Machine Learning in Games

The Magic of Research in Microsoft Products

Joaquin Quiñonero Candela, Ralf Herbrich and Thore Graepel
Online Services and Advertising
Microsoft Research Cambridge

Overview

- Why Machine Learning and Games?
- Machine Learning in Video Games
  - Drivatars™
  - Reinforcement Learning
- Machine Learning in Online Games
  - TrueSkill™
  - Halo 3
- The Path of Go
- Conclusions

Why

Tes

- Perfe meas
- Perfe
- Redu
- Redu
- Great

e AI
hes

ent

Games can be very hard!

- Partially observable stochastic games
  - States only partially observed
  - Multiple agents choose actions
  - Stochastic pay-offs and state transitions depend on state and all the other agents' actions
  - Goal: Optimise long term pay-off (reward)
- Just like life: complex, adversarial, uncertain, and we are in it for the long run!

Approximations

From single player's perspective

- Partially Observable Markov Decision Process (POMDP)

Approximate Solutions

- Reinforcement Learning
- Unsupervised Learning
- Supervised Learning

What is the best AI?

- Always takes optimal actions
- Delivers best entertainment value

Overview

- Why Machine Learning and Games?
- Machine Learning in Video Games
  - Drivatars™
  - Reinforcement Learning
- Machine Learning in Online Games
  - TrueSkill™
  - Halo 3
- The Path of Go
- Conclusions

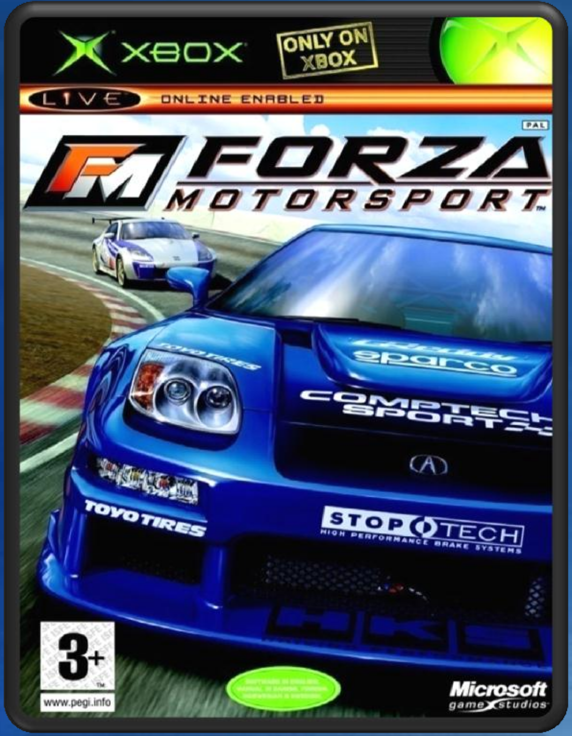
Drivatar™

Adaptive avatar for driving

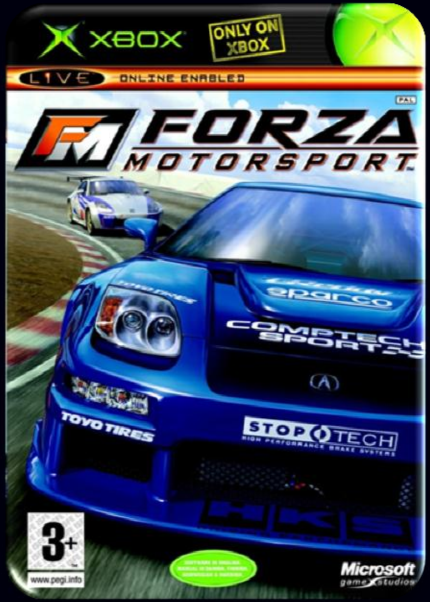
Separate game mode

Basis of all in-game AI

Basis of "dynamic" racing line



Demo: Forza Motorsport

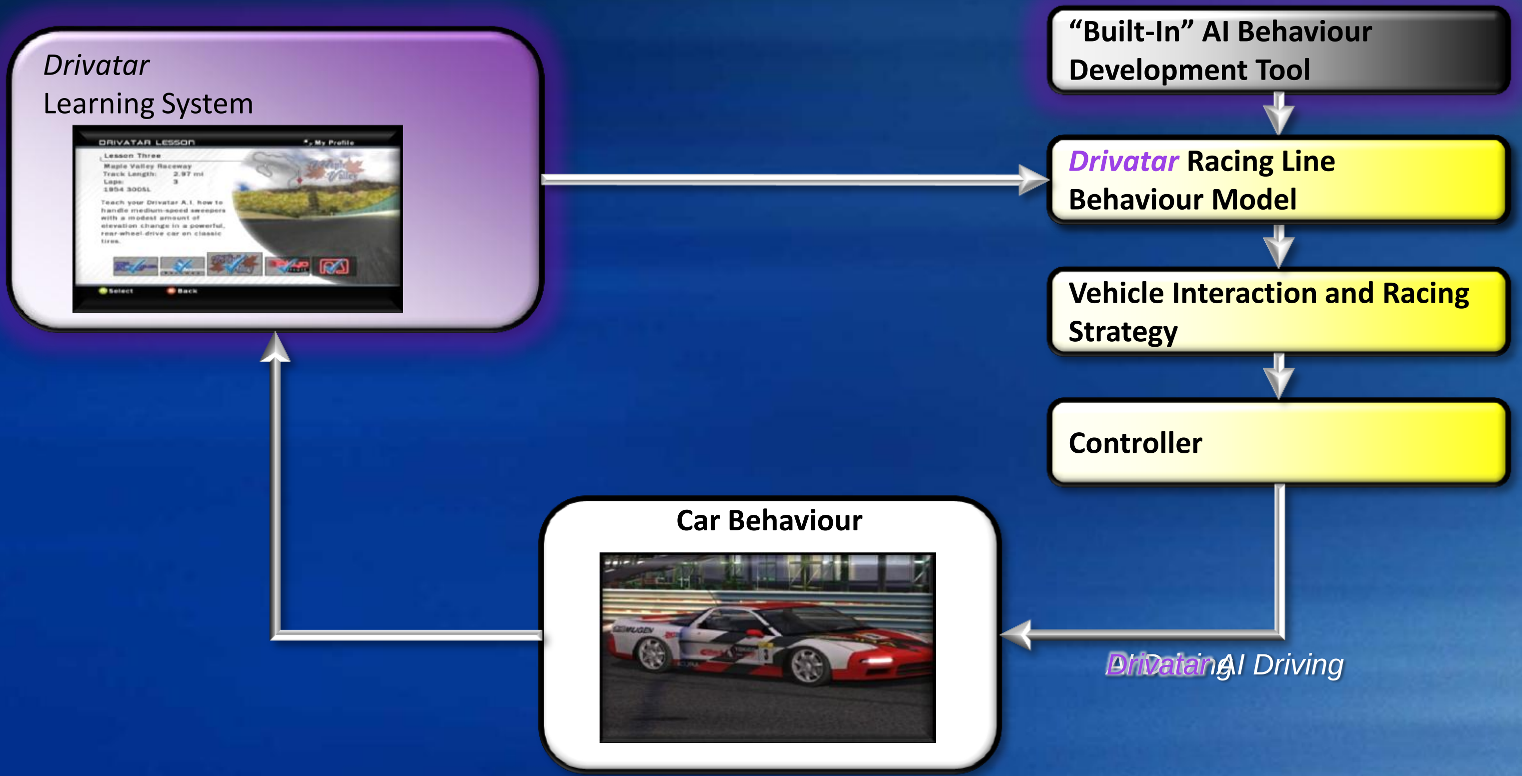


XBOX Game

- Dynamic Racing Line
- Learning a Drivatar
- Using a Drivatar


FORZA

Drivatars Unplugged



The Racing Line Model

Drivatars: Main Idea

- Two phase process:
  1. Pre-generate possible racing lines prior to the race from a (compressed) racing table.
  2. Switch the lines during the race to add variability.
- Compression reduces the memory needs per racing line segment
- Switching makes smoother racing lines.

