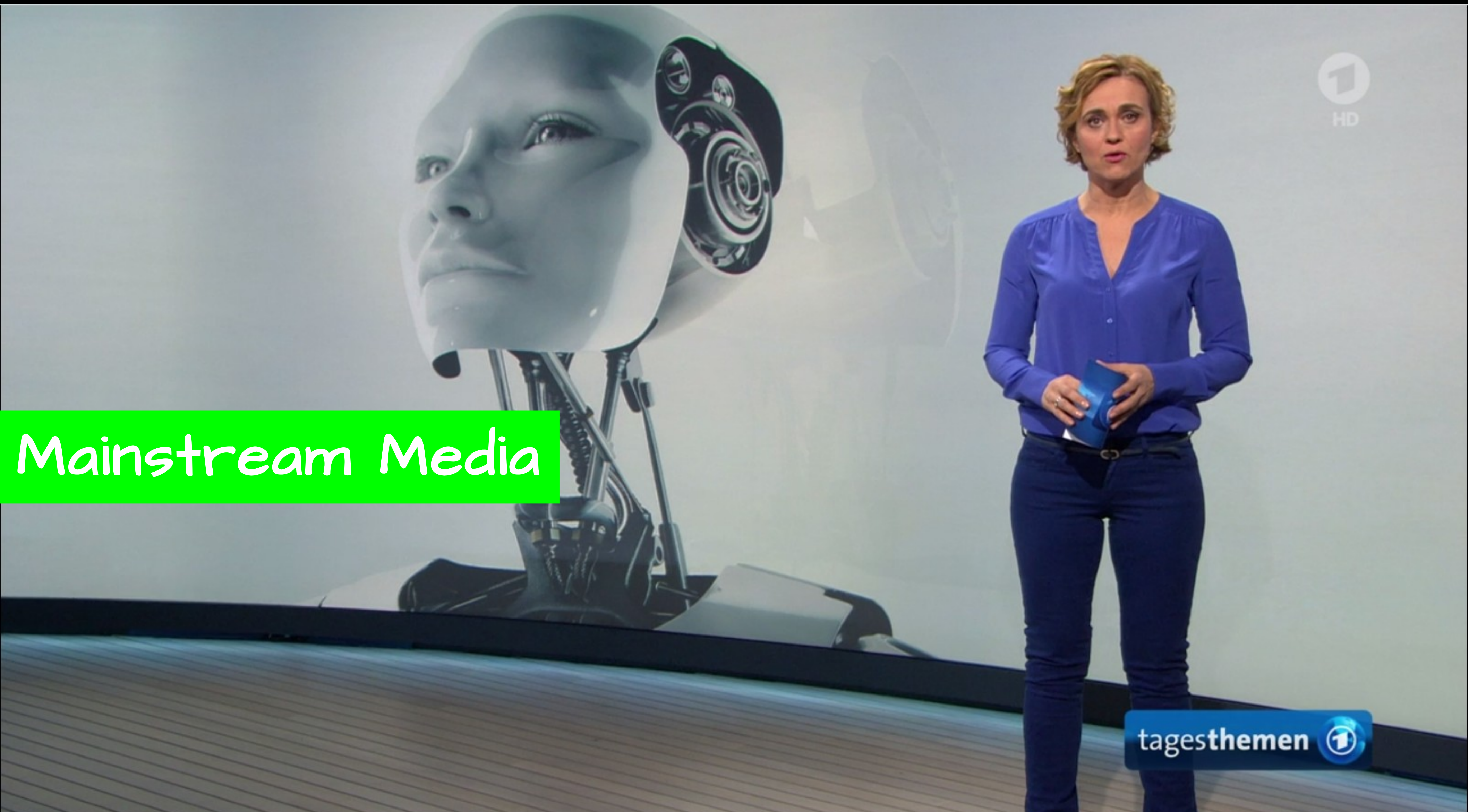
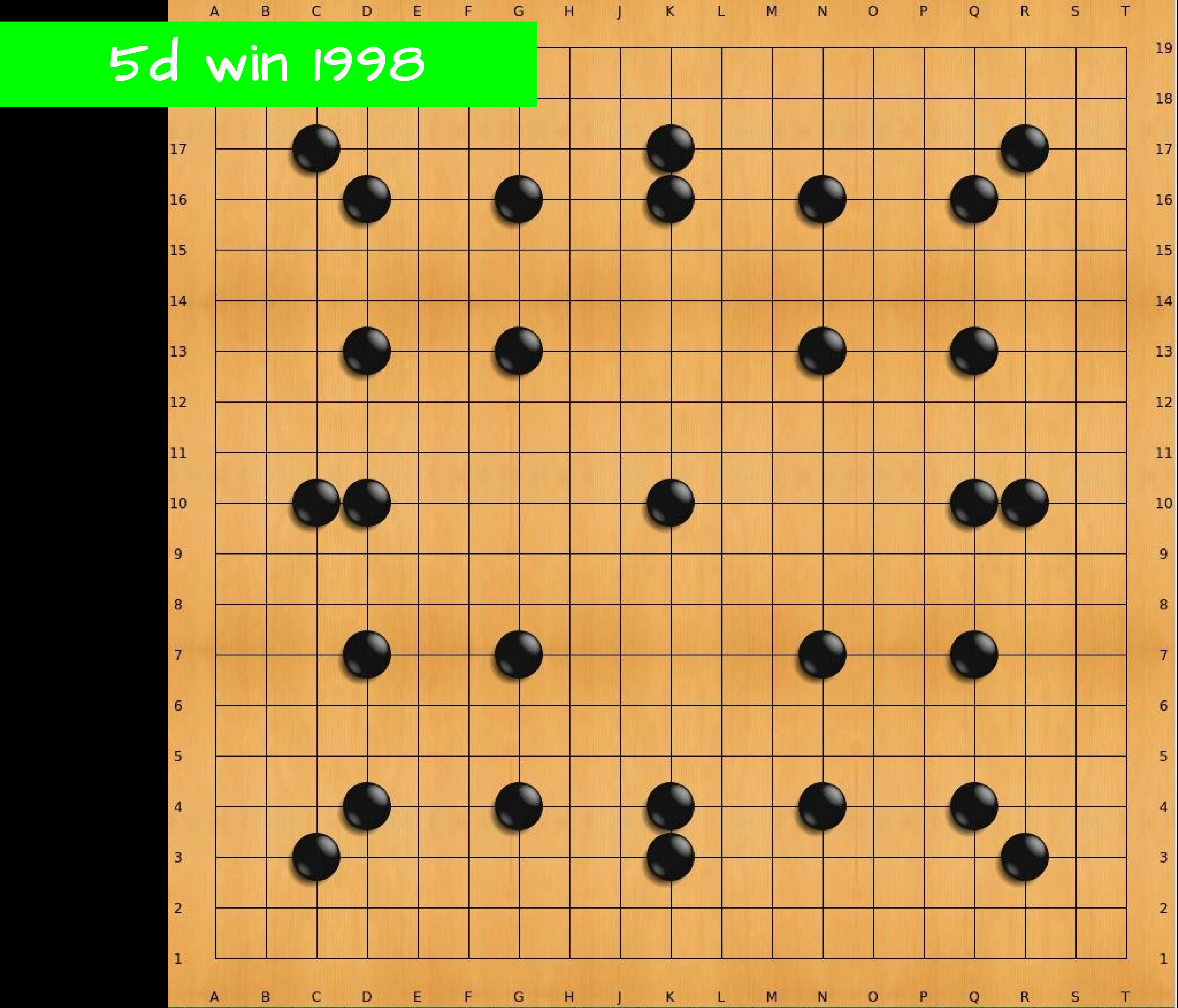

March 2016
LEE SEDOL
02:00:00
AlphaGo
Lee Sedol


Mainstream Media
HD
tagesthemen

1997


ING
`2000 "應氏杯" 世界電腦圍棋錦標賽
`2000 ING CUP WORLD COMPUTER GOE CHAMPIONSHIP
主辦: 應昌期圍棋教育基金會
承辦: 貴陽市棋類協會
貴陽應氏圍棋活動中心
(1985-2000)
1
3
THREE
联想
LEGEND


5d win 1998

October 2015

January 2016

This is the first time that a computer program has defeated a human professional player in the full-sized game of Go, a feat previously thought to be at least a decade away.

