Artificial Intelligence:

Facebook loses to Google in race to solve the ancient game of Go

ARTICLE

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Mastering the game of Go with deep neural networks and tree search

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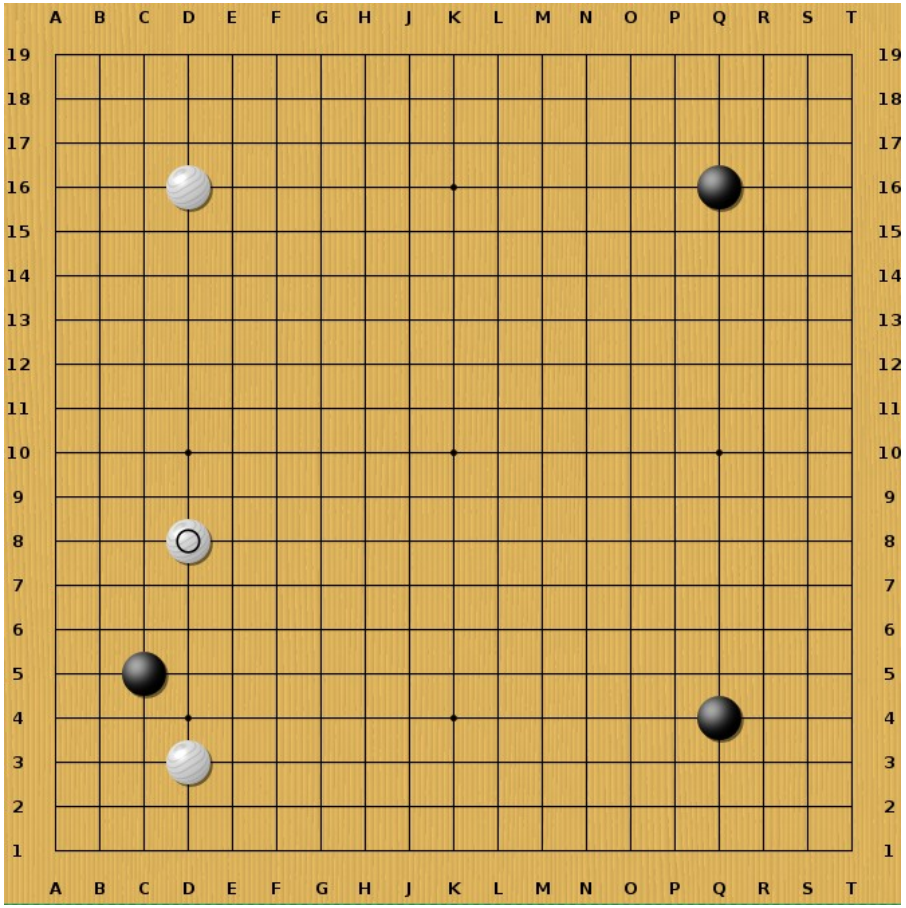
Game of Go

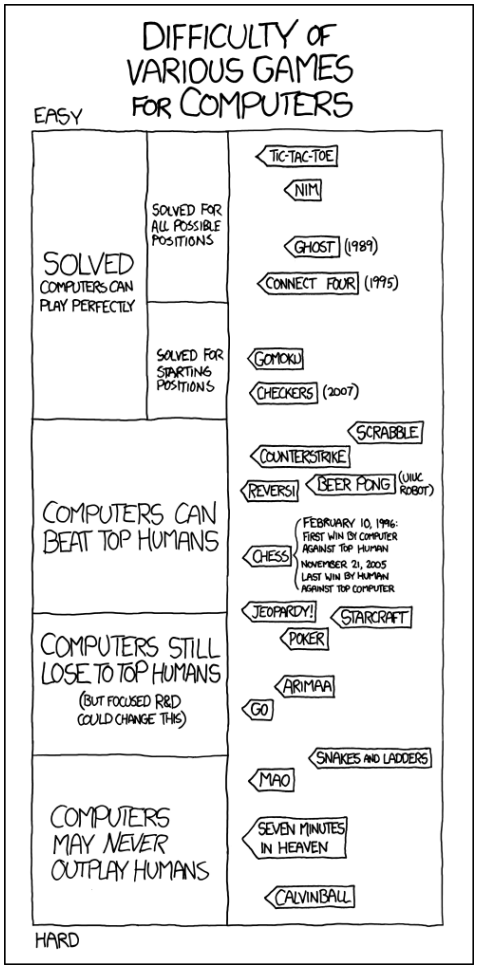
- Ancient game ~4,000 years (1st written evidence 700 bc.)
- Played on 19x19 board
- Board is empty, black & white play alternately
- Stones don't move
- Capture & suicide rules

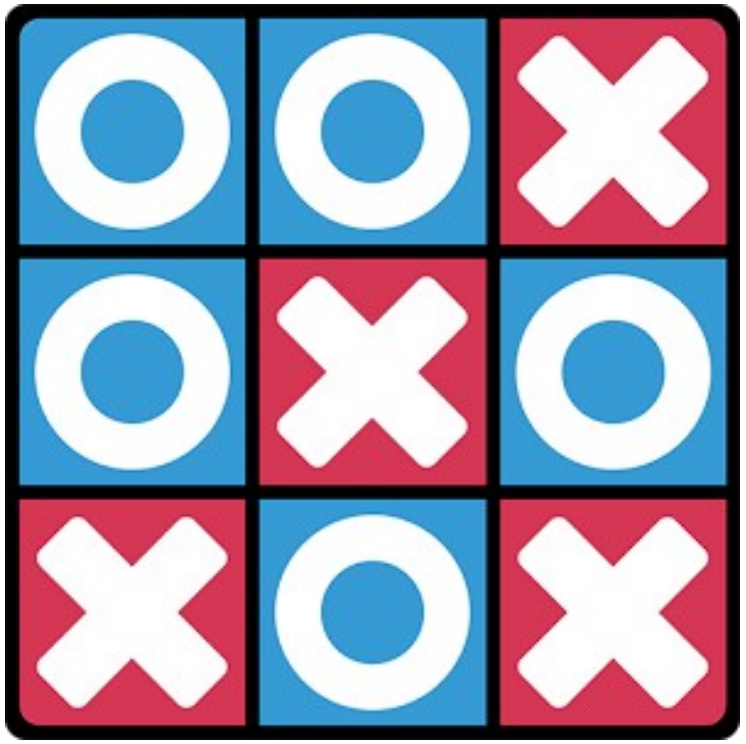


Combinatorial game theory & complexity

Game	Game depth	Game branch.	All positions	All games	Solved
Tic-Tac-Toe	9	5	2.10^4	10^{11}	y
Checkers	...	1-8	5.10^{20}	10^{40}	y
Chess	~80	~35	10^{50}	10^{120}	n
Go	~250	~150	10^{170}	10^{600}	n