Racing Tables

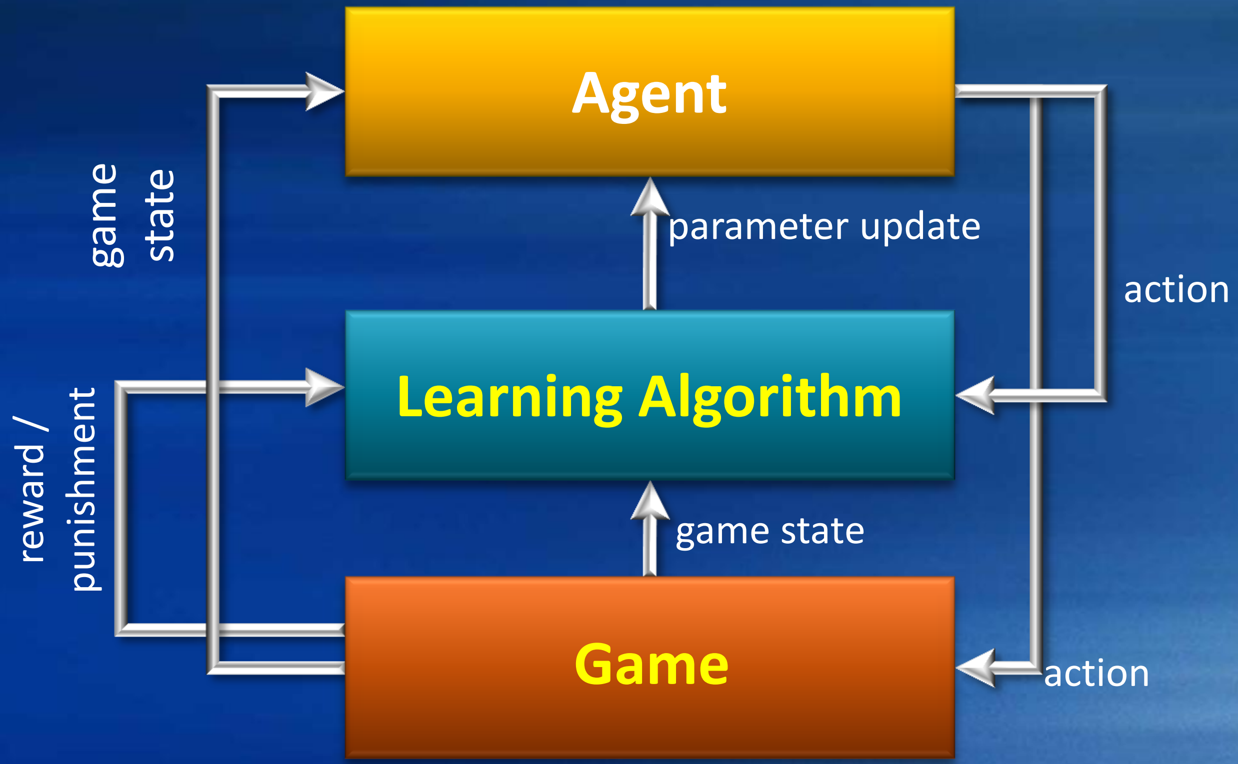
Segments	a_1	a_2	a_3	a_4
				
				
				
				

Minimal Curvature Lines

Overview

- Why Machine Learning and Games?
- Machine Learning in Video Games
  - Drivatars™
  - Reinforcement Learning
- Machine Learning in Online Games
  - TrueSkill™
  - Halo 3
- The Path of Go
- Conclusions

Reinforcement Learning



Tabular Q-Learning

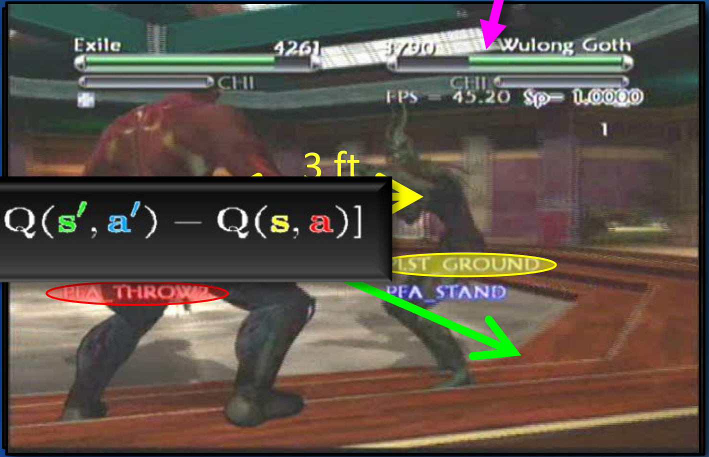
actions

game states

Q-Table	THROW	KICK	STAND
1ft / GROUND			
2ft / GROUND			
3ft / GROUND	13.2	10.2	-1.3
4ft / GROUND			
5ft / GROUND			
6ft / GROUND			
1ft / KNOCKED			
2ft / KNOCKED			
3ft / KNOCKED			
4ft / KNOCKED			
5ft / KNOCKED	3.2	6.0	4.0
6ft / KNOCKED			

$$Q(s,a) \leftarrow Q(s,a) + \alpha\left[r + \gamma \max_{a'} Q(s',a') - Q(s,a)\right]$$

+10.0



Results

- **Game state features**
  - Separation (5 binned ranges)
  - Last action (6 categories)
  - Mode (ground, air, knocked)
  - Proximity to obstacle
- **Available Actions**
  - 19 aggressive (kick, punch)
  - 10 defensive (block, lunge)
  - 8 neutral (run)
- **Q-Function Representation**
  - One layer neural net (tanh)

Reinforcement Learner

In-Game AI Code

Learning Aggressive Fighting

Reward for decrease in Wulong Goth's health

Early in the learning process …

… after 15 minutes of learning

Learning "Aikido" Style Fighting

Punishment for decrease in either player's health

Early in the learning process …

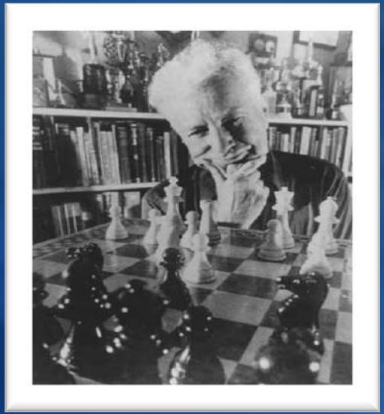
… after 15 minutes of learning

Overview

- Why Machine Learning and Games?
- Machine Learning in Video Games
  - Drivatars™
  - Reinforcement Learning
- Machine Learning in Online Games
  - TrueSkill™
  - Halo 3
- The Path of Go
- Conclusions

Motivation

- Competition is central to our lives
  - Innate biological trait
  - Driving principle of many sports
- Chess Rating for fair competition
  - ELO: Developed in 1960 by Árpád Imre Élő
  - Matchmaking system for tournaments
- Challenges of online gaming
  - Learn from few match outcomes efficiently
  - Support multiple teams and multiple players per team