Silver, D. et al., 2016. Mastering the game of Go with deep neural networks and tree search. Nature, 529(7587), p.484-489.

What did AlphaGo do to beat the strongest human Go player?

Tobias Pfeiffer

@PragTob

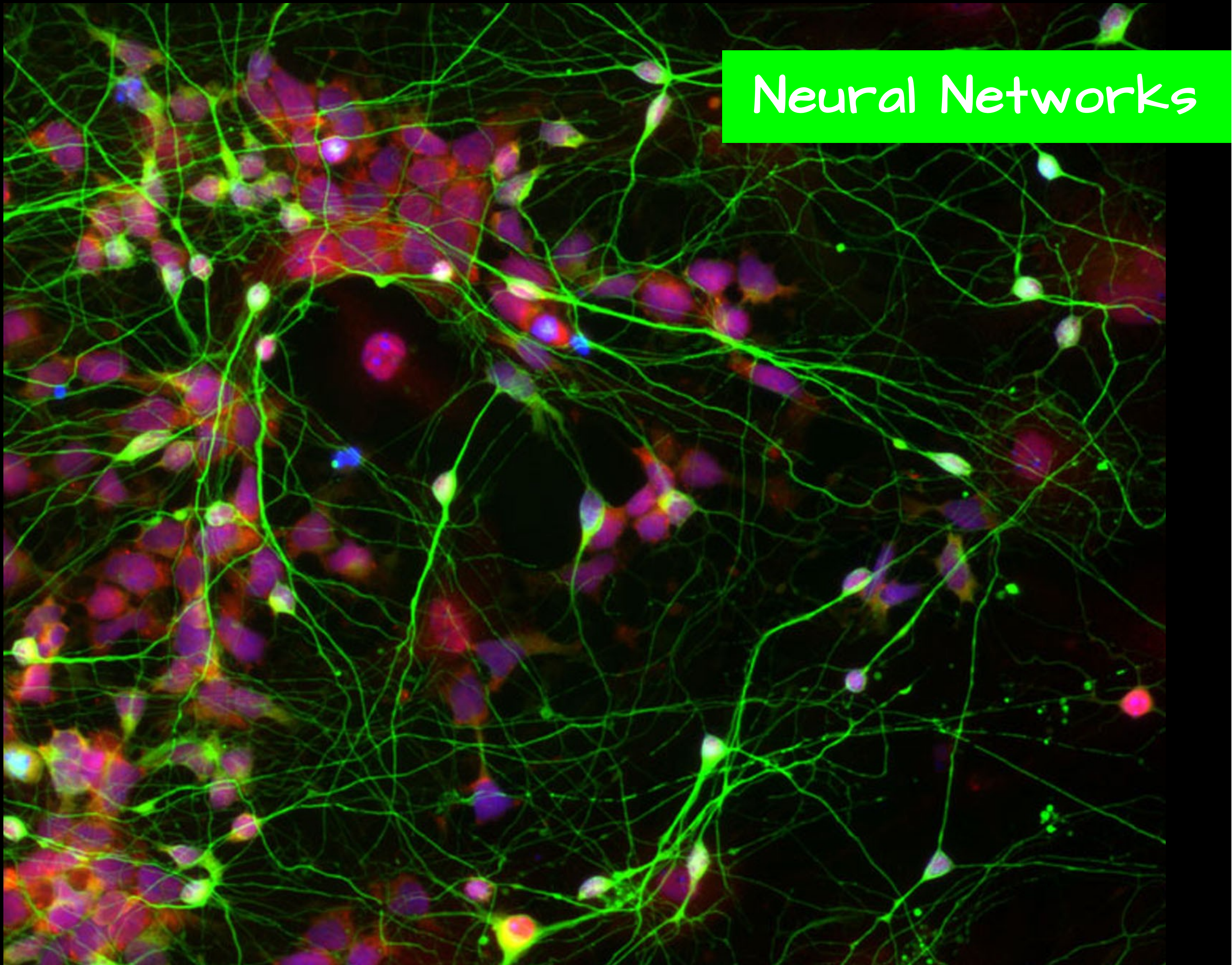
pragtob.info

bitcrowd

Go


Computational Challenge


Monte Carlo Method

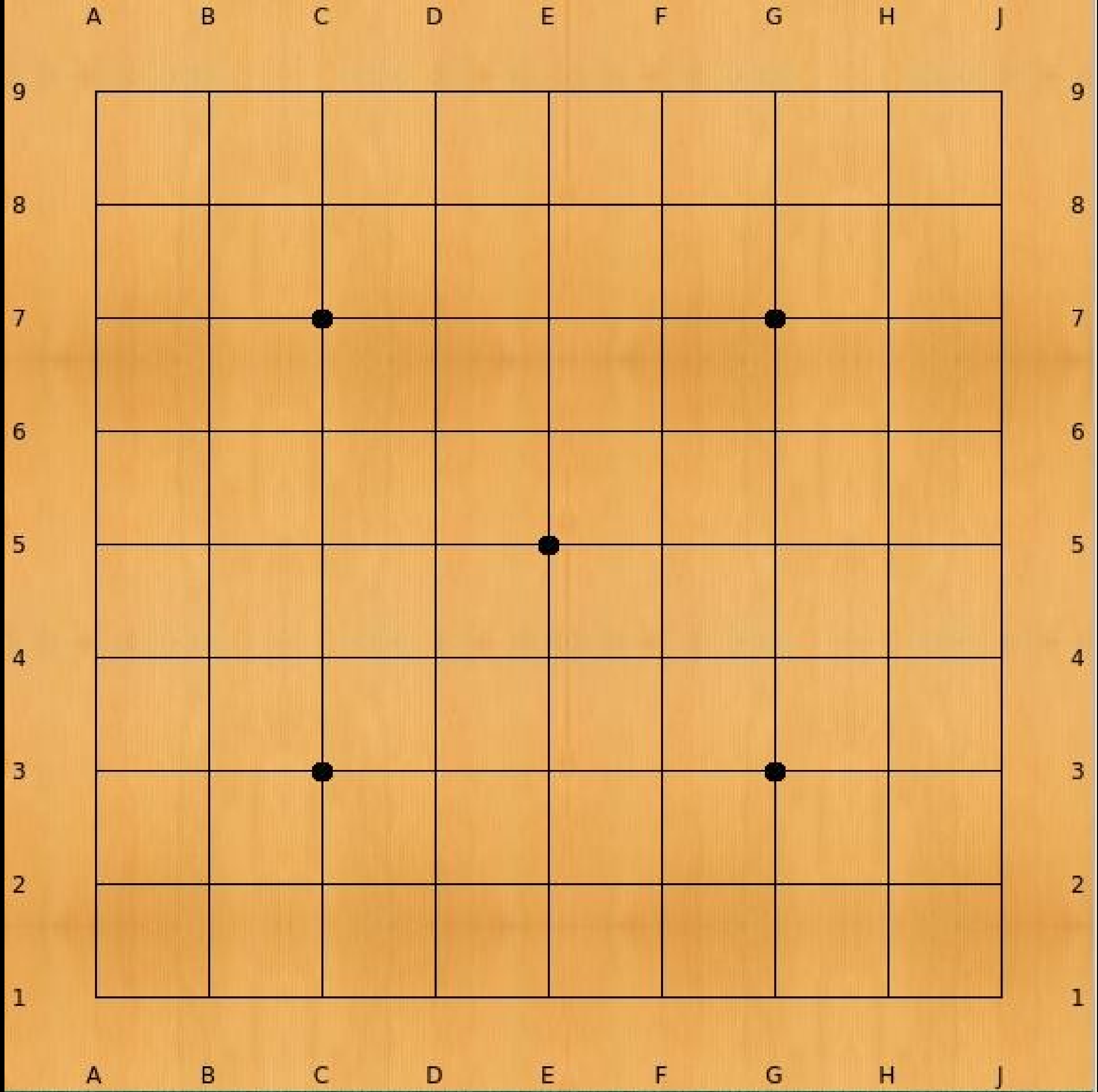

Neural Networks

Revolution with Neural Networks

AlphaGo

What did we learn?