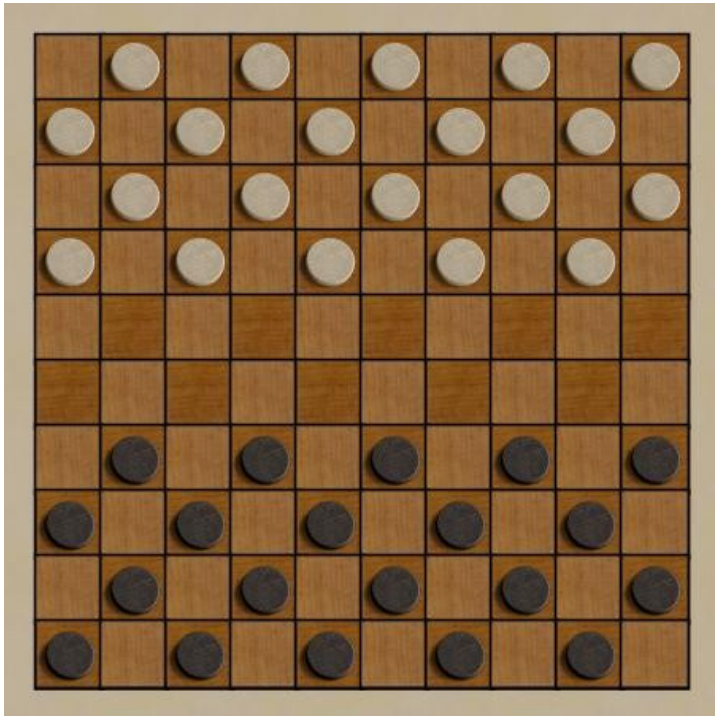
- Atoms in human body: ~10^{27}
- Bacteria on Earth: ~10^{30}
- Atoms in universe: ~10^{80}





100 000 000 000

Tic Tac Toe



Checkers

10 000 000 000 000 000 000 000 000 000 000 000 000 000

Chess

1 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000

Go

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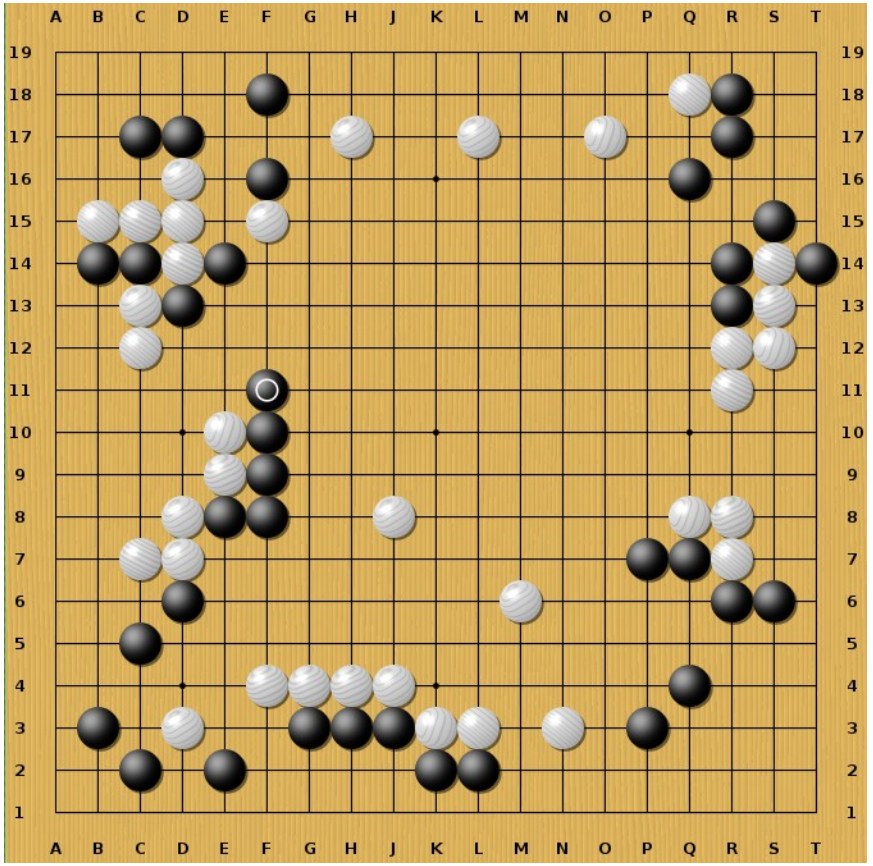
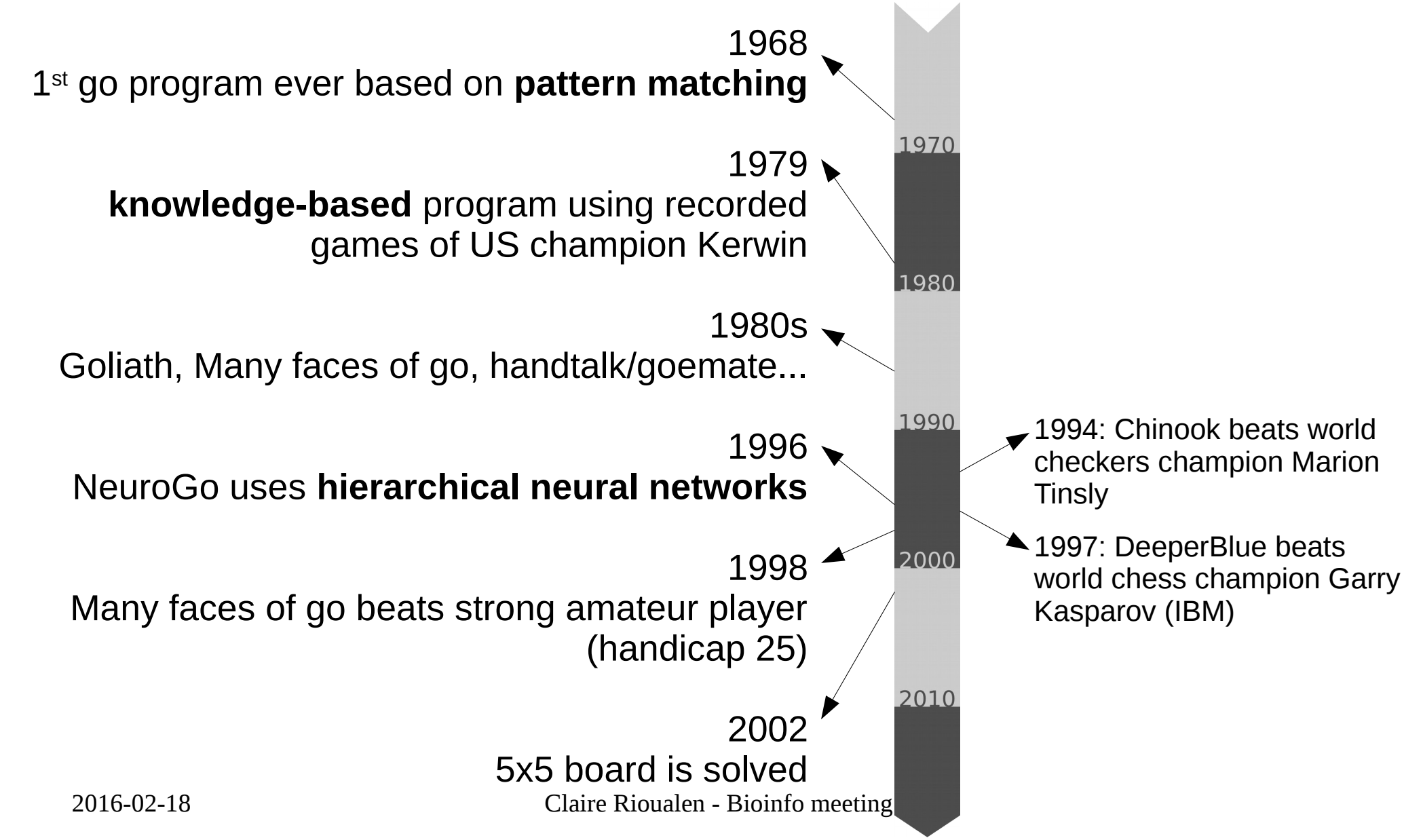
Challenges in mastering the game of Go

