GDAŃSK UNIVERSITY OF TECHNOLOGY

International Summer School on Deep Learning

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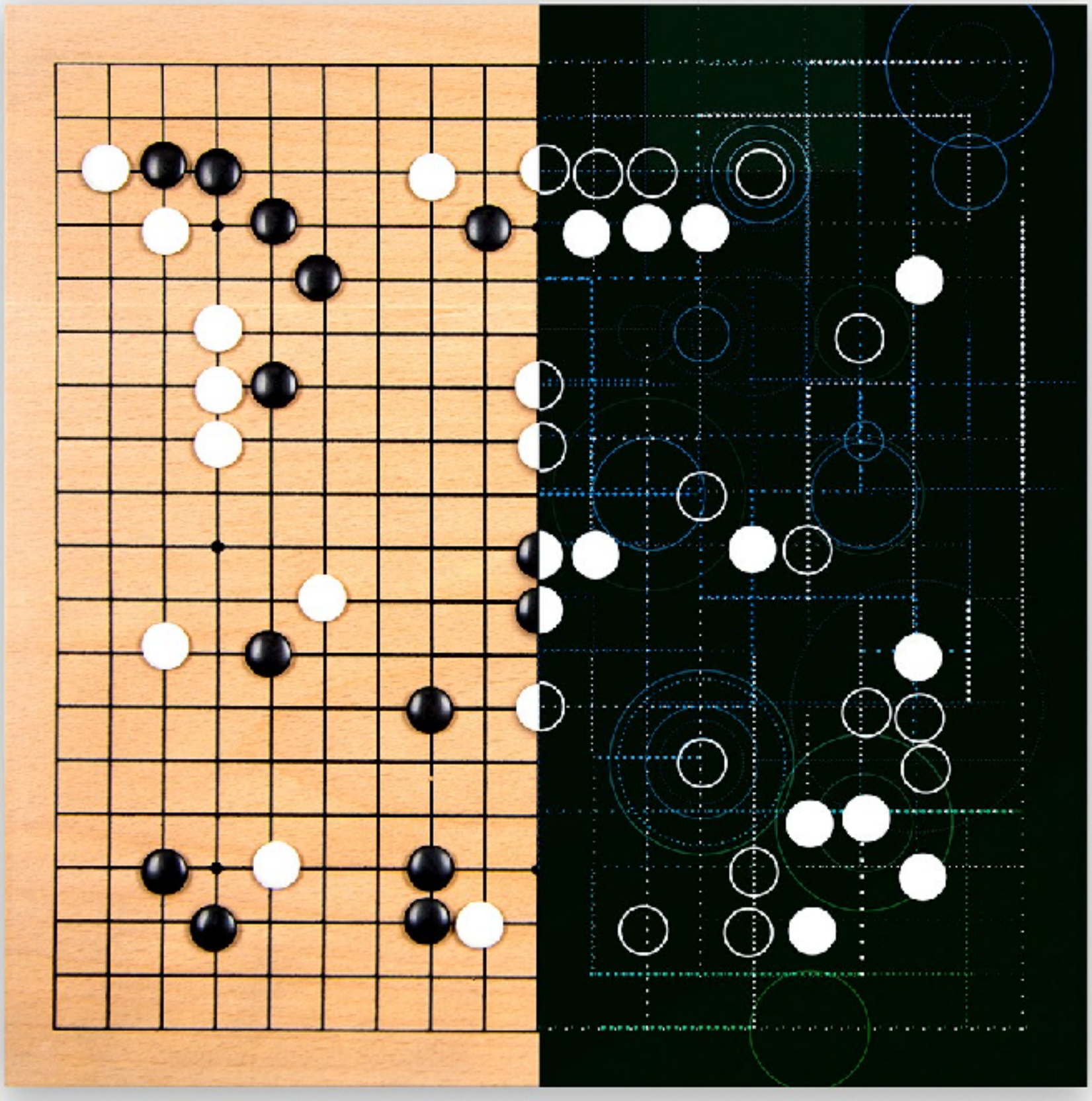
Deep Reinforcement Learning through AlphaZero lenses 🕶