Go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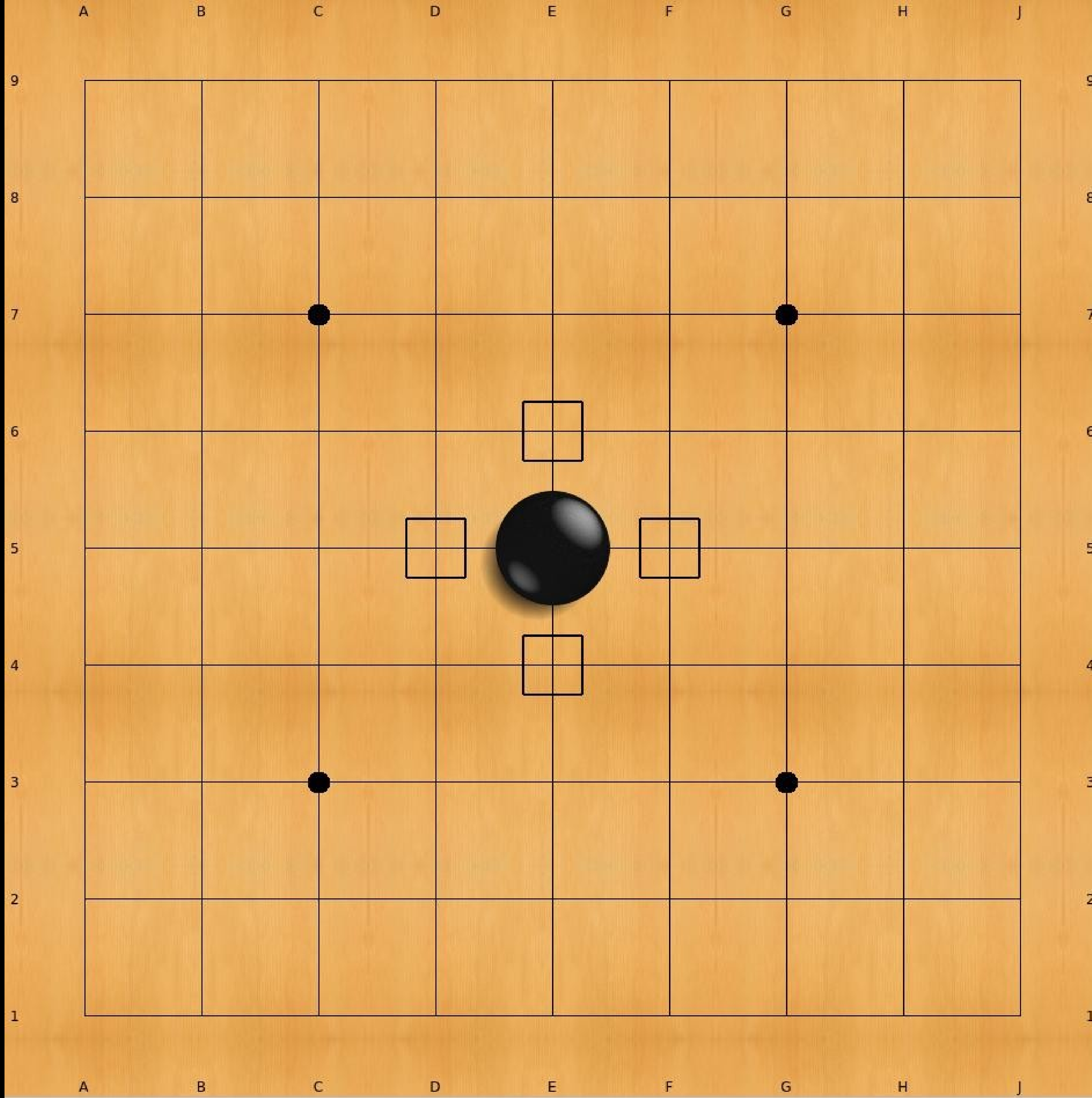
9 8 7 6 5 4 3 2 1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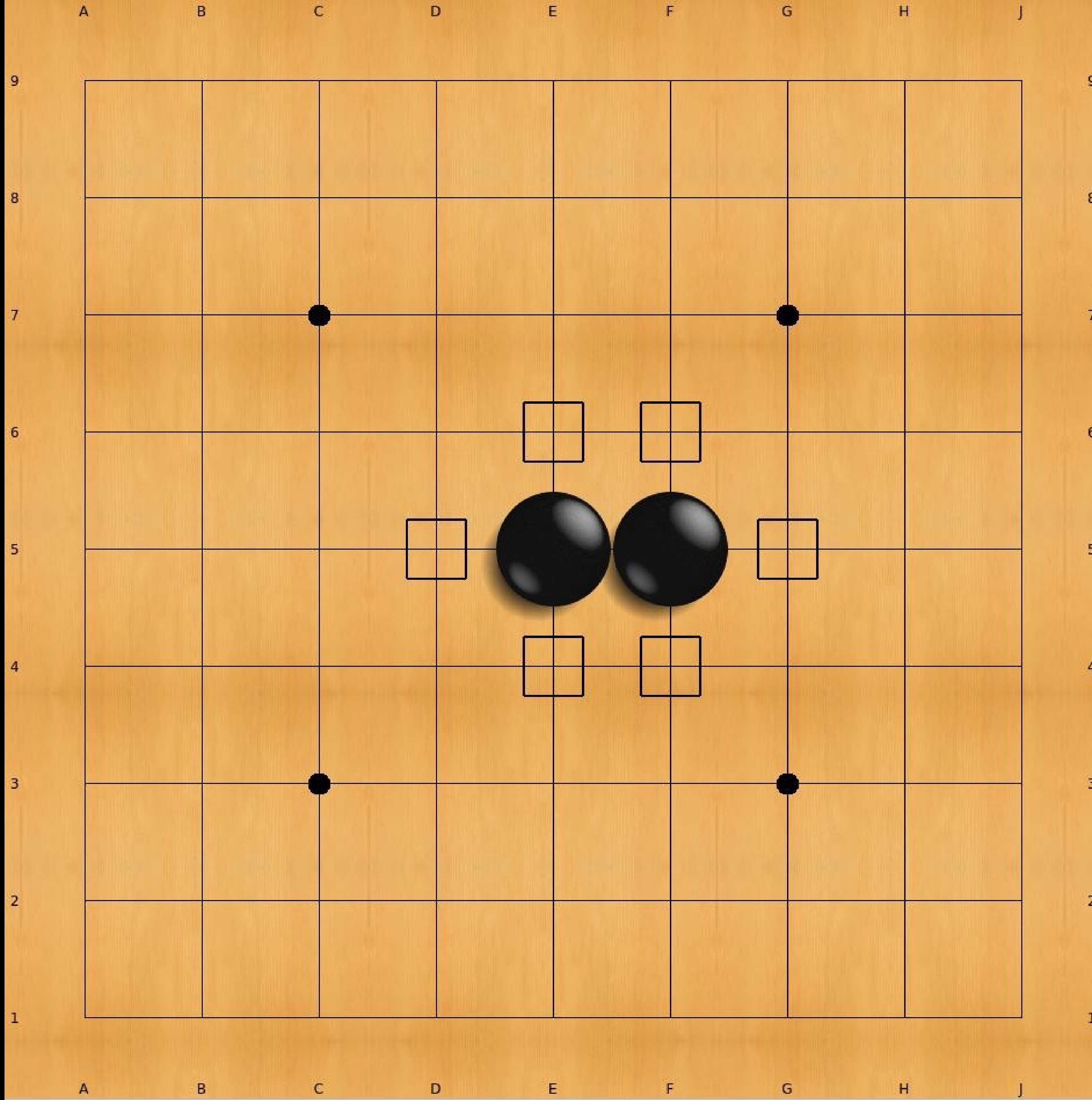
9 8 7 6 5 4 3 2 1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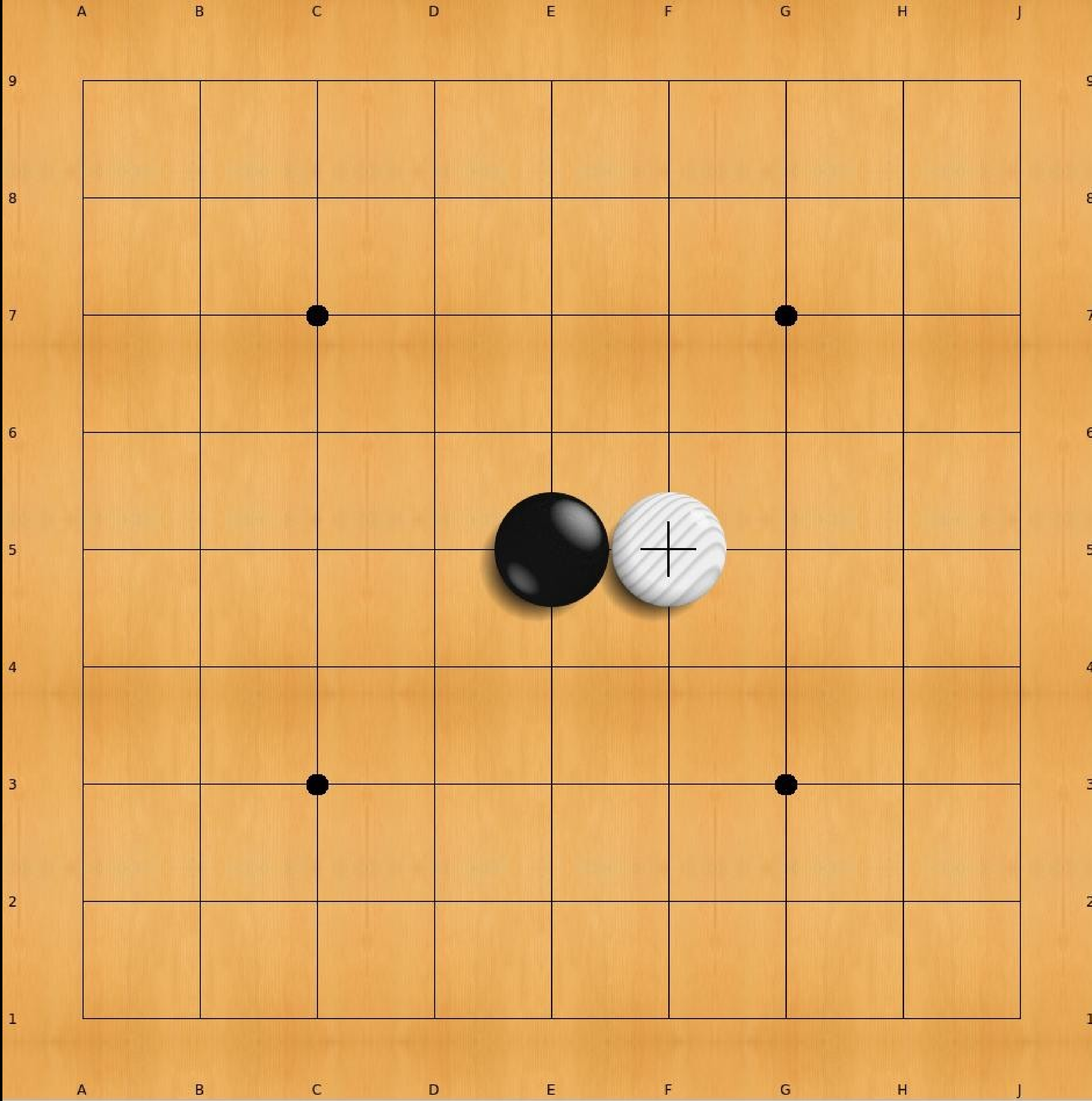
9 8 7 6 5 4 3 2 1