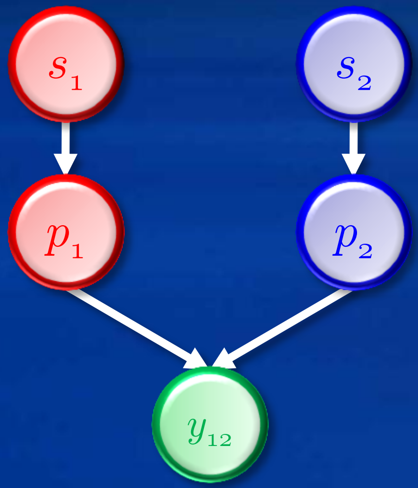


The Skill Rating Problem

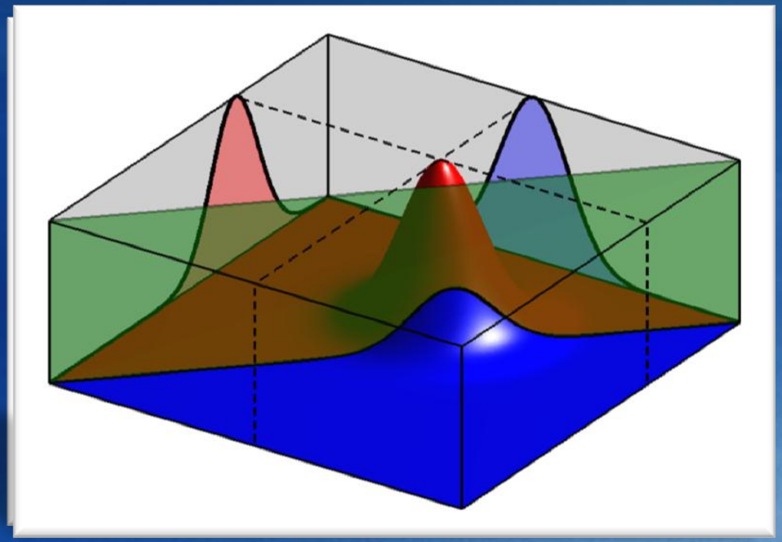
- **Given**:
  - Match outcomes: Orderings among k teams consisting of n_1, n_2, ..., n_k players, respecti
- **Questions**:
  - Skill s_i for each
  - Glob
  - Fair m

Two Player Match Outcome Model

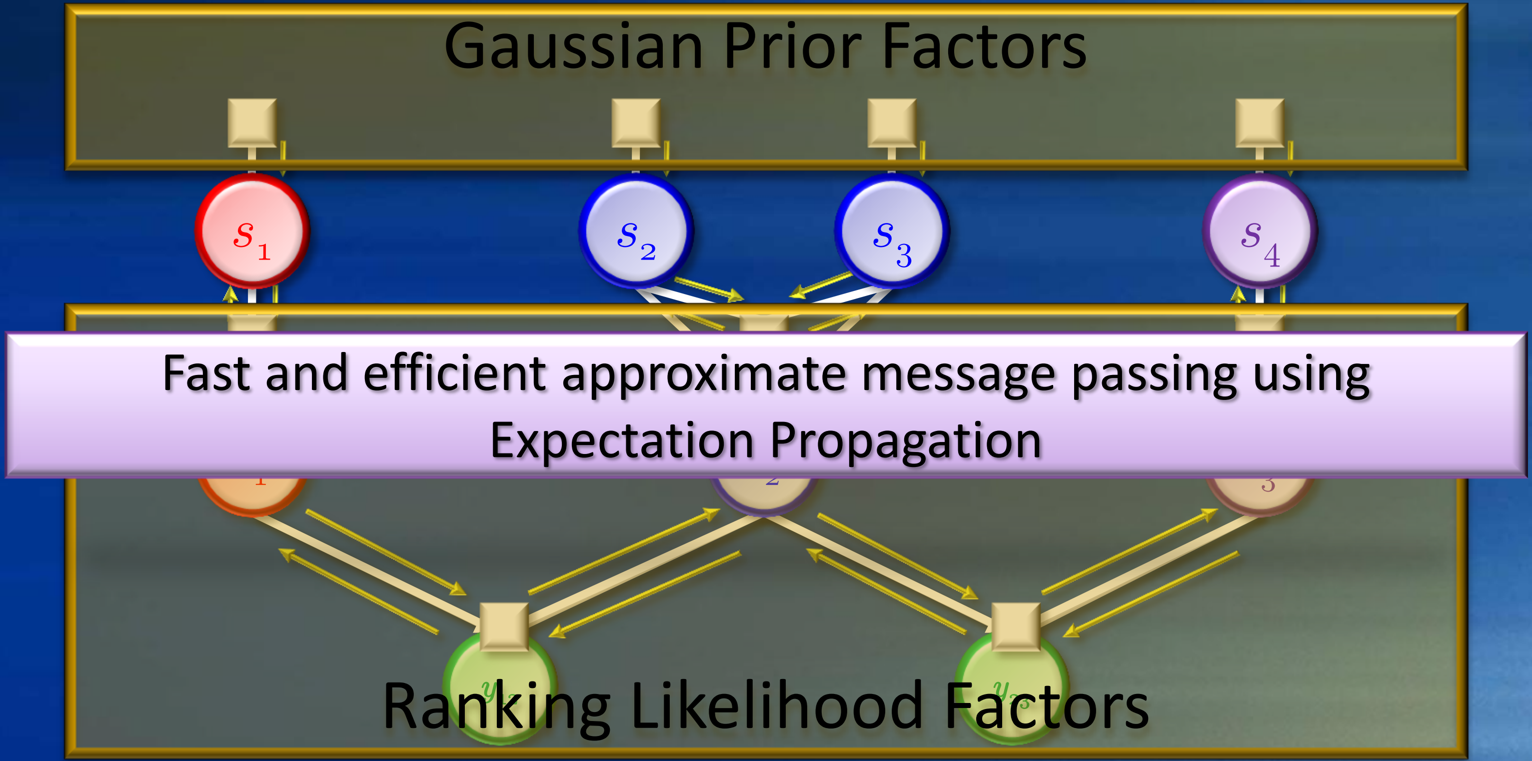
- Latent Gaussian performance model for fixed skills
- Possible outcomes: Player 1 wins over 2 (and vice versa)



$$\mathbf{P}(y_{12} = (1,2) | p_1, p_2) = \mathbb{I}(p_1 > p_2)$$



Efficient Approximate Inference

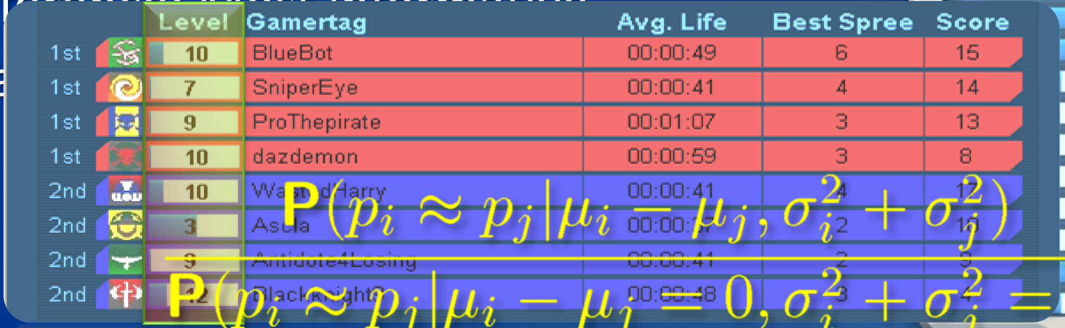


Applications to Online Gaming

- **Leaderboard**
  - Global ranking of all players

$$\mu_i - 3 \cdot \sigma_i$$

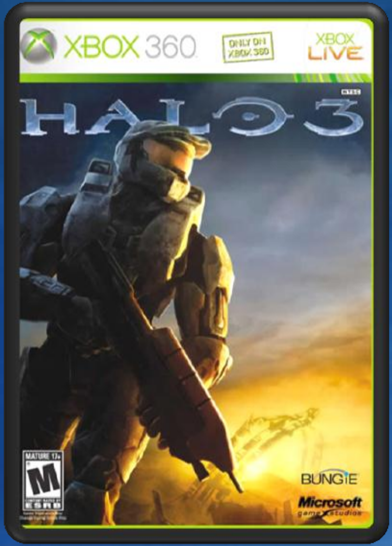
- **Matchmaking**
  - For gamers: Most uncertain outcome
  - For inference: Most informative
  - Both a