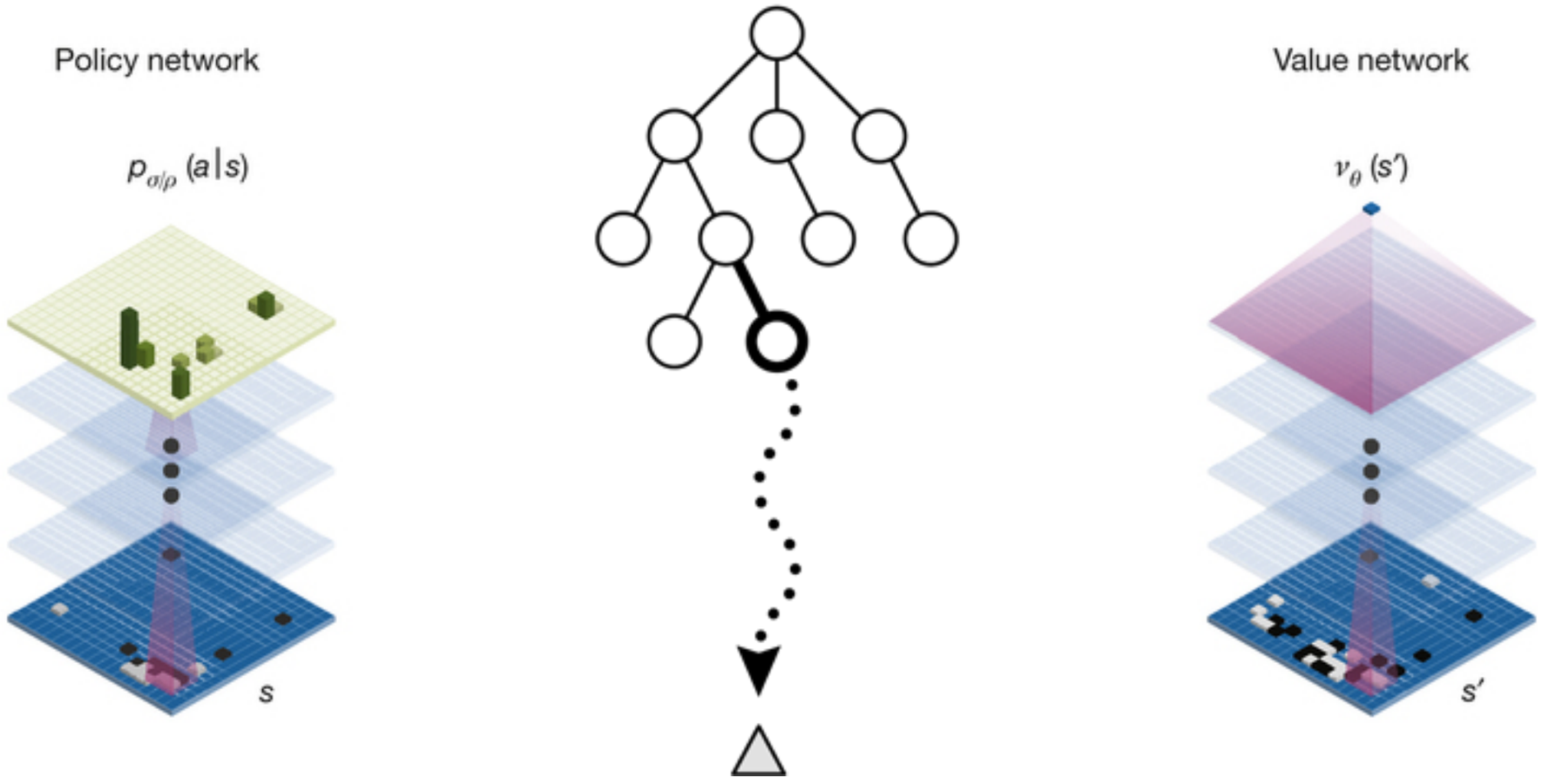
Piotr Januszewski

Who is “Gradient”?



Source: https://www.wired.com/2016/01/in-a-huge-breakthrough-googles-ai-beats-a-top-player-at-the-game-of-go/

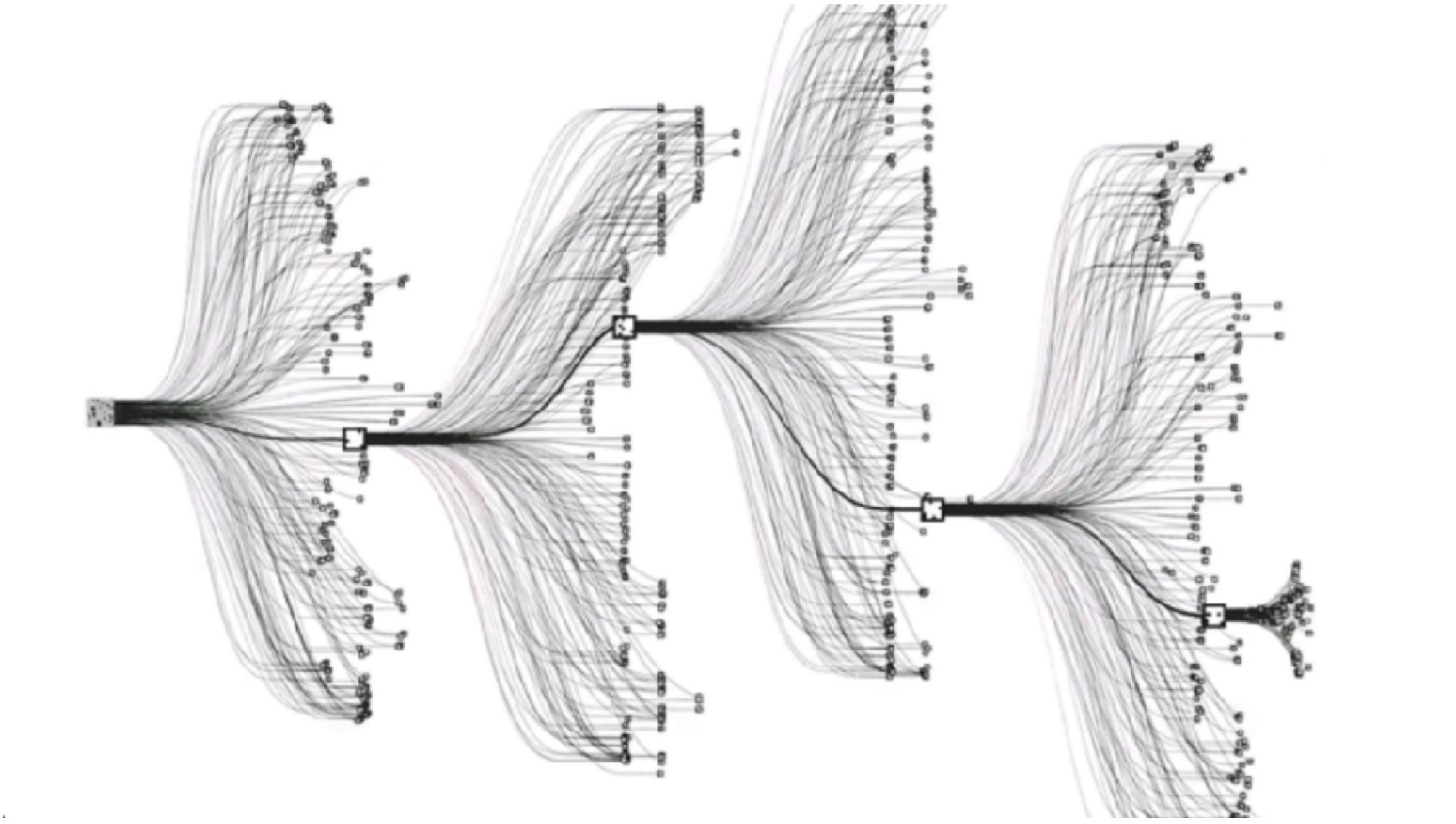
Guided Tree Search



DeepMind’s AlphaGo

AlphaGo Lee version of this algorithm became **the first AI to beat a human grandmaster of Go** in March of 2016.

It is really big achievement as for a long time people thought that **Go is the holy grail of artificial intelligence** and we were still many years before AI will beat humans in this game!