- Combinatorial complexity
- Estimating a position
- Local and global dimensions
- Several good moves
- Complexity raises
- Human dimension: traps, emotions, aesthetics, creativity, trends, trade, intuition...



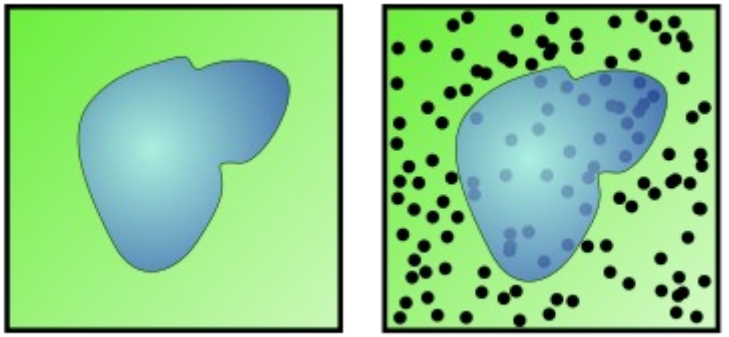
Infancy: knowledge-based algorithms



Monte-Carlo Tree Search revolution

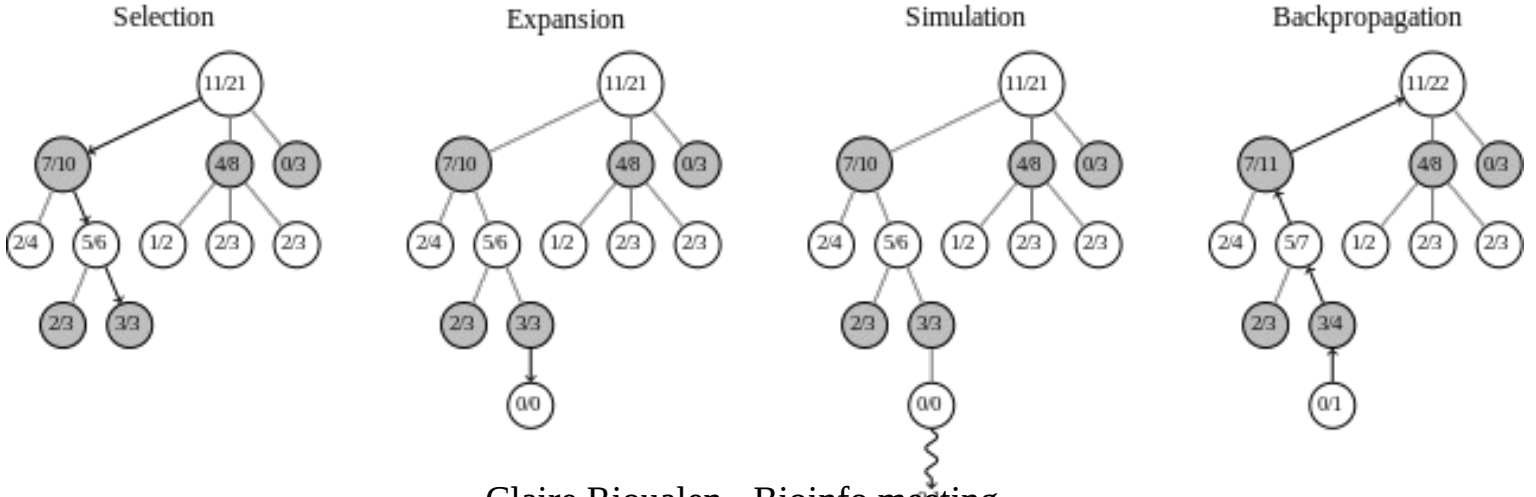
Monte-Carlo method:

- unsupervised learning
- generate many rollouts
- estimate output

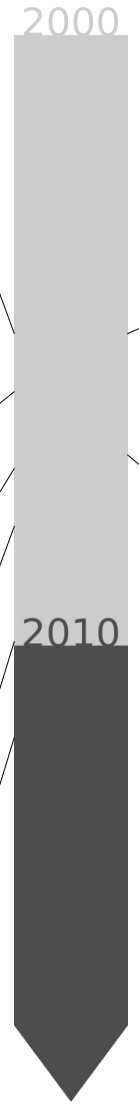


Tree Search:

- play out all possibilites
- observe outcome
- estimate best move



Monte-Carlo Tree Search revolution



2005

- Rémi Coulom & Bruno Bouzy: how about replacing exhaustive search with statistics sampling of fewer possibilities?
- CrazyStone uses MCTS + UCT (upper confidence bounds applied to trees)
- Wins bot tournament

2005: Ruslan Ponomariov is the last human to beat a computer at chess

2006

- Mogo is refined, beats strong amateur player on small (9x9) boards

2007: Checkers solved

2007

- Mogo starts winning against pro players on small boards (9x9)

2008

- Many faces of go is World computer go champion

2009 to 2013

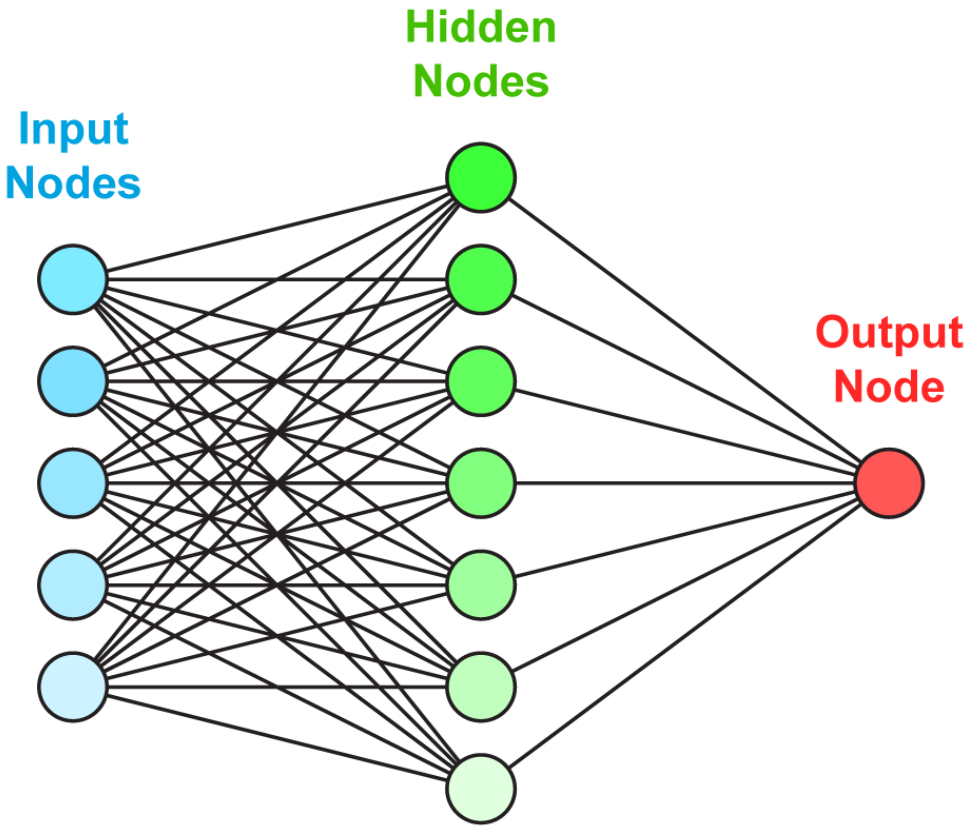
- Zen and CrazyStone fight for the top

2012

- Zen beats Takemiya Masaki (handicap of 5 stones)

The advent of deep learning methods

- **Neural networks**
  - popular until the 80s
  - too few available data
  - unsufficient computer power



- Advent in **deep learning** renewed interest in NN around the end of the 90s

The advent of deep learning methods

- **Deep convolutional neural networks** are at the core of voice recognition or image recognition programs
- Multinationals start being interested around the 2010s:

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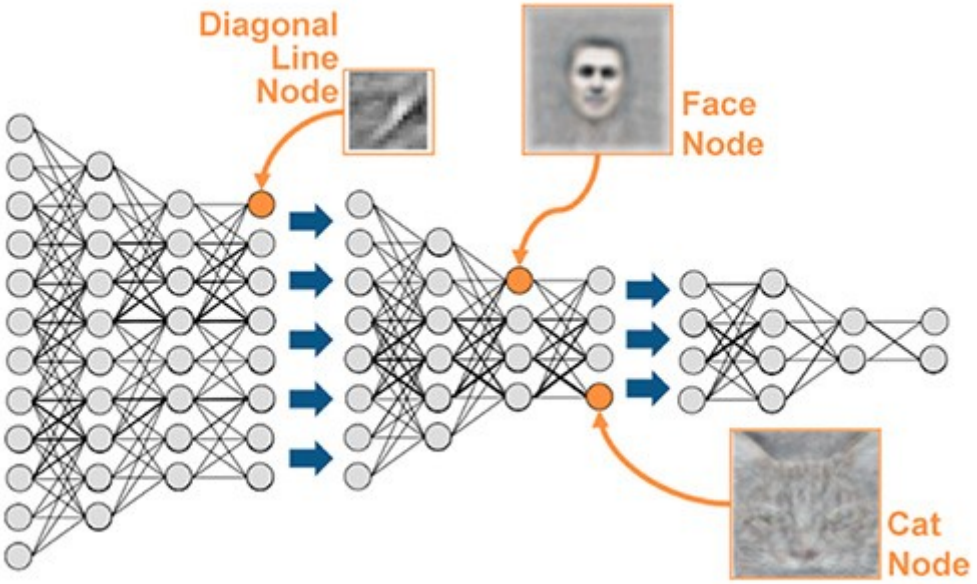
  - Apple's Siri assistant, **voice recognition**
  - Google Brain: a program can recognize a cat on a picture without prior knowledge, using unsupervised layered method