A B C D E F G H J
9
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6
5
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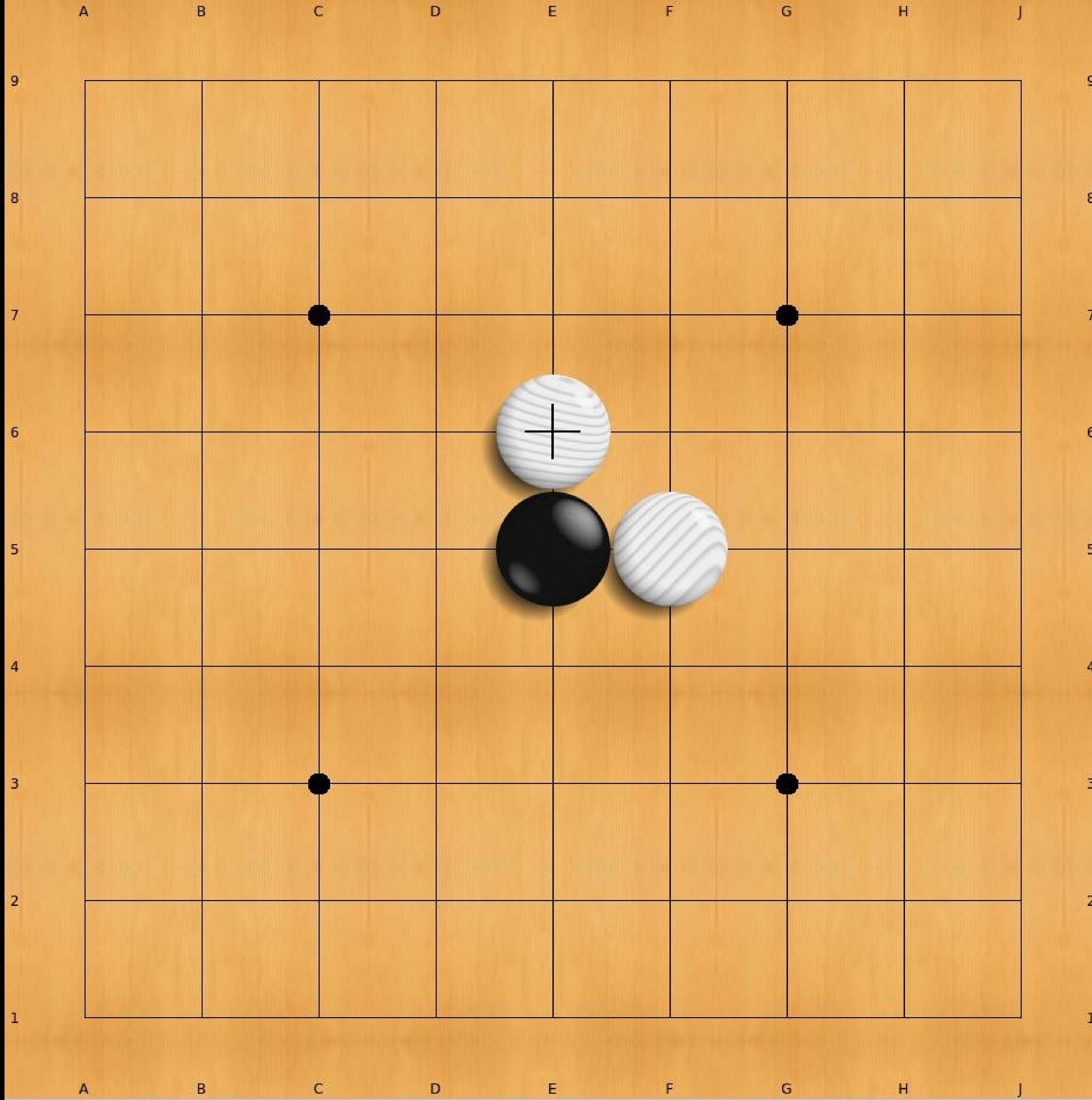
3
2
1