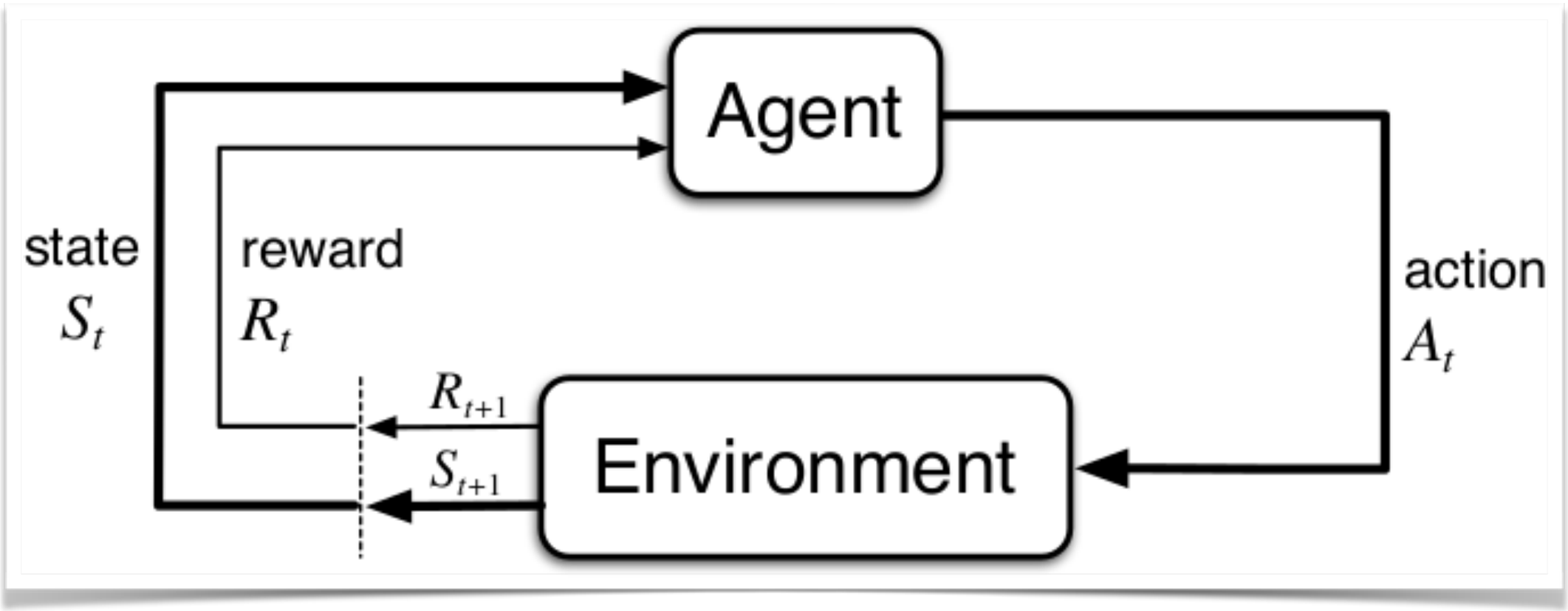
The ancient Game of **Go has more states then there are atoms in the known universe** and it’s branching factor is more then seven times bigger then the one of chess.

DeepMind’s AlphaZero

In October of 2017, DeepMind published new AlphaGo version. **AlphaGo Zero had defeated AlphaGo 100–0**. Incredibly, it had done so **by learning solely through self-play**. No longer was a database of human expert games required to build a super-human AI.

48 days later they publish current state-of-the-art version AlphaZero, which can play other games like Chess and Shogi too. **It can beat the world-champion programs StockFish and Elmo learning through self-play for only about 4 and 2 hours respectively!**

Reinforcement Learning



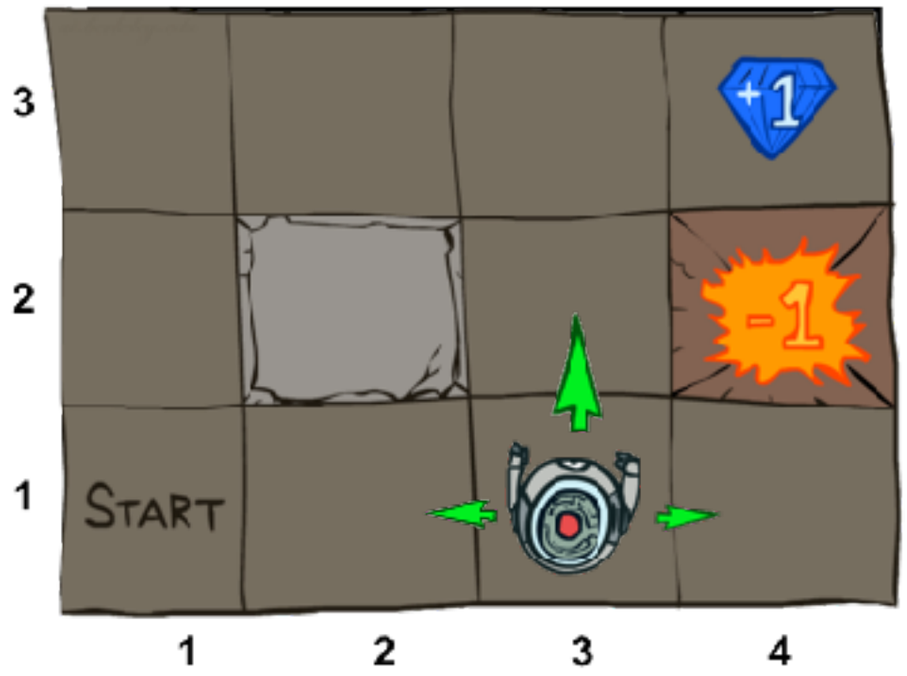
- Learning by trial-and-error, in real-time.
- Improves with experience
- Inspired by psychology – Agent + Environment
  – Agent selects actions to maximise total reward (return)

Example: Grid World

- A maze-like problem
  - The agent lives in a grid
  - Walls block the agent's path
  - States are robot positions

- The agent receives rewards each time step
  - Small "living" reward each step (can be negative)
  - Big rewards come at the end (good or bad)