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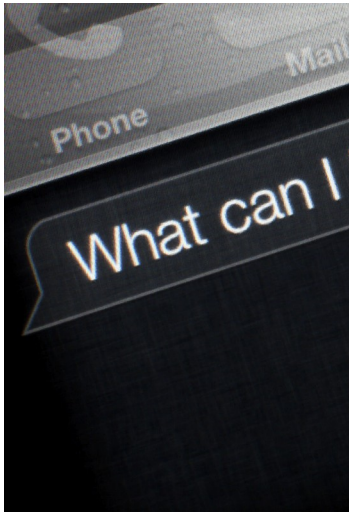
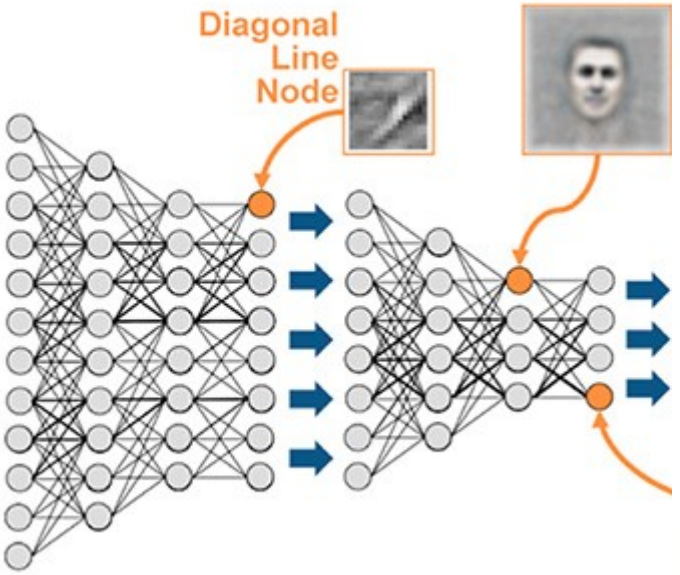
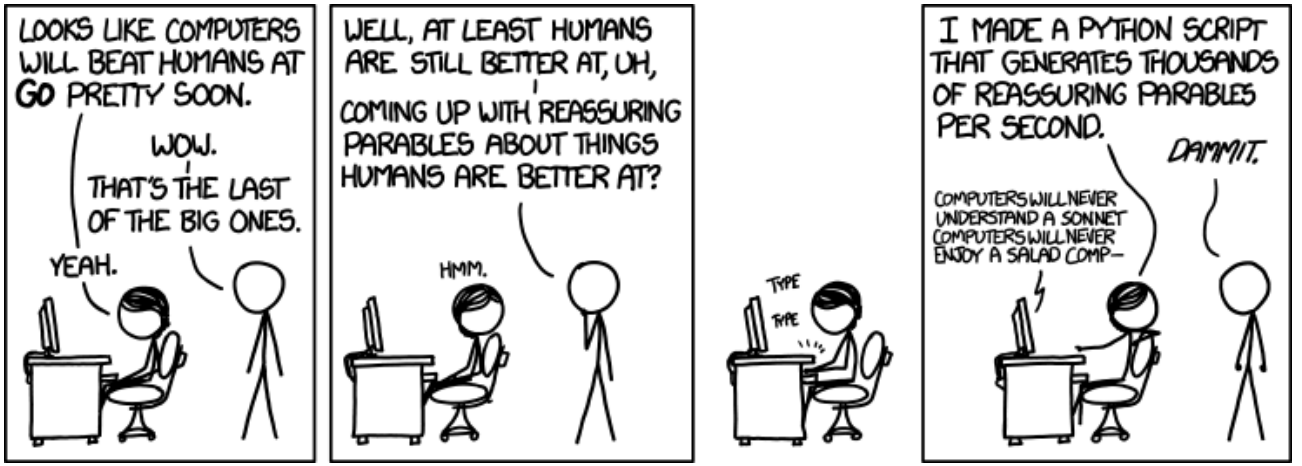
  - Apple's Siri assistant, **voice recognition**
  - Google Brain: a program can recognize a cat on a picture without prior knowledge, using a supervised layered method
  - Facebook & Google experiment **face recognition**...





The advent of deep learning methods

May 2014:
CrazyStone beats Yoda Norimoto
with 4 stones of handicap



Facebook enters the race

- Jun 2015: creation of the Facebook Artificial Intelligence Research center in Paris
- Hirement of Yann LeCun, expert in deep learning

BETTER COMPUTER GO PLAYER WITH NEURAL NETWORK AND LONG-TERM PREDICTION

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Yan Zhu
Rutgers University
Facebook AI Research
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- Nov 2015: publication of Darkforest, an AI that outperforms previous programs
- Uses **MCTS** + **deep learning** with **pattern recognition**
- The point is to mimic **human intuition**

Google makes an announcement in reaction...

Facebook gets feverish...

- 26 Jan 2016: publication is updated

Facebook gets feverish...

- 26 Jan 2016: publication is updated
- 27 Jan 2016, 7am: Yann LeCun posts a long message on Facebook about the paper's update

Yann LeCun Follow

January 27 at 7:50am ·

Today, we posted on arXiv.org a new version of Yuandong Tian's paper on deep learning methods applied to the game of Go: http://arxiv.org/abs/1511.06410 "Better Computer Go Player with Neural Network and Long-term Prediction" by Yuandong Tian and Yan Zhu.

The lone FAIR research scientist working on this project, Yuandong just started pursuing Go a few months ago and is working on a bot called DarkForest. The latest version described in this paper uses a combination of convolutional networks (ConvNet) and a now-classical method for computer Go called Monte Carlo Tree Search (MCTS).