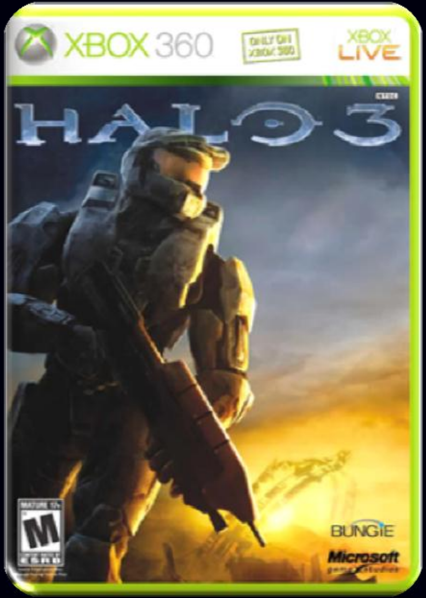
$$\frac{\mathbf{P}(p_i \approx p_j | \mu_i - \mu_j, \sigma_i^2 + \sigma_j^2)}{\mathbf{P}(p_i \approx p_j | \mu_i - \mu_j = 0, \sigma_i^2 + \sigma_j^2 = 0)}$$

Xbox 360 & Halo 3

- **Xbox 360 Live**
  - Launched in September 2005
  - Every game uses TrueSkill™ to match players
  - > 35 million players
  - > 4 million matches per day
  - > 2 billion hours of gameplay / month
- **Halo 3**
  - Launched on 25th September 2007
  - Largest entertainment launch in history
  - > 200,000 player concurrently (peak: 1,000,000)



Demo: Halo 3



Halo 3 Game

- Matchmaking
- Skill Stats
- Tight Matches

Halo 3 in Action

Overview

- Why Machine Learning and Games?
- Machine Learning in Video Games
  - Drivatars™
  - Reinforcement Learning
- Machine Learning in Online Games
  - TrueSkill™
  - Halo 3
- The Path of Go
- Conclusions

Learning to Play Go

The Game of Go

- Started about 4000 years ago in ancient China.
- About 60 million players worldwide.
- 2 Players: Black and White.
- Board: 19×19 grid.
- Rules:
  - Turn: stone placed on vertex.
  - Capture.
- Aim: Gather territory

Computer Go

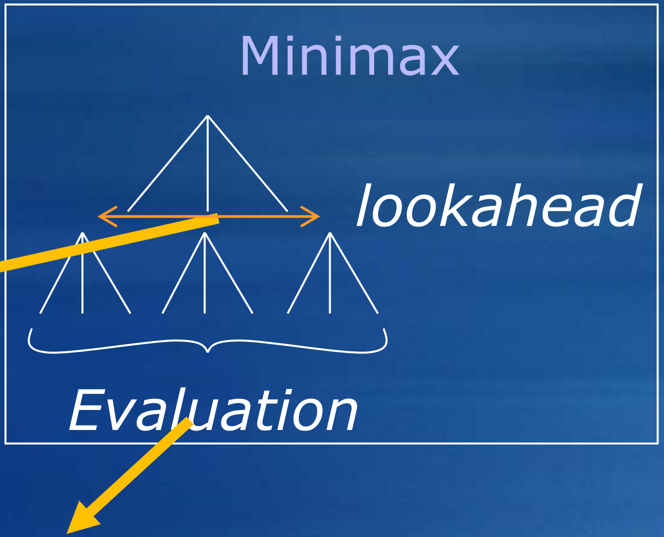
- 5th November 1997:
  Gary Kasparov beaten by Deep Blue.

Kasparov ponders his next move (CNN)

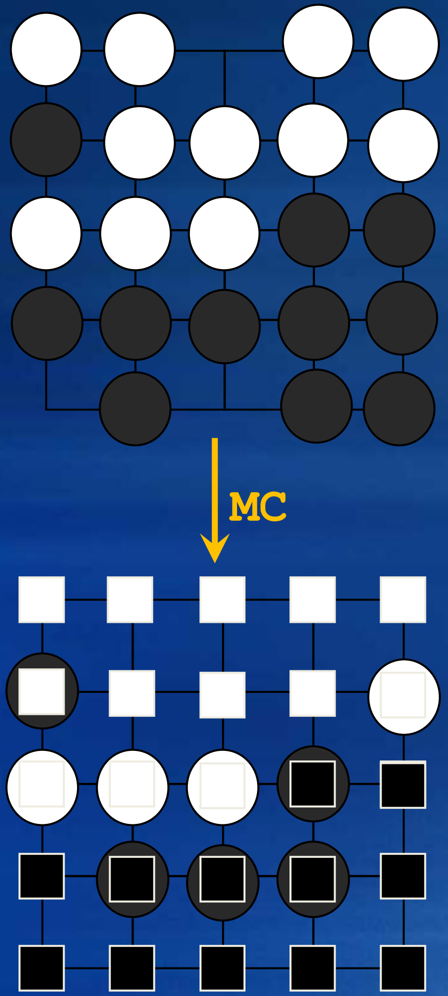
- Best Go programs cannot beat amateurs.

Computer Go

- Minimax search defeated.
- High **Branching Factor**.
  - Go: ~200
  - Chess: ~35
- Complex **Position Evaluation**.
  - Stone's value derived from configuration of surrounding stones.