A B C D E F G H J
9
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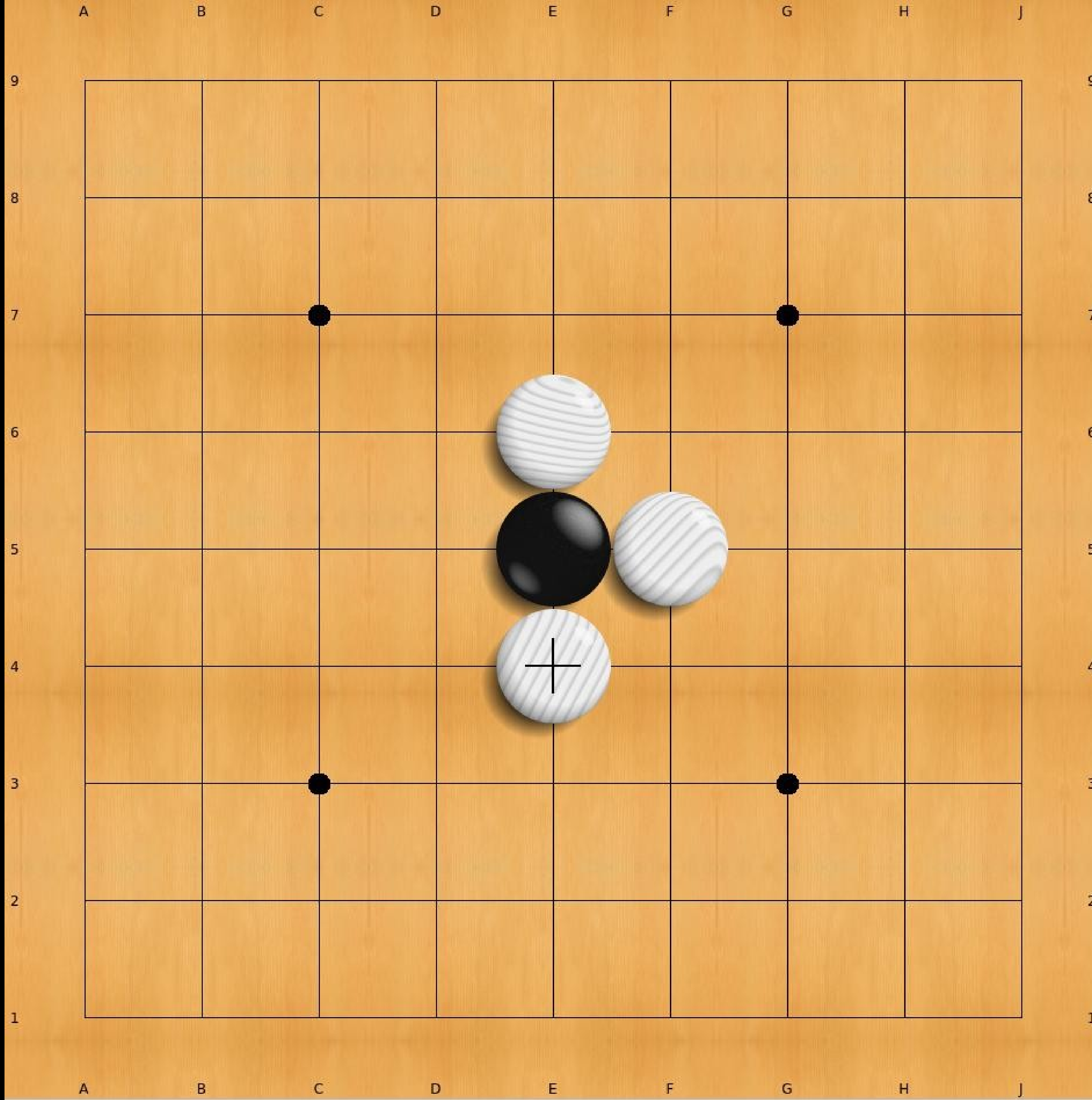
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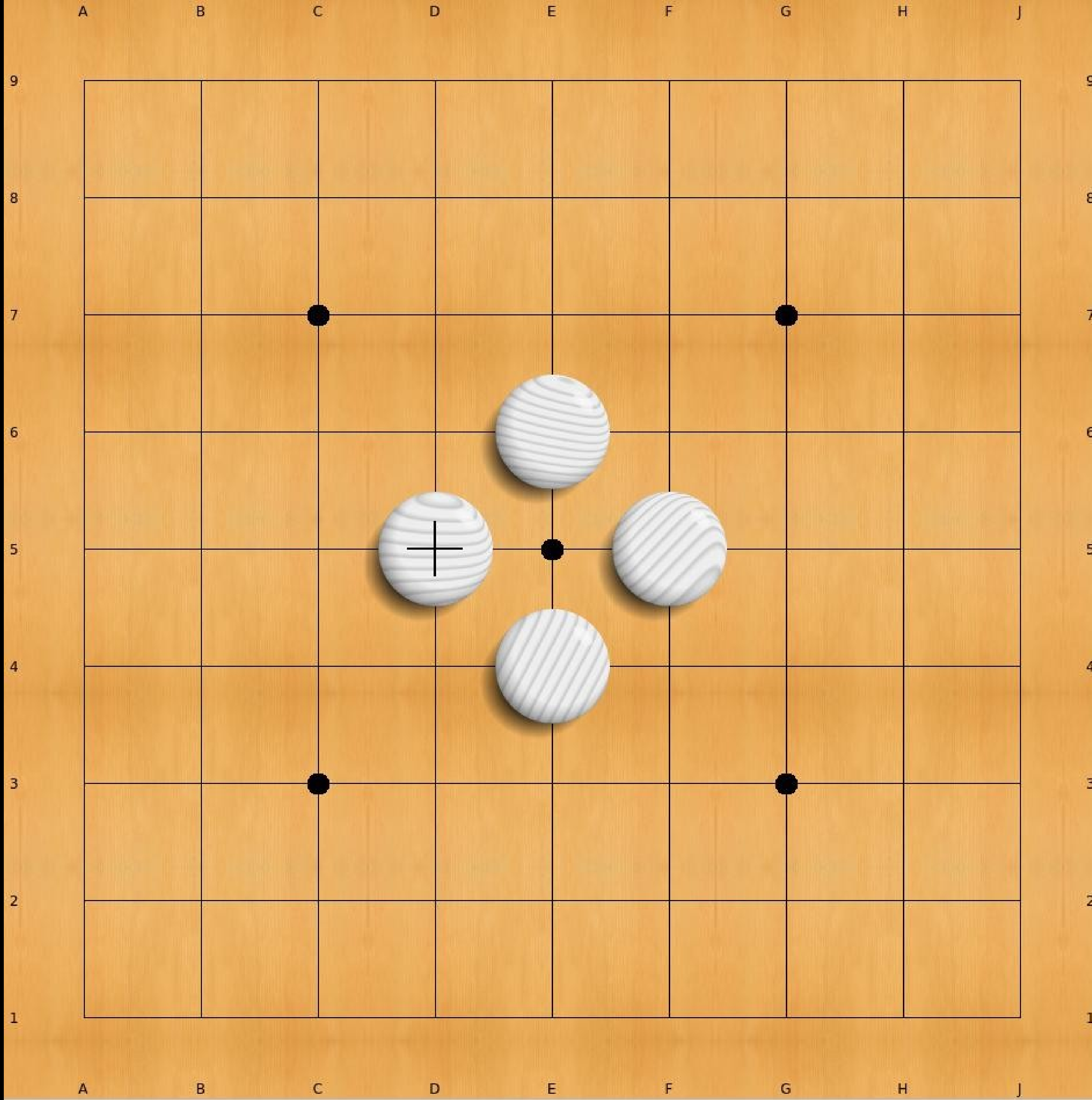