Why are we working on computer Go? It is a nice example of difficult problem that requires a combination of learned skill, pattern recognition, problem solving, and planning. It's a very good vehicle to test new ideas that combine machine learning, reasoning, and planning. Our findings show that a combination of trained ConvNets and MCTS could be used to add tactical evaluation to pattern matching. This could benefit other applications outside of games like natural language generation too, adding spontaneity and variety to responses, as well as reasoning, which requires searching possible answers and picking the best logic chain. We are not particularly interested in producing the world's best Go player, but it's an interesting exercise to see how far we can get.

Since November, several versions of DarkForest have been playing against humans and other Go bots on the public Go server KGS (http://www.gokgs.com/ (https://www.gokgs.com/)). The first version of

Facebook gets feverish...

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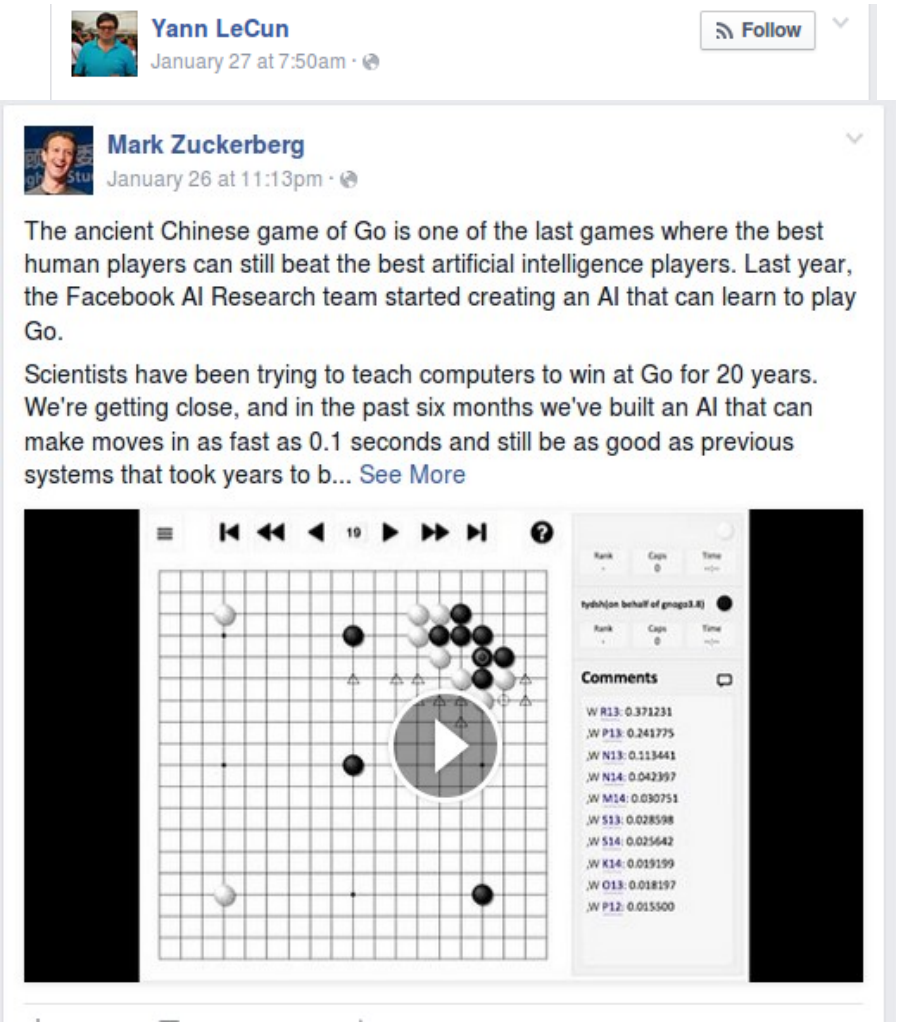
- 27 Jan 2016, 8am: Mark Zuckerberg posts about his interest in the game of Go



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- 27 Jan 2016, 8am: Mark Zuckerberg posts about his interest in the game of Go
- 27 Jan 2016, 5pm: Mark Zuckerberg talks at lengths about his interest in AI

Yann LeCun
January 27 at 7:50am ·
Follow

Mark Zuckerberg
January 26 at 11:13pm ·

Mark Zuckerberg building AI.
January 27 at 5:37pm ·
Follow

My personal challenge for 2016 is to build a simple AI -- like Jarvis from Iron Man -- to help run my home and help me with work.

I'm planning on writing up some thoughts every month on what I've built and what I'm learning. I'm still early in coding, so I'll start this month with a summary of the state of the AI field.

Artificial intelligence may seem like something out of science fiction, but most of us already use tools and services every day that rely on AI. When you do a voice search on your phone, put a check into an ATM, or use a fitness tracker to count your steps, you're using basic forms of pattern recognition and artificial intelligence. More sophisticated AI systems can already diagnose diseases, drive cars and search the skies for planets better than people. This is why AI is such an exciting field -- it opens up so many new possibilities for enhancing humanity's capabilities.

So what can AI do and what are its limits? What things is AI good at and what is AI bad at?

Simply put, today's AI is good at recognizing patterns and bad at what we would call "common sense".

The primary method used to train AI systems is called supervised learning. This is like when you show a picture book to a child and tell them the names of everything they see. If you show an AI thousands of pictures of dogs, you can train it to start recognizing dogs.

You can teach AIs to do a lot of things this way. For example, we can teach an AI to recognize all of your friends' faces by showing it thousands

...and Google wins the battle!