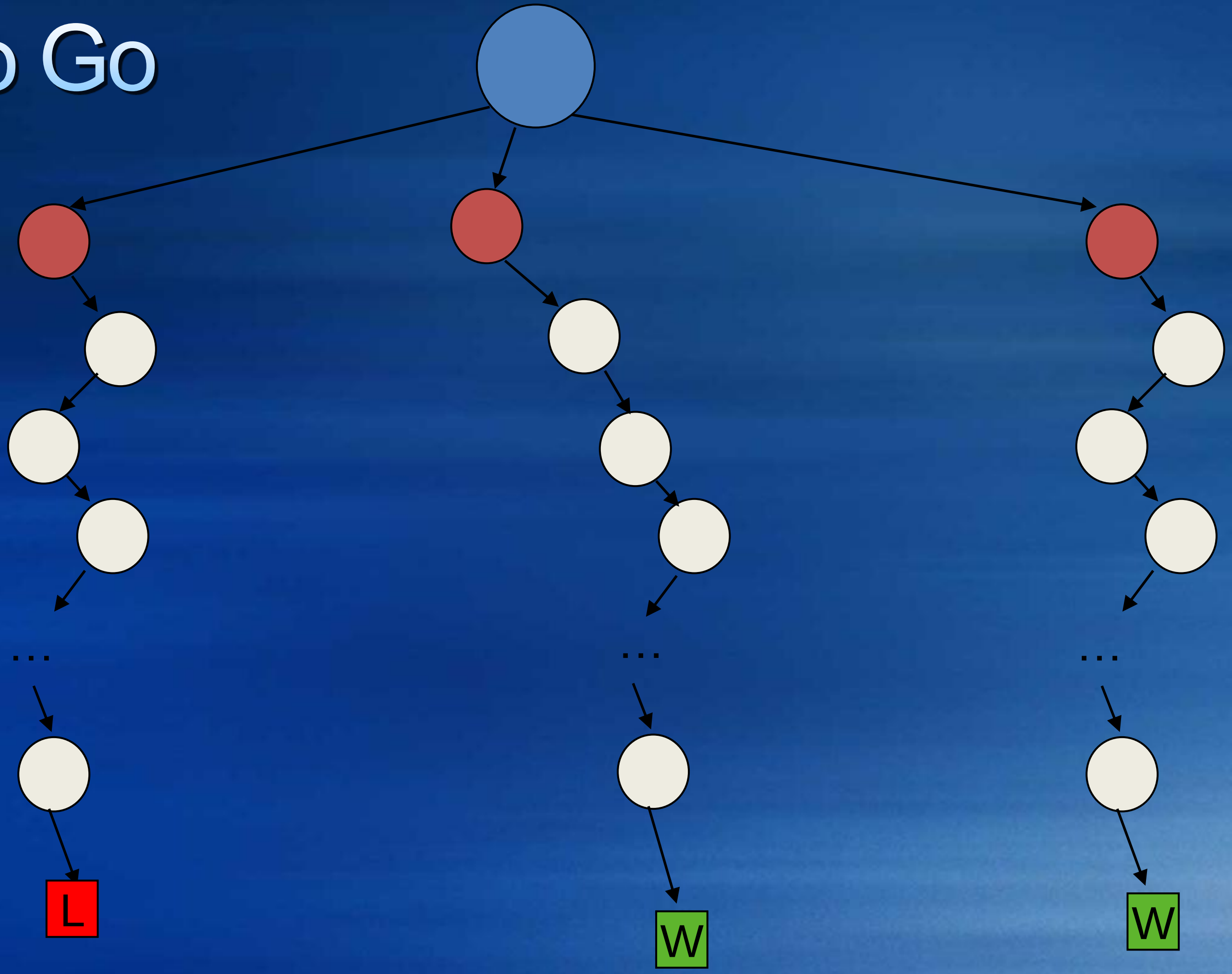


Monte Carlo Go

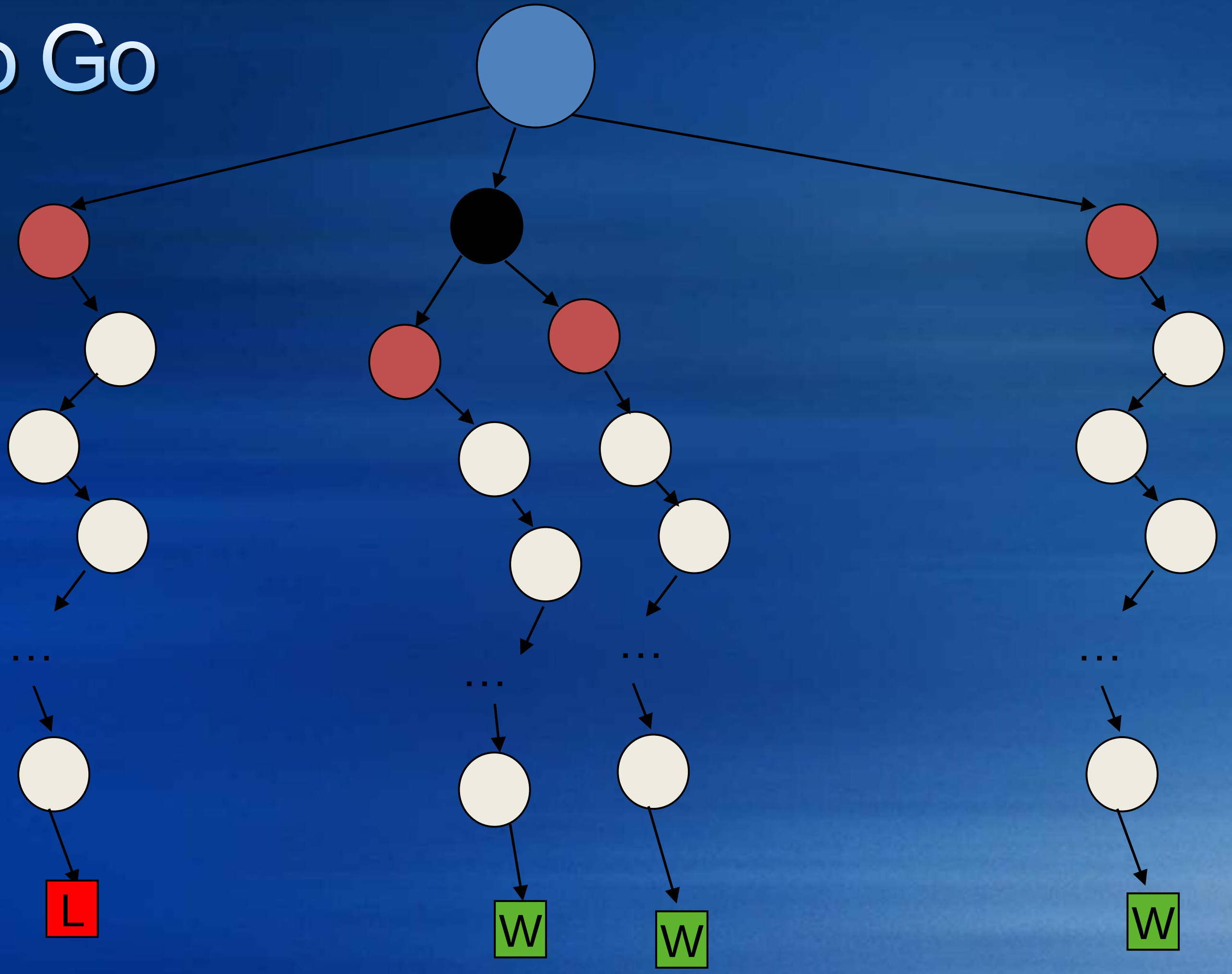


Territory Hypothesis

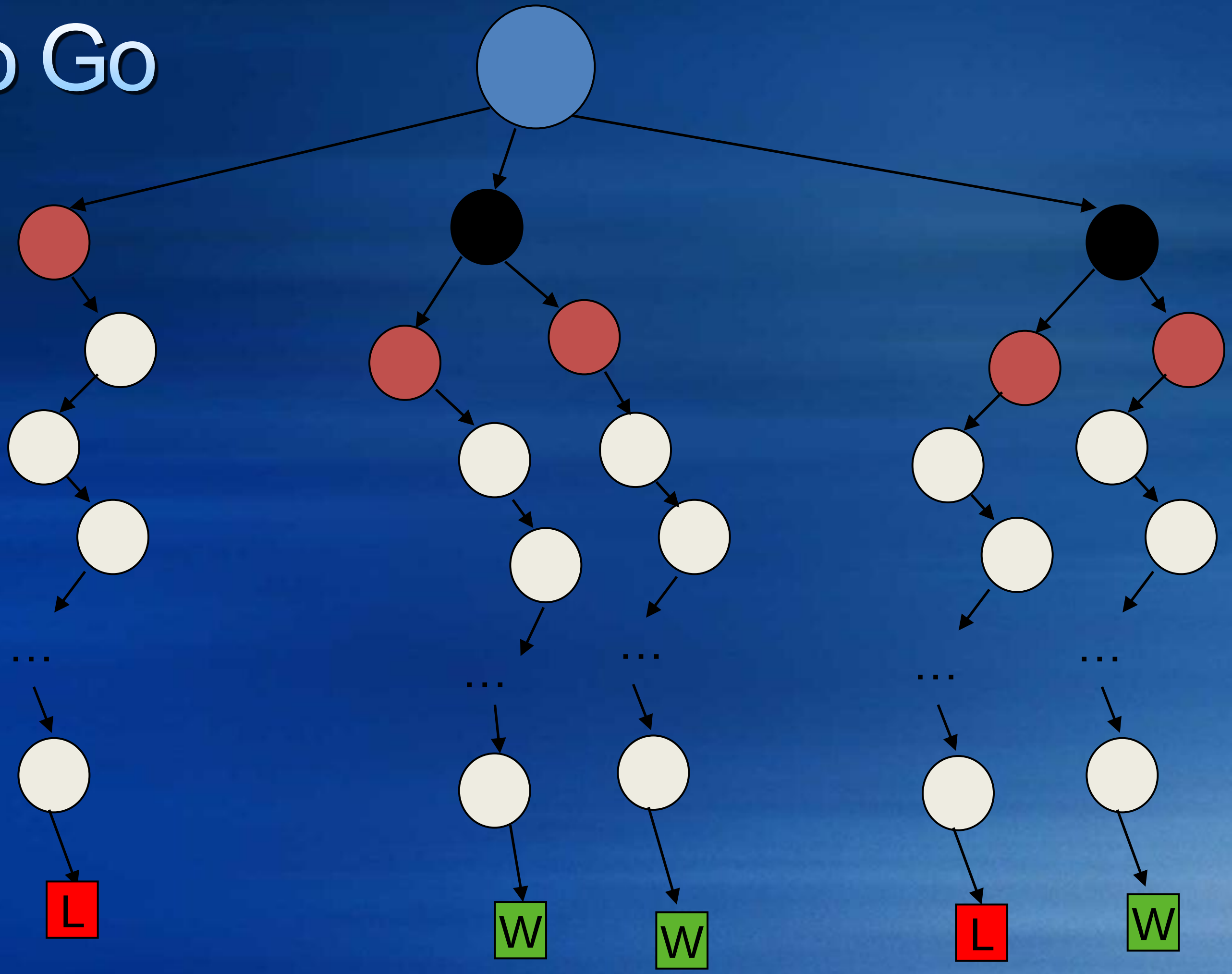
Monte Carlo Go



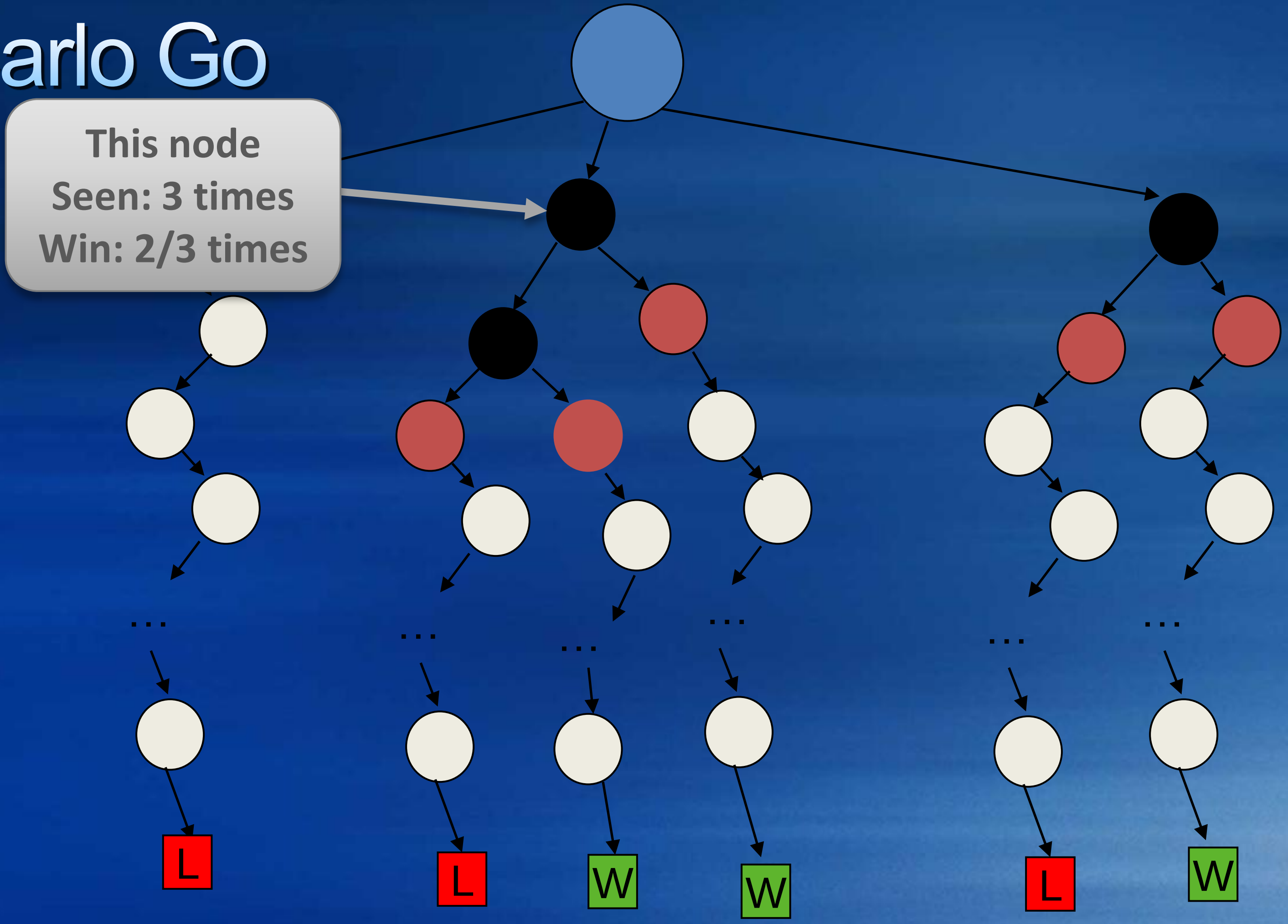