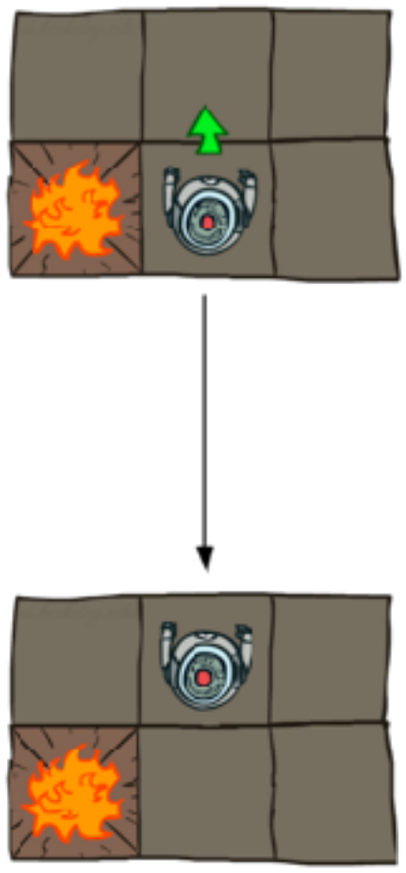
- Goal: maximise sum of rewards



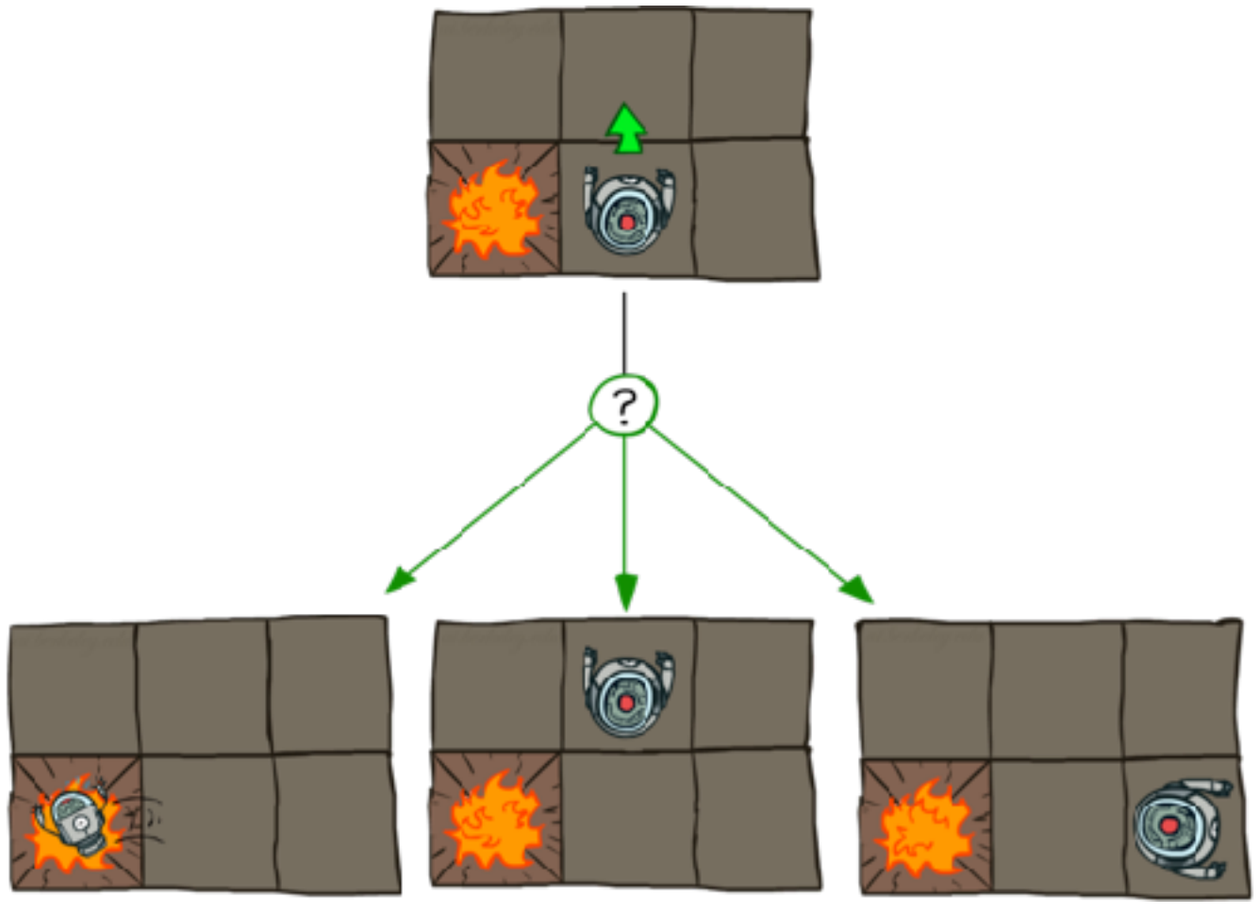
Source: UC Berkeley CS188 Intro to AI

Grid World Actions

Deterministic Grid World



Stochastic Grid World



Source: [UC Berkeley CS188 Intro to AI]

When to use RL?

- Data in the form of trajectories.
- Need to make a sequence of (related) decisions.
- Observe (partial, noisy) feedback to choice of actions.
- Tasks that require both learning and planning.

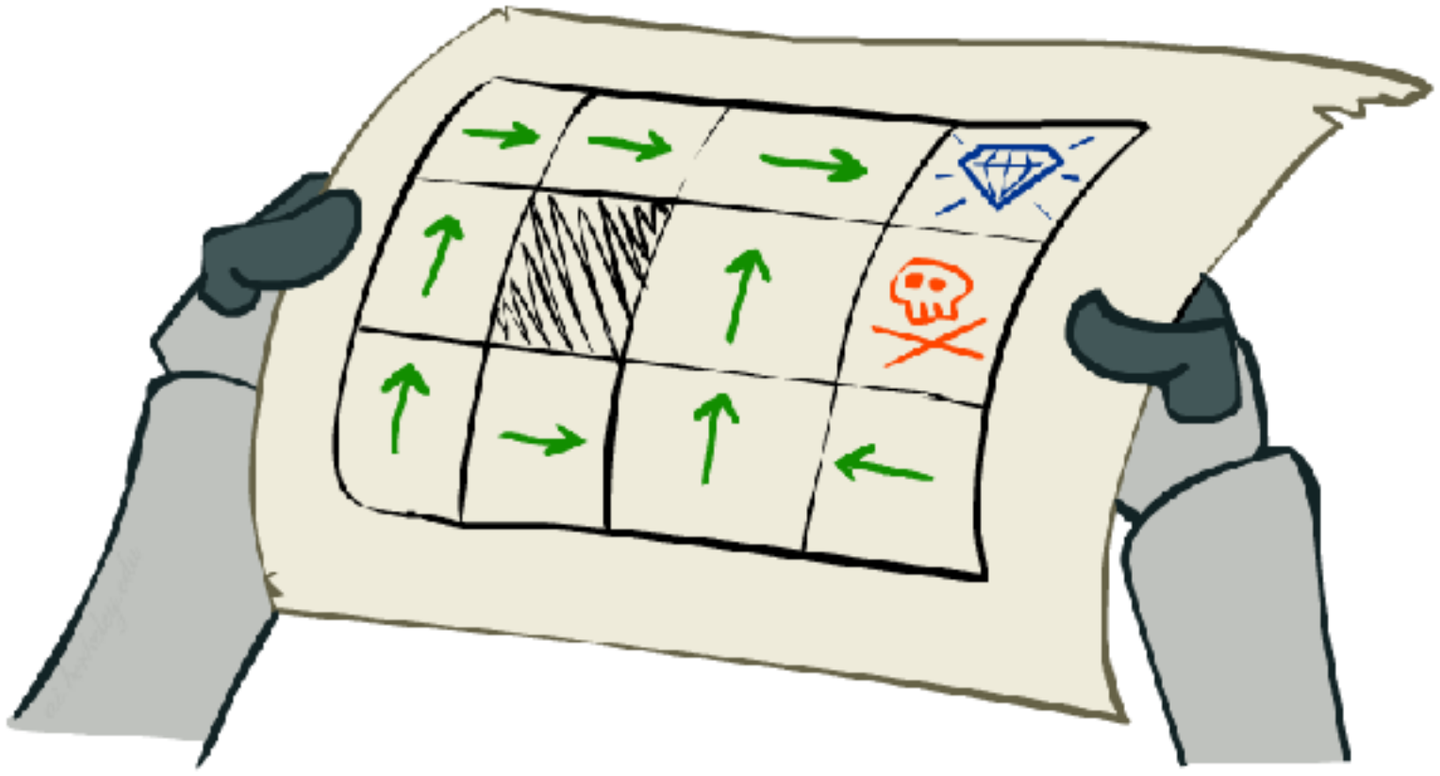
Where is it used?