Jan 27th, 7 pm

Google makes a huge announcement:

The program AlphaGo, developed by Google's DeepMind company, has beaten European champion Fan Hui in a 5-0 series in October

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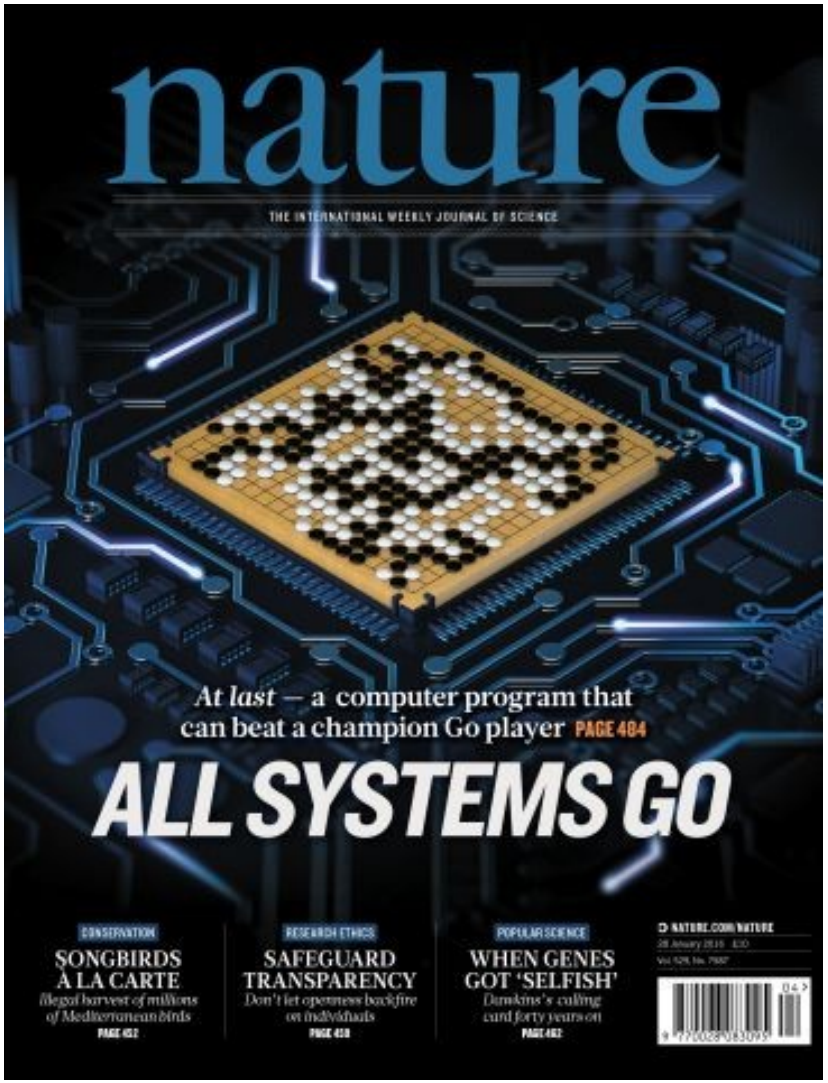
Jan 28th

Publication in Nature



AlphaGo

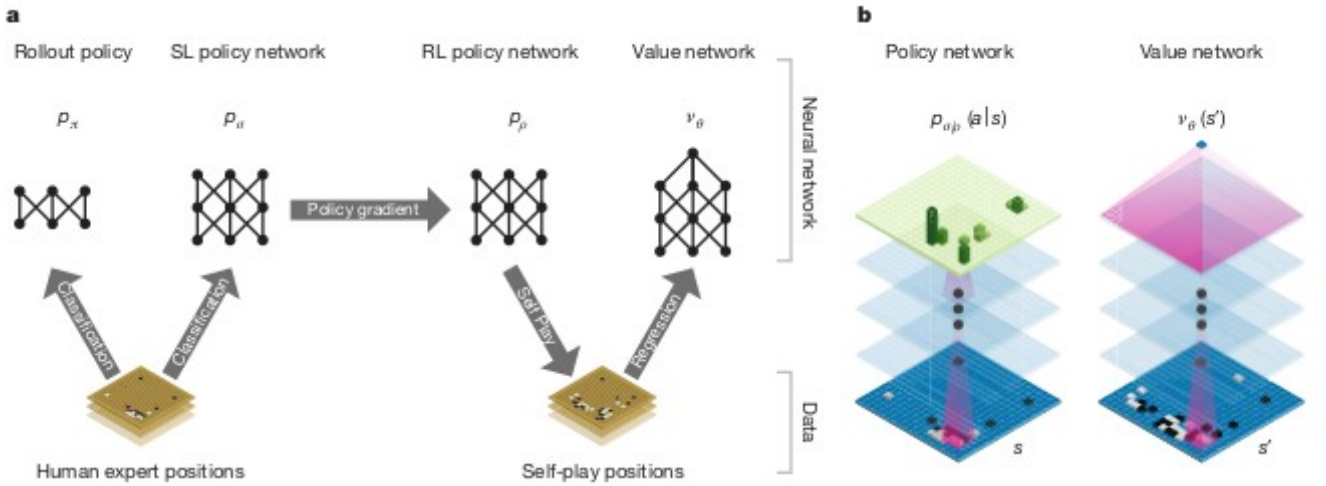
- Exhaustive search being impossible, the search space has to be reduced:
  - Depth reduced by position evaluation with a value function $v(s) \sim v^*(s)$
  - Breadth reduced by sampling actions from a policy $p(a|s)$

→ Previous MCTS algorithms work on these principles

AlphaGo applies these principles on a whole new level...

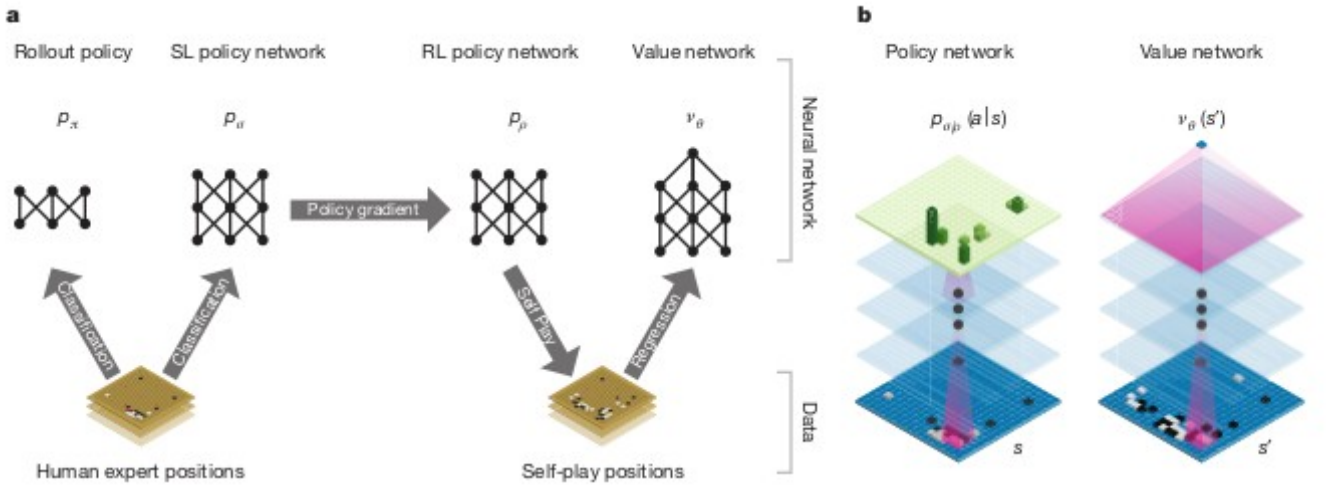
- Deep convolutional networks are used to model positions
- These networks are used to reduce depth and breadth
- Achieved 99.8% winning rate against previous programs
- Final version uses 40 threads, 48CPUs, 8GPUs