Monte Carlo Go



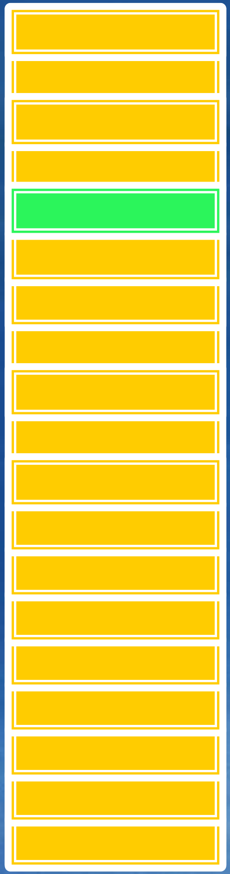
Monte Carlo Go



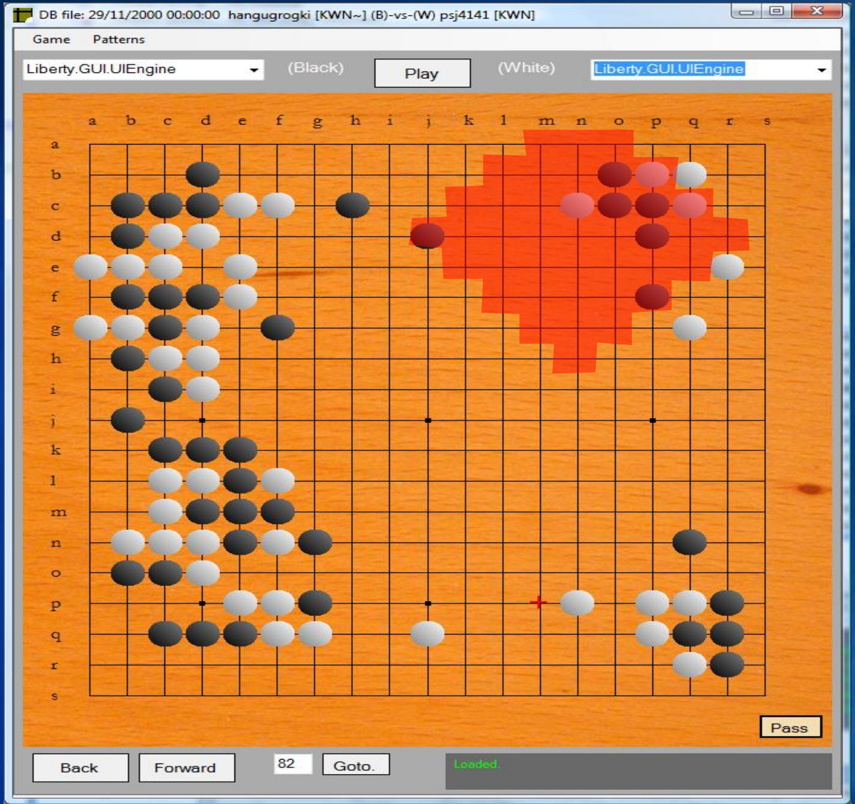
Monte Carlo Go

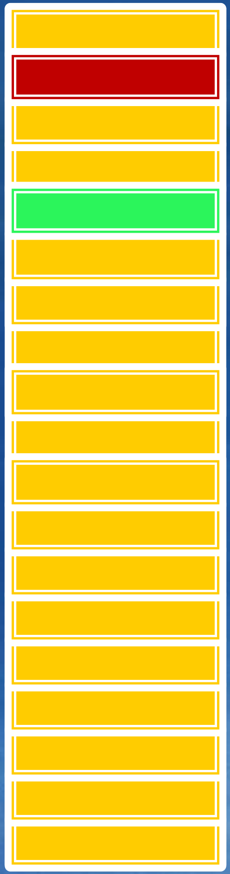


Learning From the Experts with TrueSkill

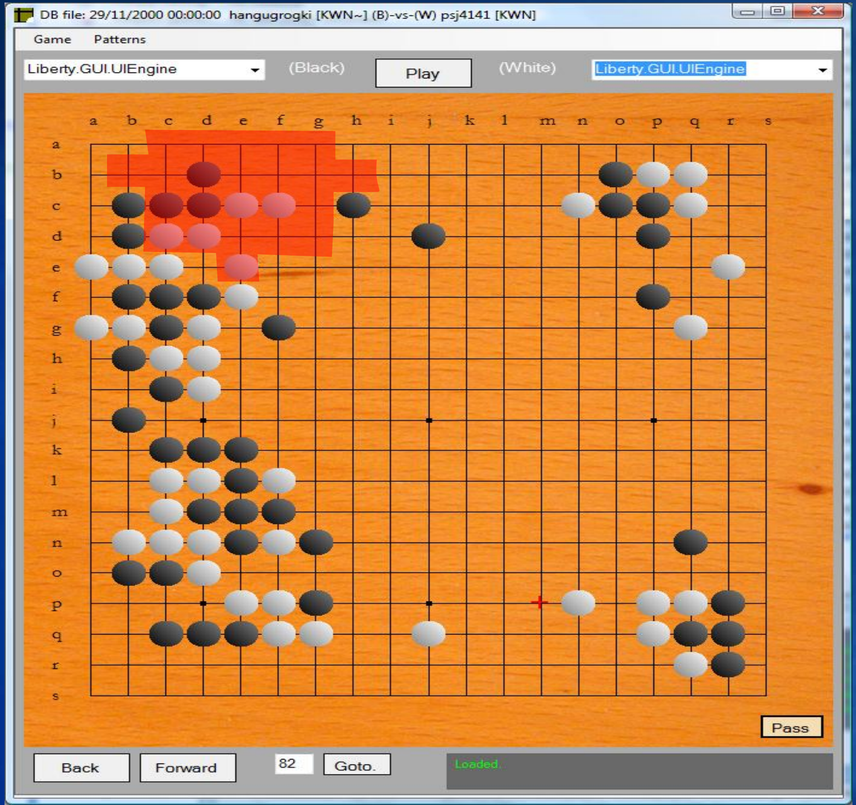