- Robotics
- Video games
- Conversational systems
- Medical intervention
- Algorithm improvement
- Improvisational theatre
- Autonomous driving
- Prosthetic arm control
- Financial trading
- Query completion

RL applications at RLDM 2017

Policy Iteration

Policy tells agent how it should behave



Expected return

$$G_t \doteq R_{t+1} + R_{t+2} + R_{t+3} + \cdots + R_T,$$

$$G_t \doteq R_{t+1} + \gamma R_{t+2} + \gamma^2 R_{t+3} + \cdots = \sum_{k=0}^{\infty} \gamma^k R_{t+k+1},$$

Discounting

1

Worth Now

γ

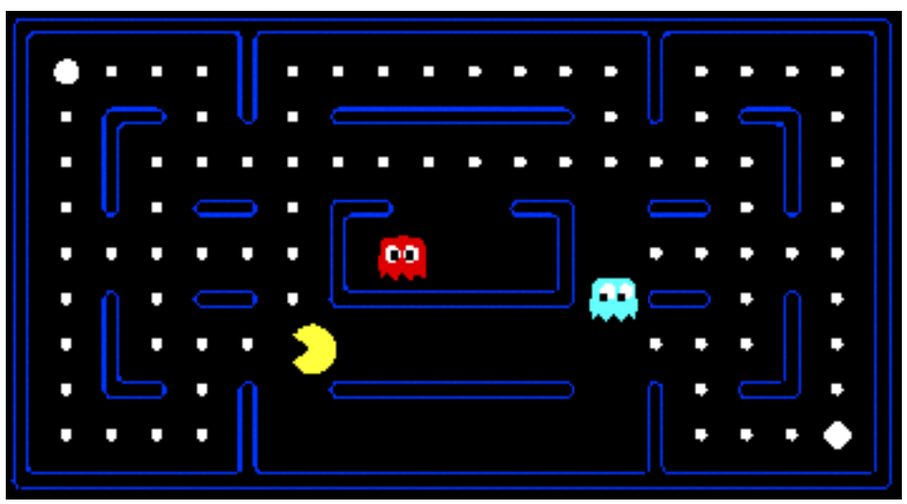
Worth Next Step

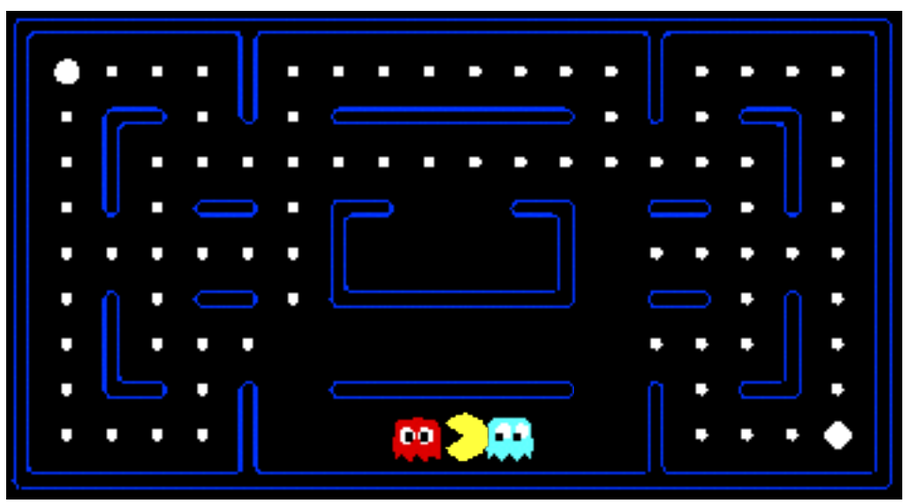
γ^2

Worth In Two Steps

State value

$$
\begin{aligned}
v_\pi(s) &\doteq \mathbb{E}_\pi[G_t \mid S_t = s] \\
&= \mathbb{E}_\pi[R_{t+1} + \gamma G_{t+1} \mid S_t = s] \\
&= \sum_a \pi(a|s) \sum_{s'} \sum_r p(s', r \,|\, s, a) \Big[r + \gamma \mathbb{E}_\pi[G_{t+1} | S_{t+1} = s'] \Big] \\
&= \sum_a \pi(a|s) \sum_{s', r} p(s', r \,|\, s, a) \Big[r + \gamma v_\pi(s') \Big], \quad \text{for all } s \in \mathcal{S},
\end{aligned}
$$



