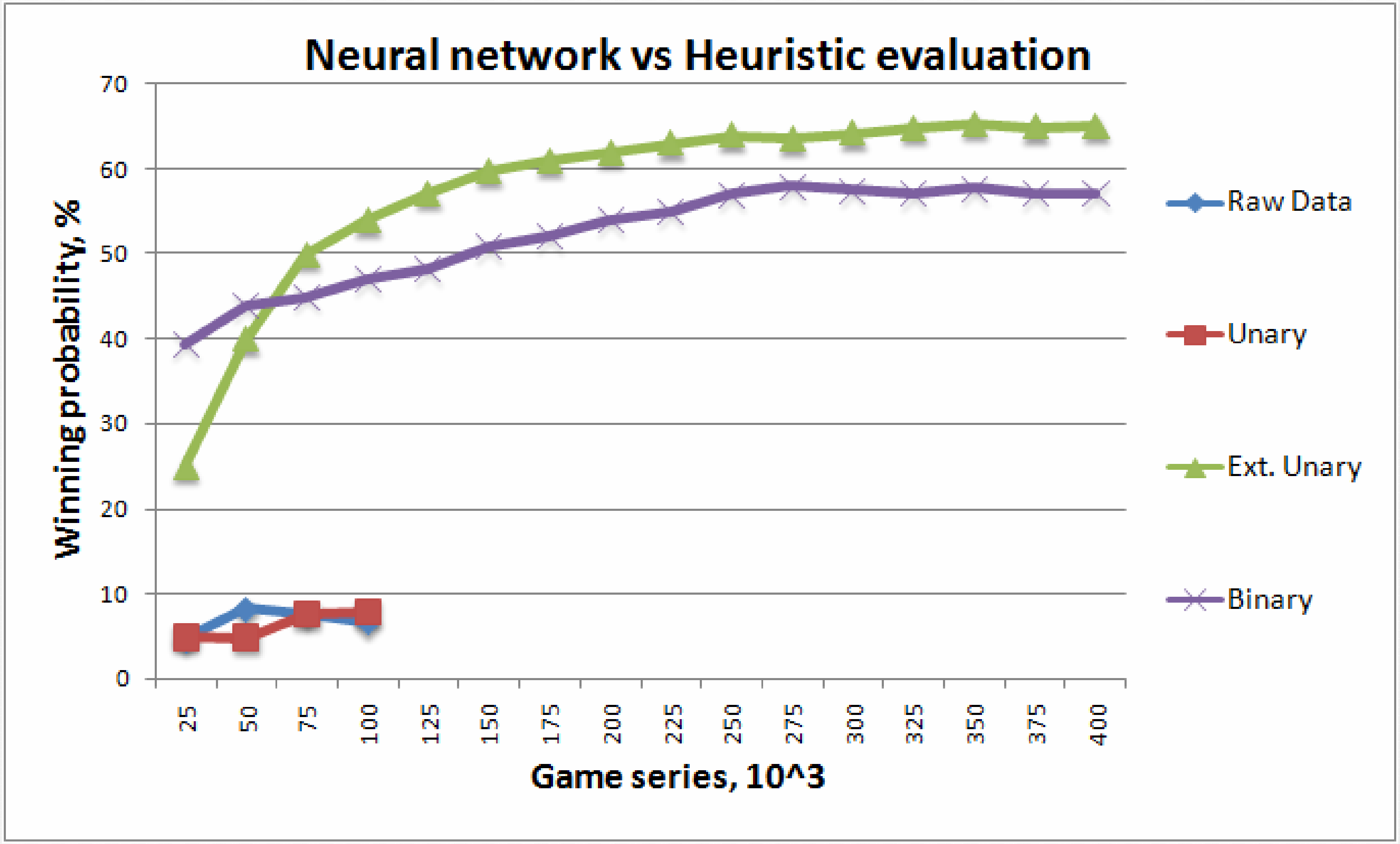


Experimental setup

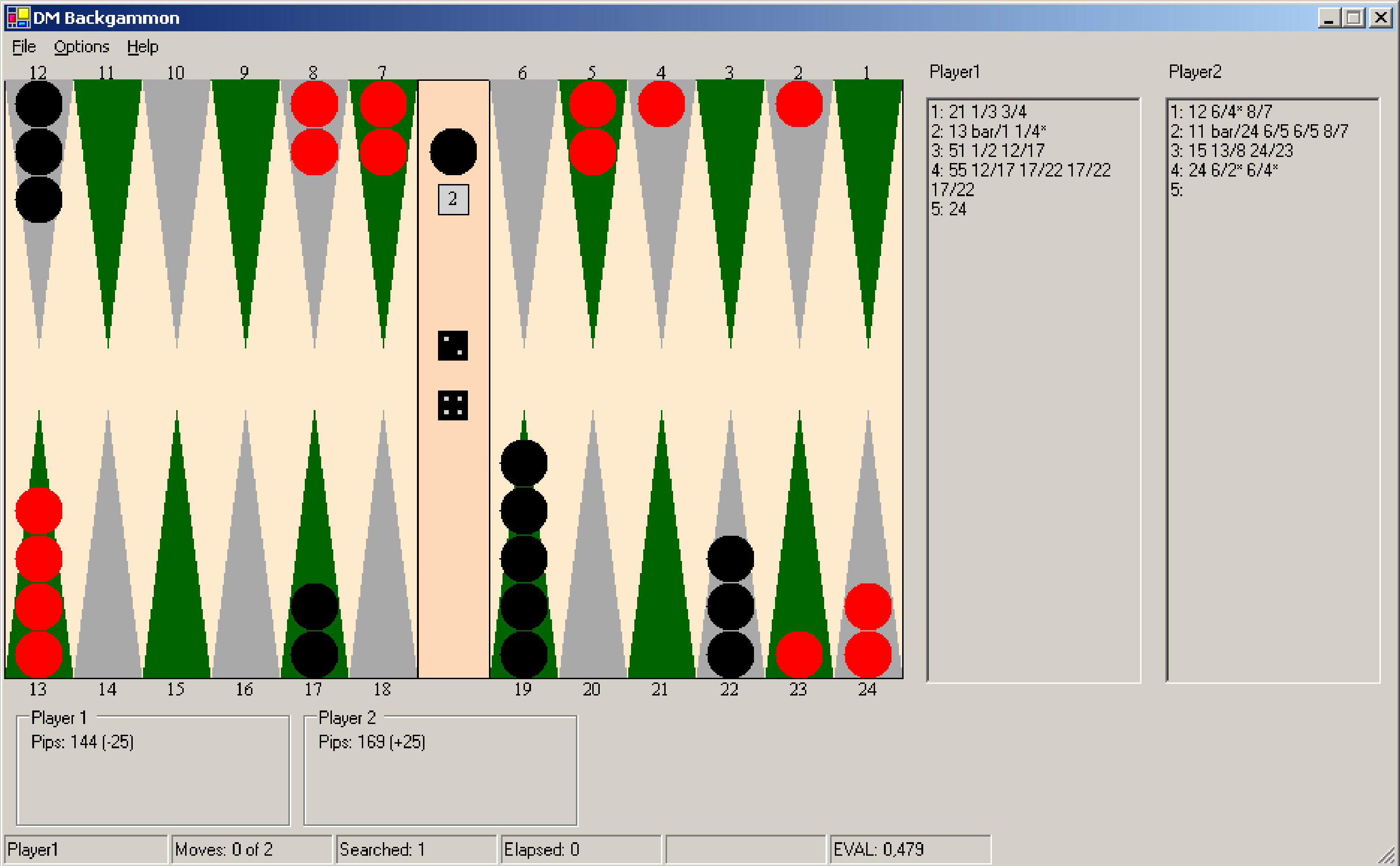
- Multi-layer perceptron
- Representation encoding
  - Raw data (27 inputs)
  - Unary (157 inputs)
  - Extended unary (201 inputs)
  - Binary (201 input)
- Training game series – 400 000 games



Learning results



Program “DM Backgammon”



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Artificial Intelligence and Poker*

AI Problems	**Poker problems**
Imperfect information	Hidden cards
Multiple agents	Multiple human players
Risk management	Bet strategy and outcome
Agent modeling	Opponent(s) modeling
Misleading information	Bluffing
Unreliable information	Taking bluffing into account

* Joint work with Annija Rupeneite

Questions ?

dim_rut@inbox.lv