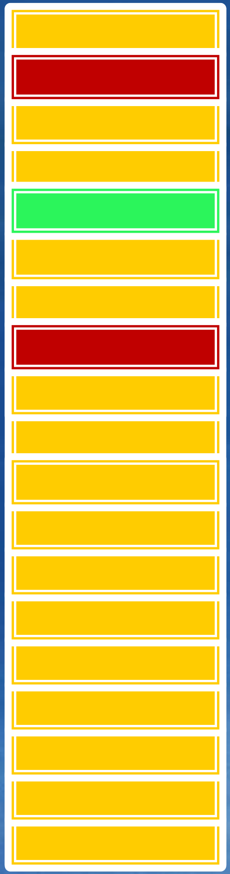
Learning From the Experts with TrueSkill



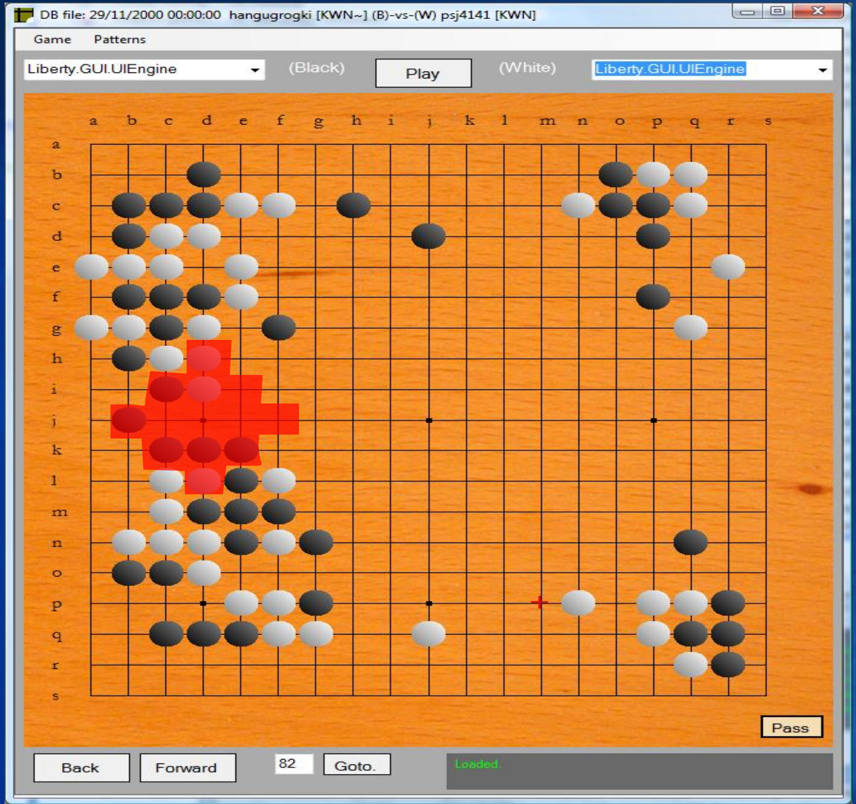


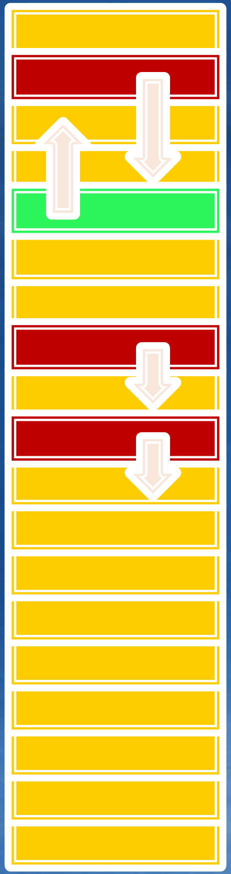
Learning From the Experts with TrueSkill