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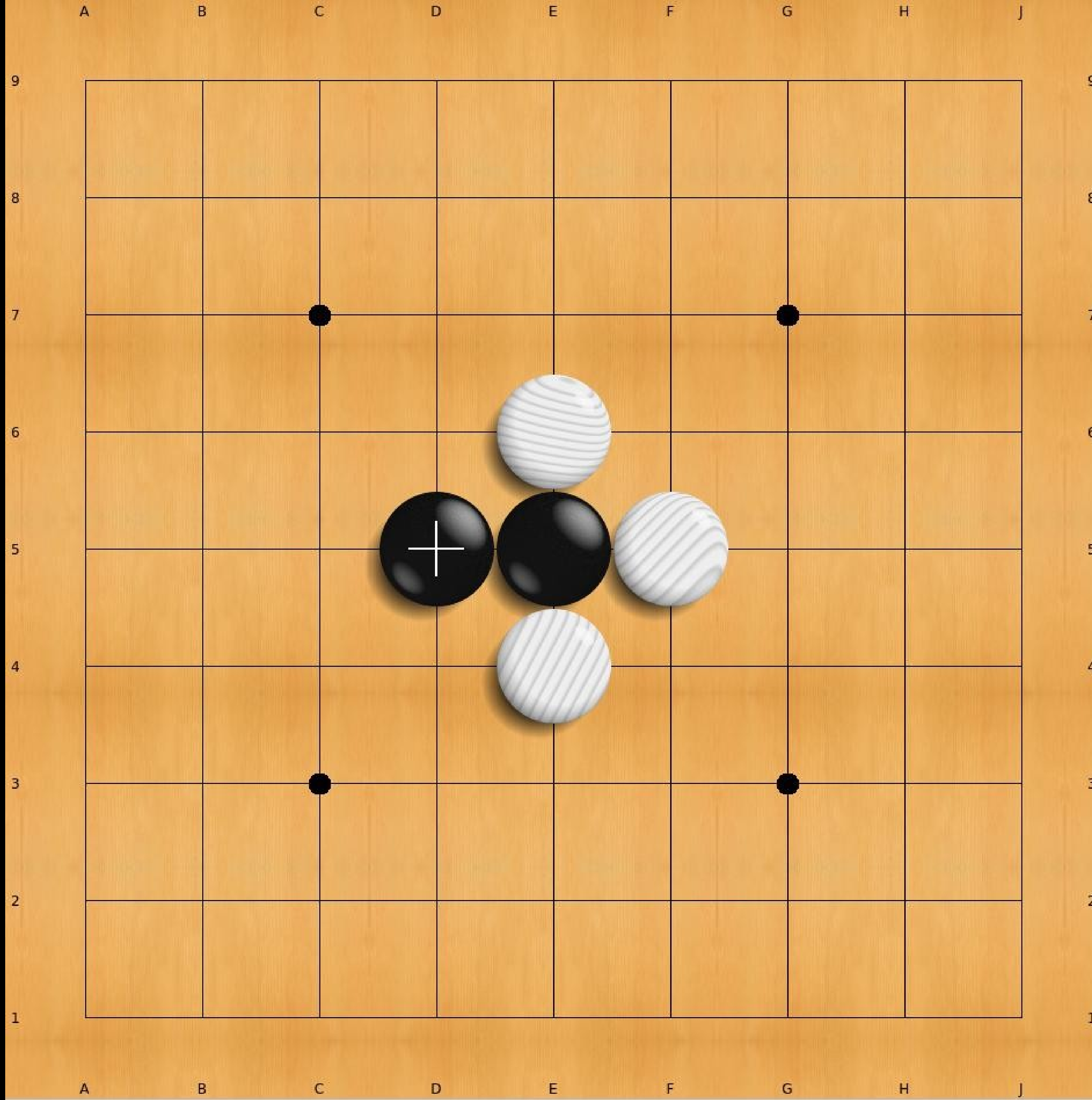
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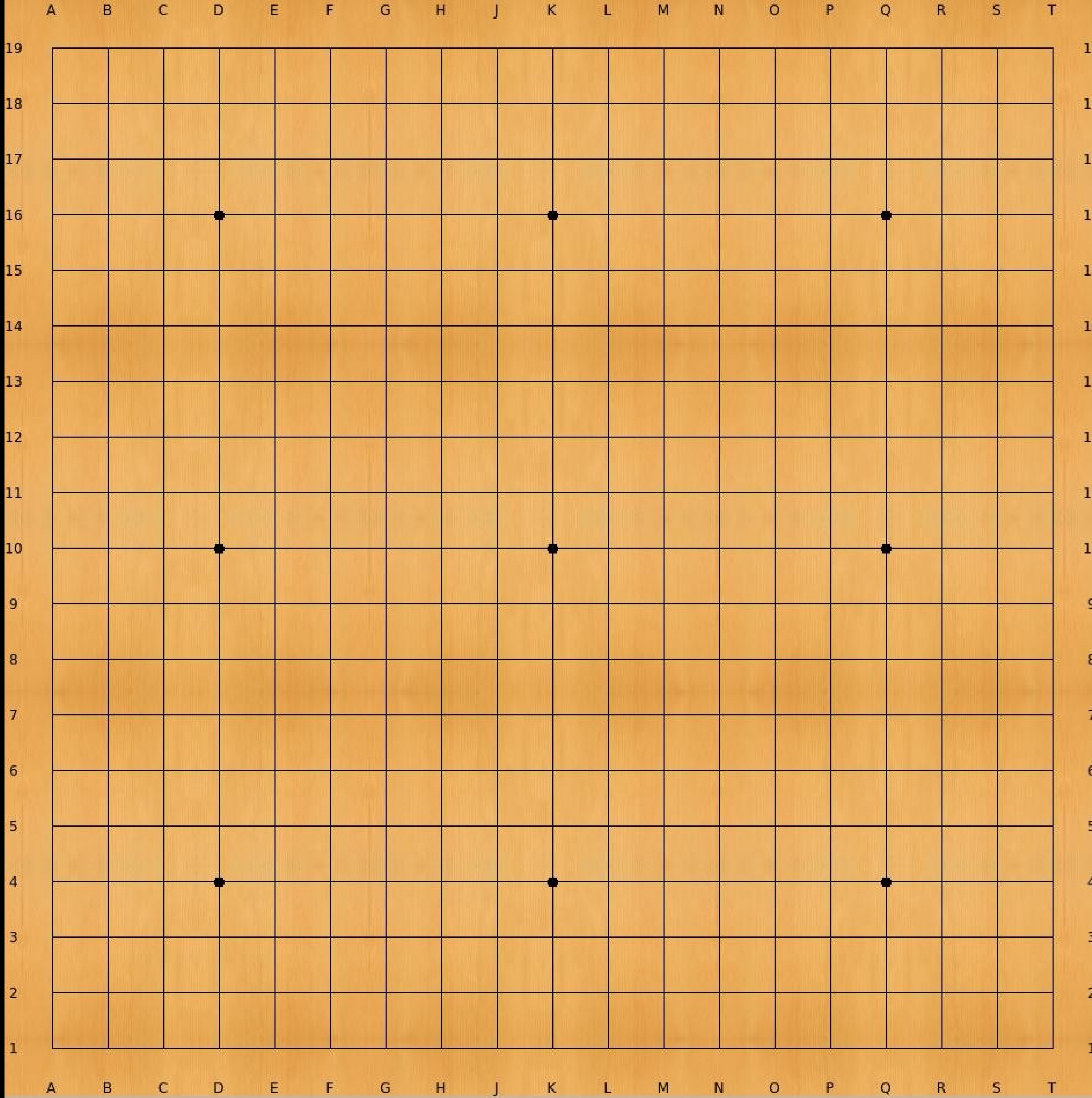