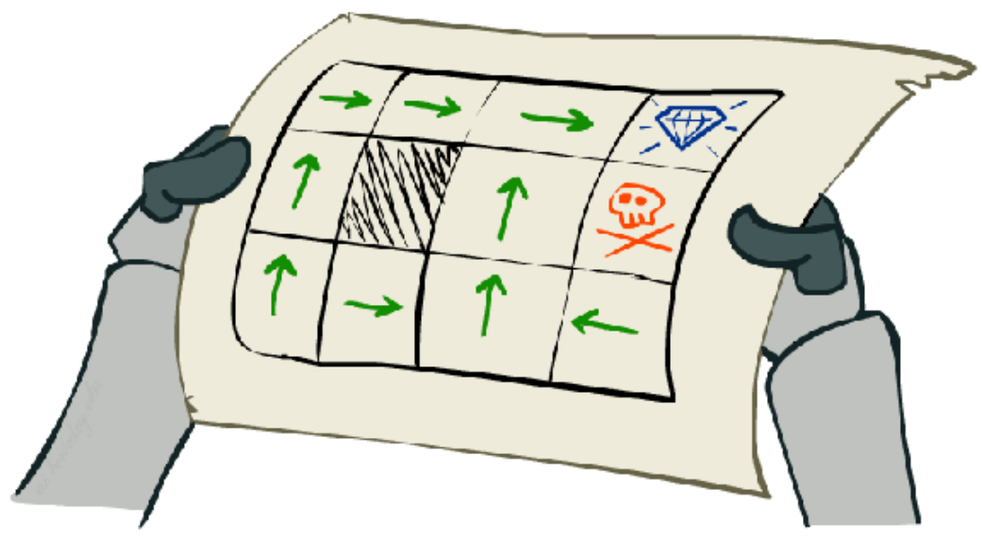


Iterative policy evaluation

$$
\begin{aligned}
v_{k+1}(s) &\doteq \mathbb{E}_\pi[R_{t+1} + \gamma v_k(S_{t+1}) \mid S_t = s] \\
&= \sum_a \pi(a|s) \sum_{s',r} p(s', r \,|\, s, a) \Big[r + \gamma v_k(s') \Big],
\end{aligned}
$$

Policy improvement

$$
\begin{aligned}
\pi'(s) &\doteq \arg\max_a q_\pi(s,a) \\
&= \arg\max_a \mathbb{E}[R_{t+1} + \gamma v_\pi(S_{t+1}) \mid S_t = s, A_t = a] \\
&= \arg\max_a \sum_{s',r} p(s', r \mid s, a)\Big[r + \gamma v_\pi(s')\Big],
\end{aligned}
$$



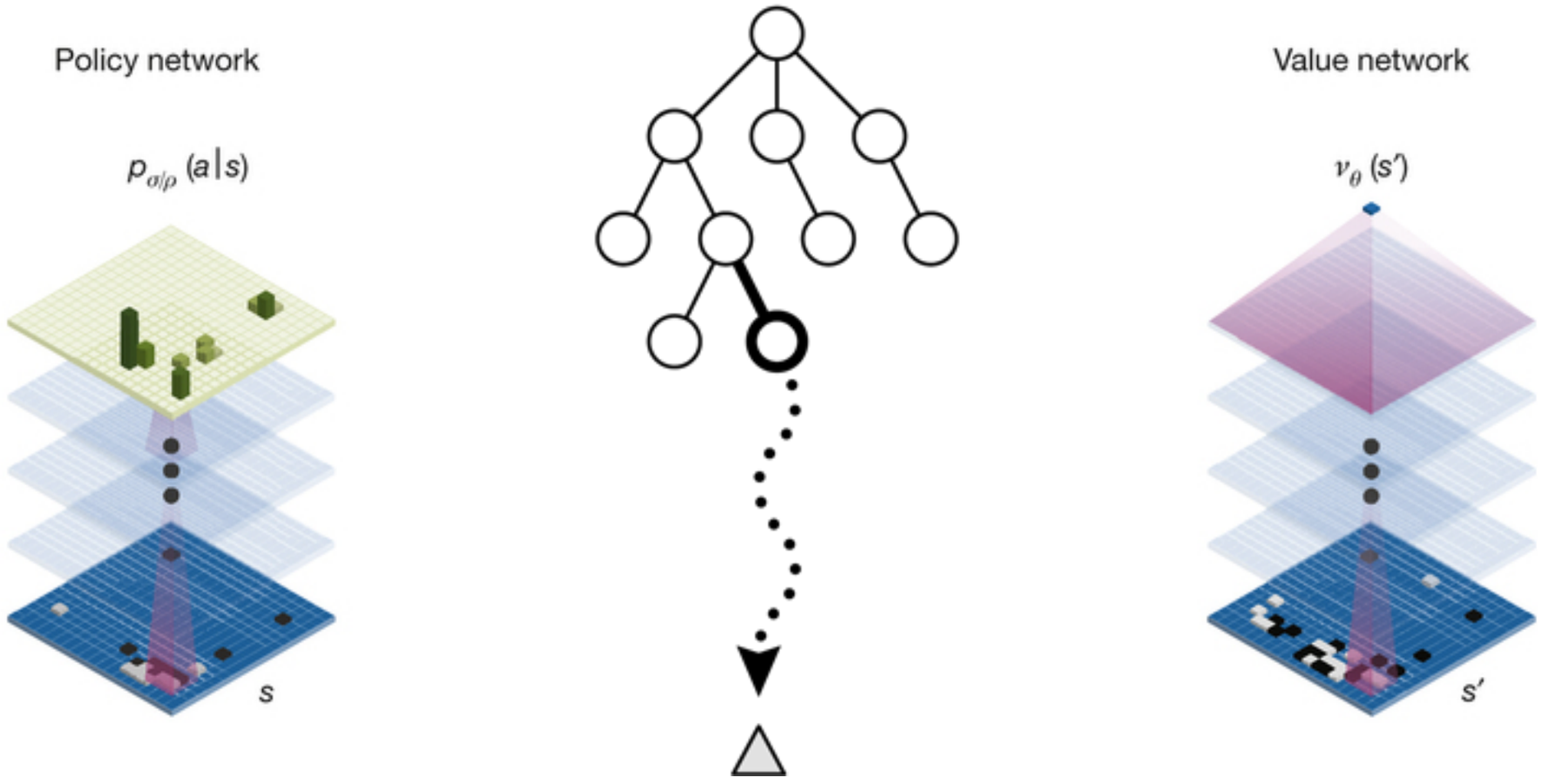
How to connect the dots?