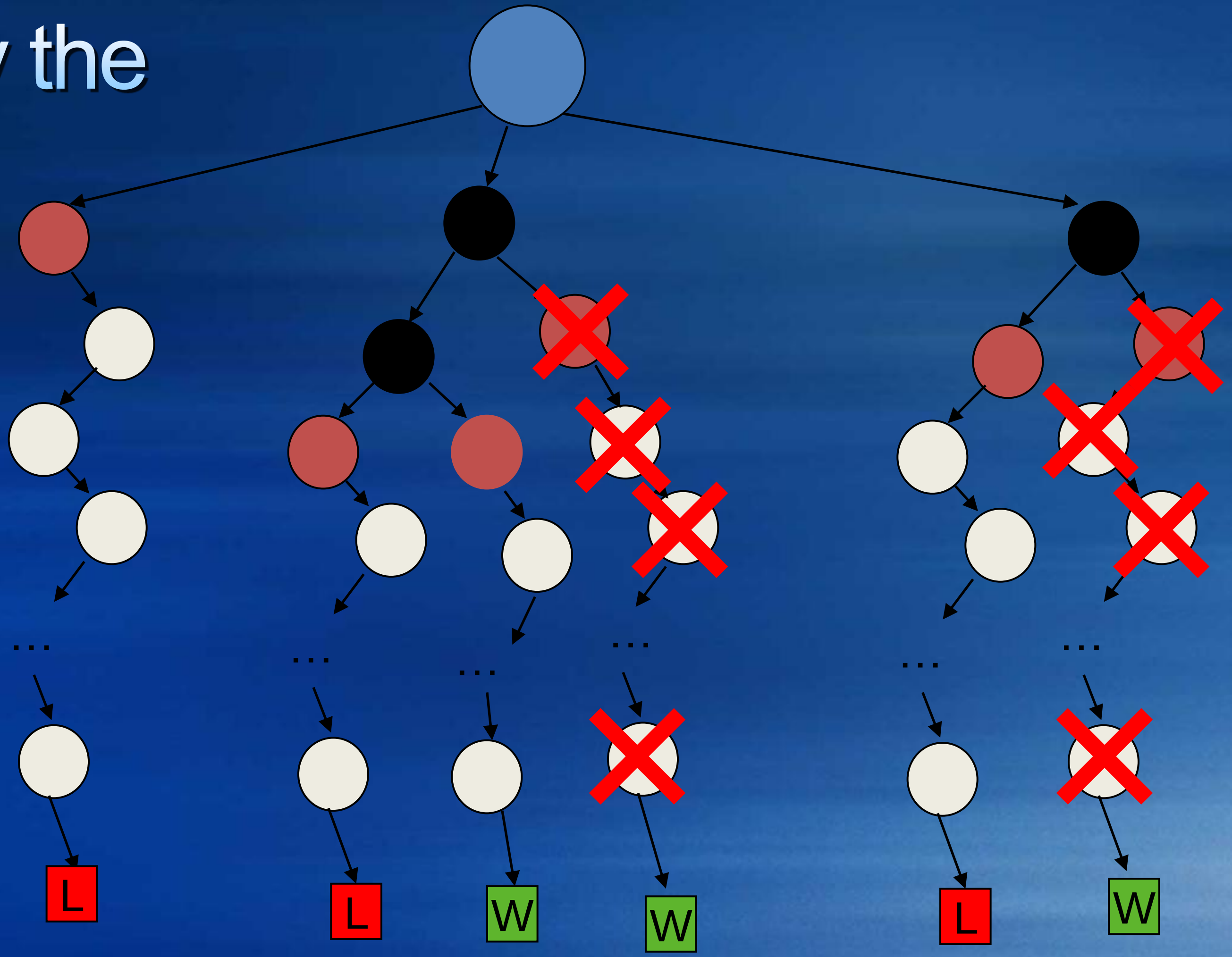


Learning From the Experts with TrueSkill



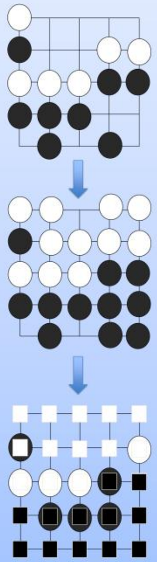


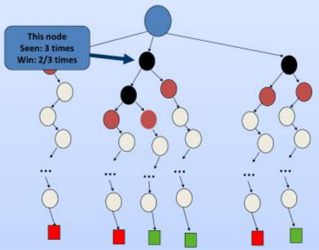
Prune Away the Bad Moves



Machine Learning Assisted Monte Carlo Go

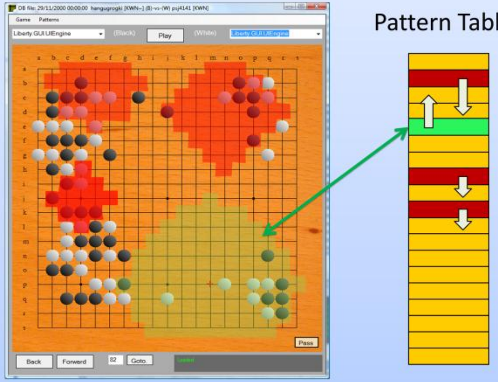
Monte Carlo Go





- Play random games (‘rollouts’).
- Each game gives a sample win/loss.
- Average estimates position value.
- Store game tree in memory.
- Bootstrap rollout policy.

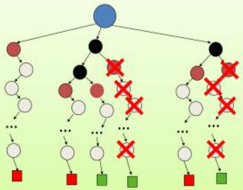
Pattern Ranking System



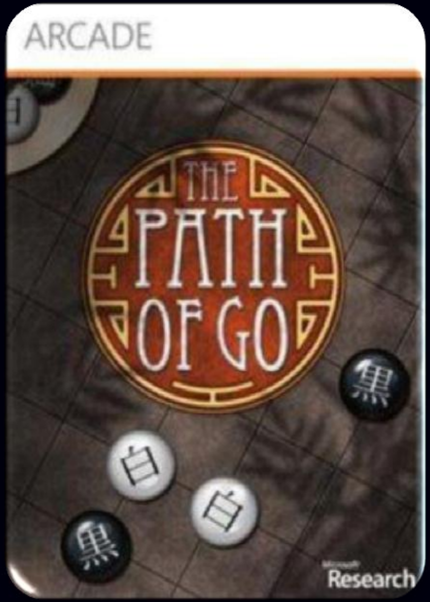
- Learn pattern rankings using TrueSkill.
- Moves chosen over other moves by experts are inferred to have higher value.
- Training Data: 200,000 Expert Go Games.

Pattern Pruning

- Too many possible moves to evaluate.
- Pattern system estimates move quality.
- Prune bad moves from the game tree.



Demo: The Path of Go



The Path of Go

- MSRC Go AI (written in F#)
- TrueSkill Match Making
- XNA Game Studio

Overview

- Why Machine Learning and Games?
- Machine Learning in Video Games
  - Drivatars™
  - Reinforcement Learning
- Machine Learning in Online Games
  - TrueSkill™
  - Halo 3
- The Path of Go
- Conclusions

Conclusions

- Computer games can be used as test beds for research.
- Machine learning can be used to improve the user experience in computer games.
- Both research and applications are in their infancy and there are many open questions.
- XNA framework exists to plug in machine learning algorithms.
- For more question, please drop us a line

Joaquin Quiñonero Candela, Ralf Herbrich, Thore Graepel
Online Services and Advertising Group

joaquinc @ microsoft.com

Microsoft®

Your potential. Our passion.™