9 8 7 6 5 4 3 2 1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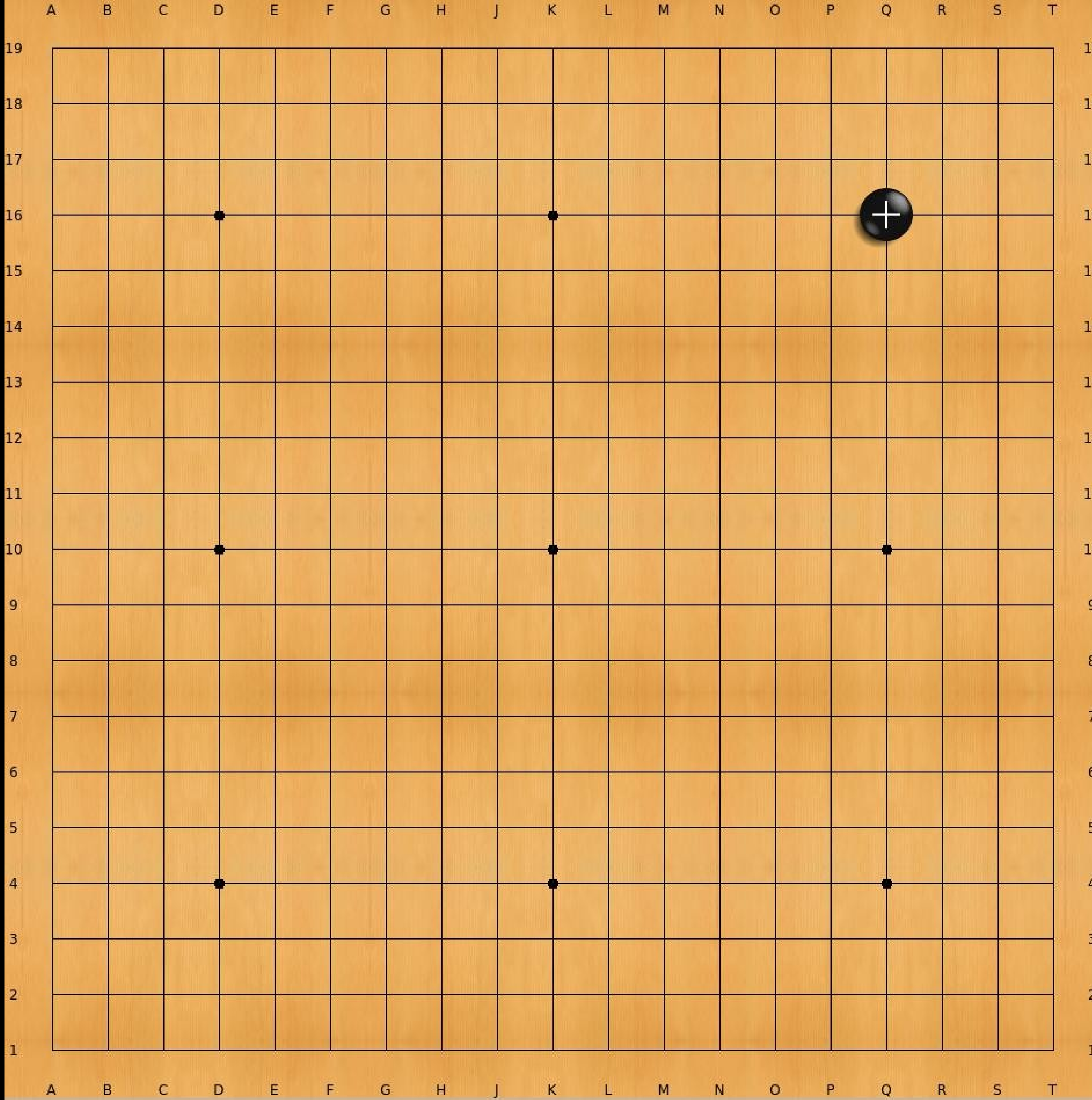
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1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