Lets see in practice!

goo.gl/BxFggi

Planning and learning

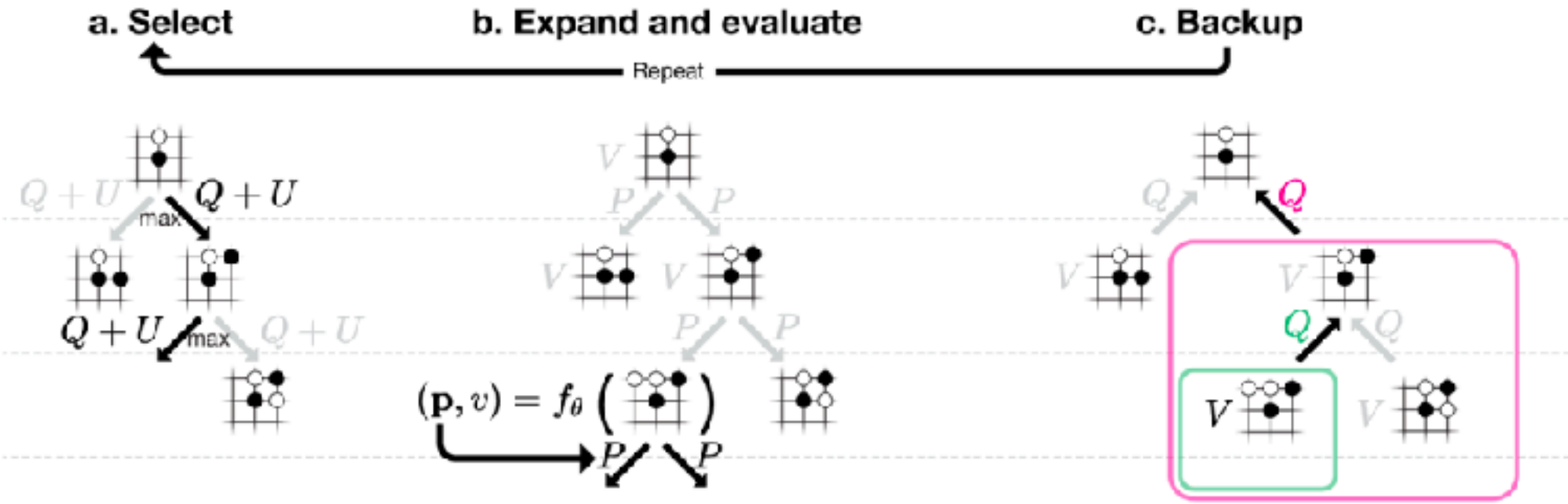
Guided Tree Search



Requirements on problem kinds

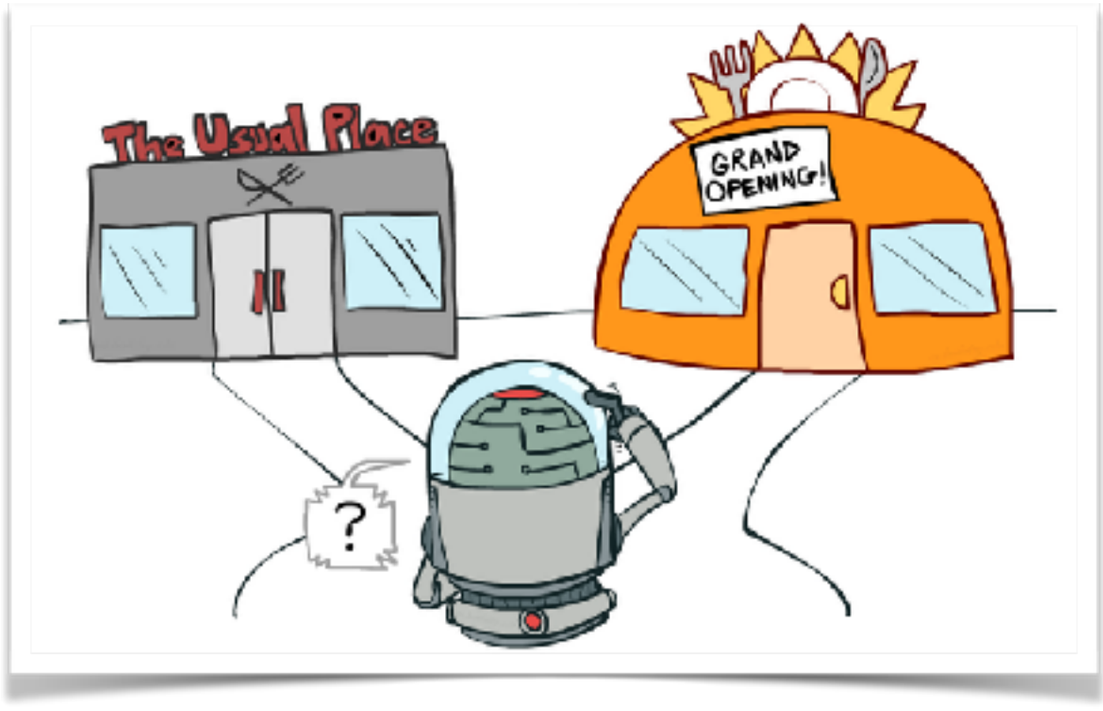
- discrete - states and actions sets form a discontinuous sequences, put simply they are discrete.
- deterministic - every move has one possible outcome.
- with perfect information - both players have perfect knowledge about current game state.
- access to game rules - there need to be some sort of environment simulator.

AlphaZero Tree Search



This algorithm meets anytime property. Estimates gets better and better with each simulation and we can cut calculations any time we have to.

Exploration-exploitation



ε-greedy downside is it chooses action completely at random while exploring, so it can also choose action that we know for sure is bad.

Upper Confidence Tree

$$U_i = \frac{W_i}{N_i} + c\sqrt{\frac{\ln N_p}{N_i}}$$

We choose action that maximises U_i (UCT value of particular action)

Efficiency Through Expert Policies

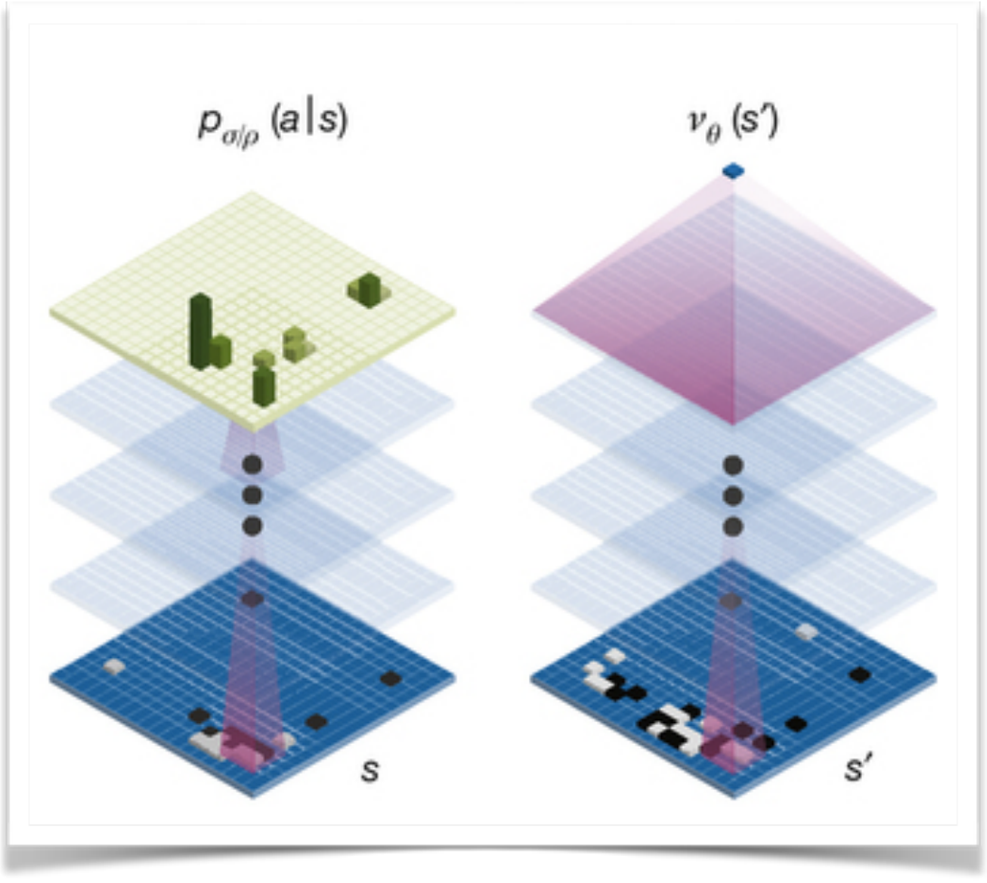
Games like chess ♛ and Go ⚪ have very (in Go I mean VERY) large branching factor and number of legal positions.