AlphaGo



1. Rapidly sample actions in rollouts → fast policy p_π
2. 30M positions from human experts → Supervised Learning (SL) policy network p_σ
3. Improve SL → Reinforcement Learning (RL) policy network p_ρ
4. Predict the winner of RL games → value network v_θ

AlphaGo



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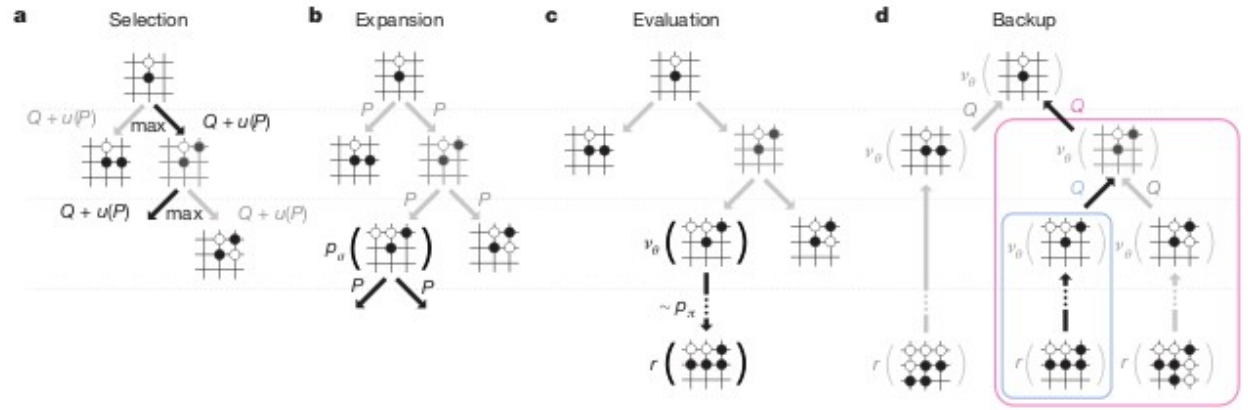

The search tree stores:

- Action value $Q(s,a)$
- Prior probability $P(s,a)$
- Visit count $N(s,a)$

5. AlphaGo combines policy & value networks with MCTS

A historical breakthrough?

- On March 9-15, a series of matches is scheduled between World's top player Lee Sedol
- $1,000,000 USD prize
- AlphaGo is still improving by training
- Unlike a human, a computer can play thousands of games a day...

Deep learning & biology

Predicting the sequence specificities of DNA- and RNA-binding proteins by deep learning

Babak Alipanahi[1,2,6], Andrew Delong[1,6], Matthew T Weirauch[3–5] & Brendan J Frey[1–3]

Aug 2015, Computational Biology

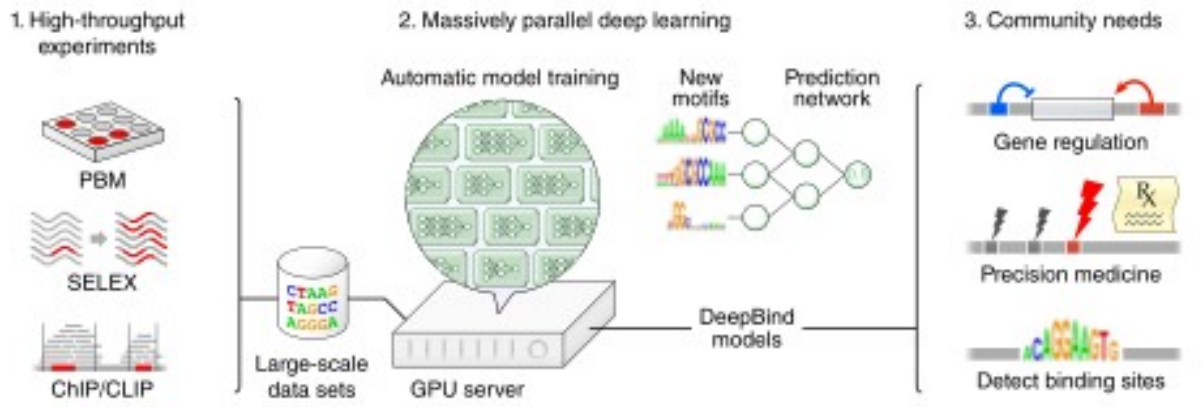

Figure 1 DeepBind's input data, training procedure and applications. 1. The sequence specificities of DNA- and RNA-binding proteins can now be measured by several types of high-throughput assay, including PBM, SELEX, and ChIP- and CLIP-seq techniques. 2. DeepBind captures these binding specificities from raw sequence data by jointly discovering new sequence motifs along with rules for combining them into a predictive binding score. Graphics processing units (GPUs) are used to automatically train high-quality models, with expert tuning allowed but not required. 3. The resulting DeepBind models can then be used to identify binding sites in test sequences and to score the effects of novel mutations.

The final word...

Yann LeCun

“This is not a competition. It's a quest for human knowledge. Everyone wins when progress is made by anyone who is willing to share knowledge. Science progresses when researchers exchange ideas and results, and build on top of each other's work.”