It would be nice to have some expert policy, that would tell us which moves are good and which are bad. So we can focus on exploring only those promising moves.

Any ideas how to obtain expert policy?

$$U(s,a) = Q(s,a) + c_{puct} \cdot P(s,a) \cdot \frac{\sqrt{\Sigma_b N(s,b)}}{1 + N(s,a)}$$

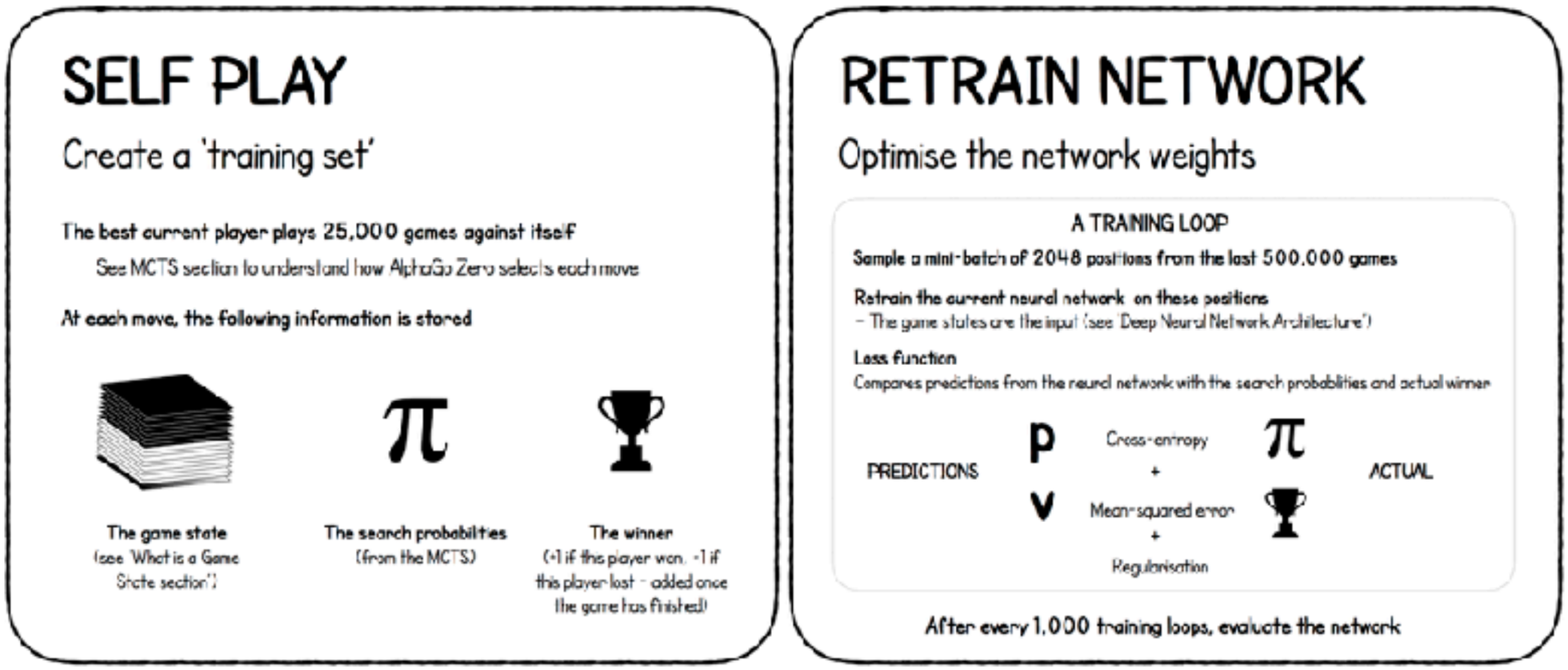
AlphaZero Neural Net



How to model those two?

Deep Learning for rescue!

Train through Policy Iteration



<u>Full infographic</u> in references, highly recommend to give a look

Case Study 

Sources and Good Reads

- A Simple Alpha(Go) Zero Tutorial by Surag Nair
- **AlphaGo Zero cheatsheet by David Foster**
- **AlphaGo Zero - How and Why it Works by Tim Wheeler**
- Deep Reinforcement Learning: Pong from Pixels by Andrej Karpathy
- UC Berkeley AI course
- Mastering the game of Go with deep neural networks and tree search by David Silver et al.
- Mastering the game of Go without Human Knowledge by David Silver et al.
- The Multi-Armed Bandit Problem and Its Solutions by Lilian Weng
- Deep Learning and Reinforcement Learning Summer School, Montreal 2017
- Reinforcement Learning: An Introduction 2nd edition
- **AlphaGo movie on Netflix** 📽️

Thank you 😊

A word about promised open-sourced AlphaZero implementation

I know I told you, that you will have a chance to play with my team's implementation of AlphaZero, but I don't want to open source it YET! There is couple of thinks missing, like tools to represent training logs graphically, some things from paper that aren't implemented yet and no good documentation (at least good README). When we will finish with those things (in about two weeks to one month) you can expect it on my GitHub account, here: https://github.com/piojanu.

Thanks for you attention and I hope to see you in the future at other events! :)