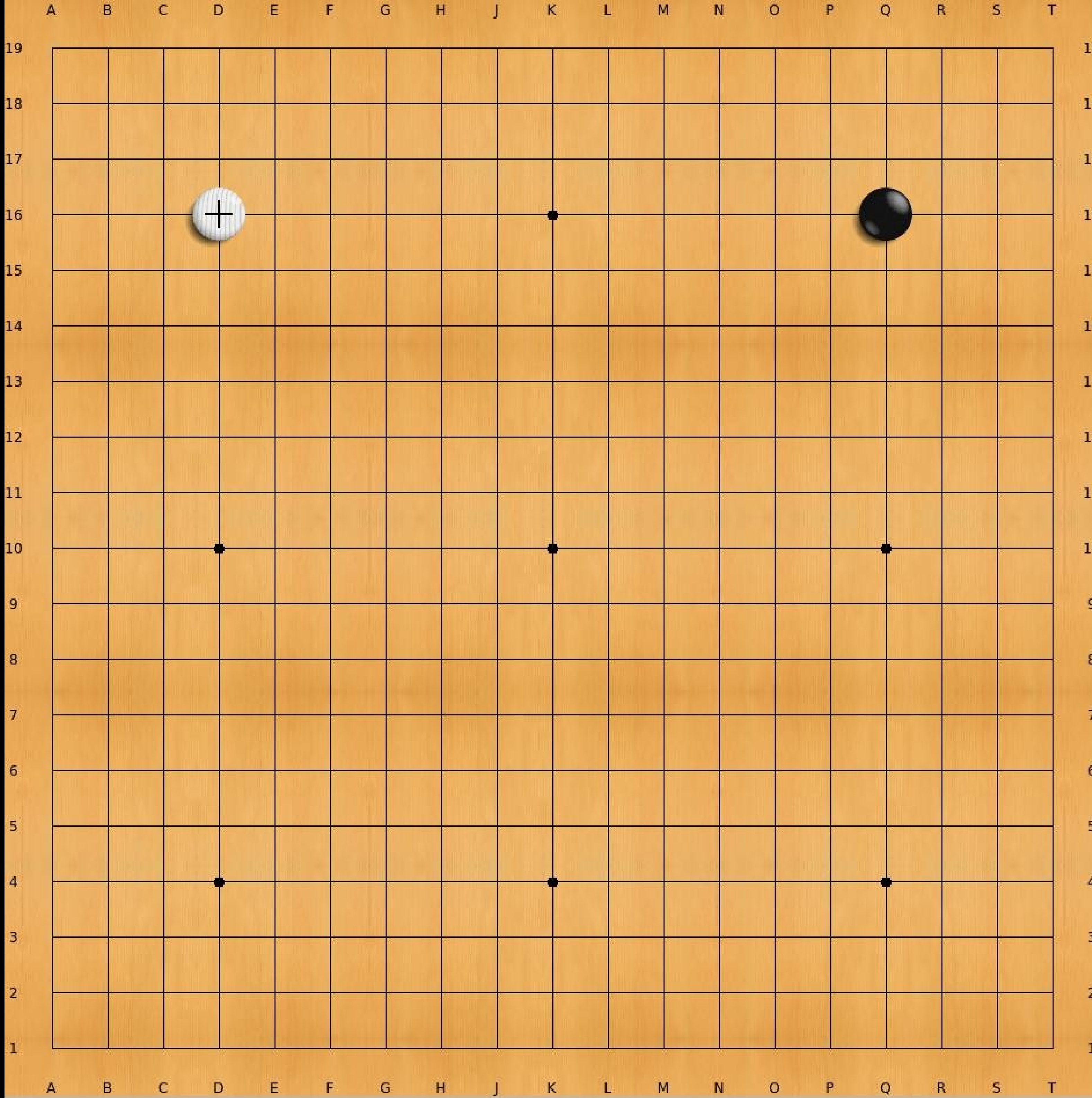
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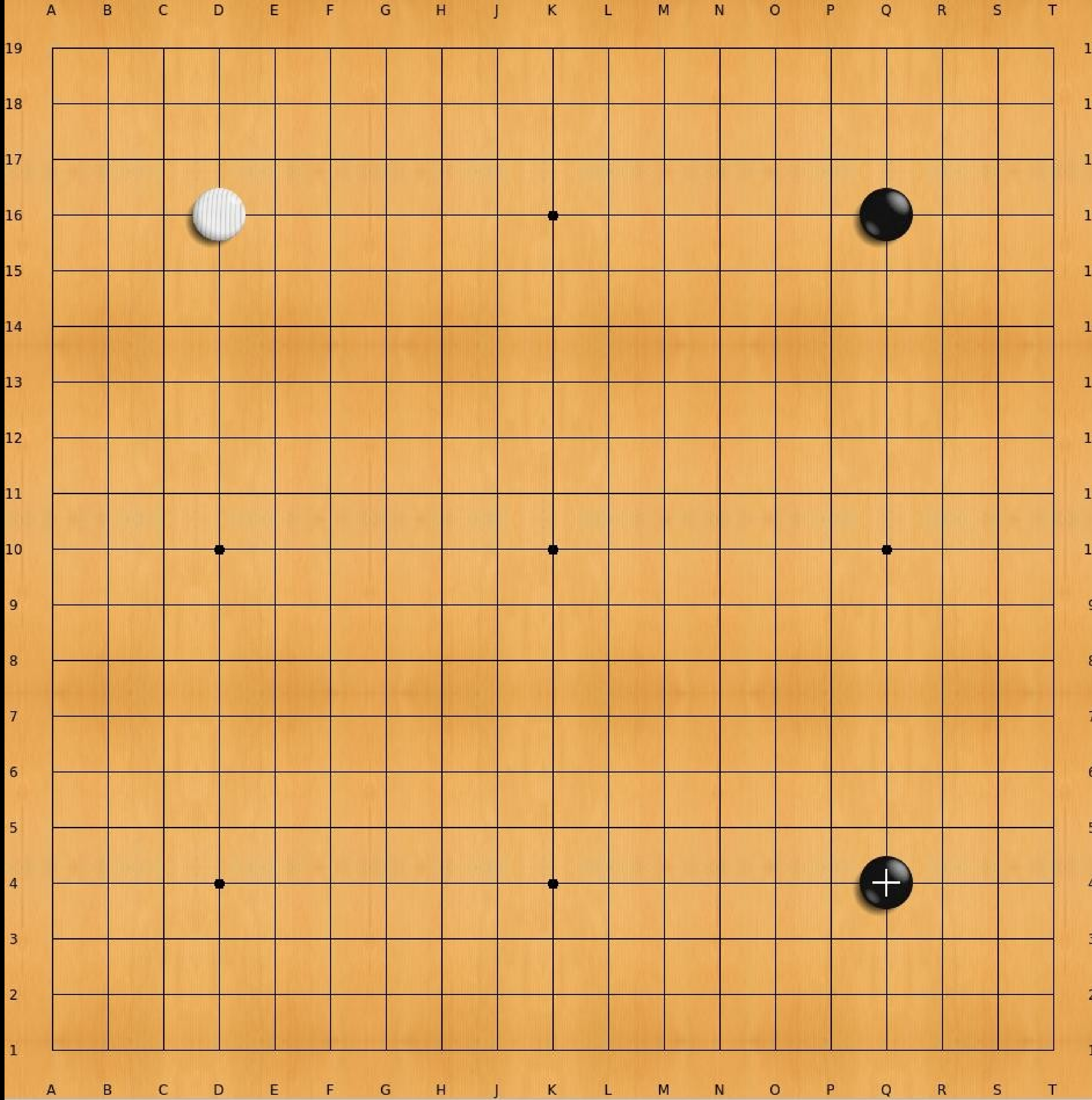
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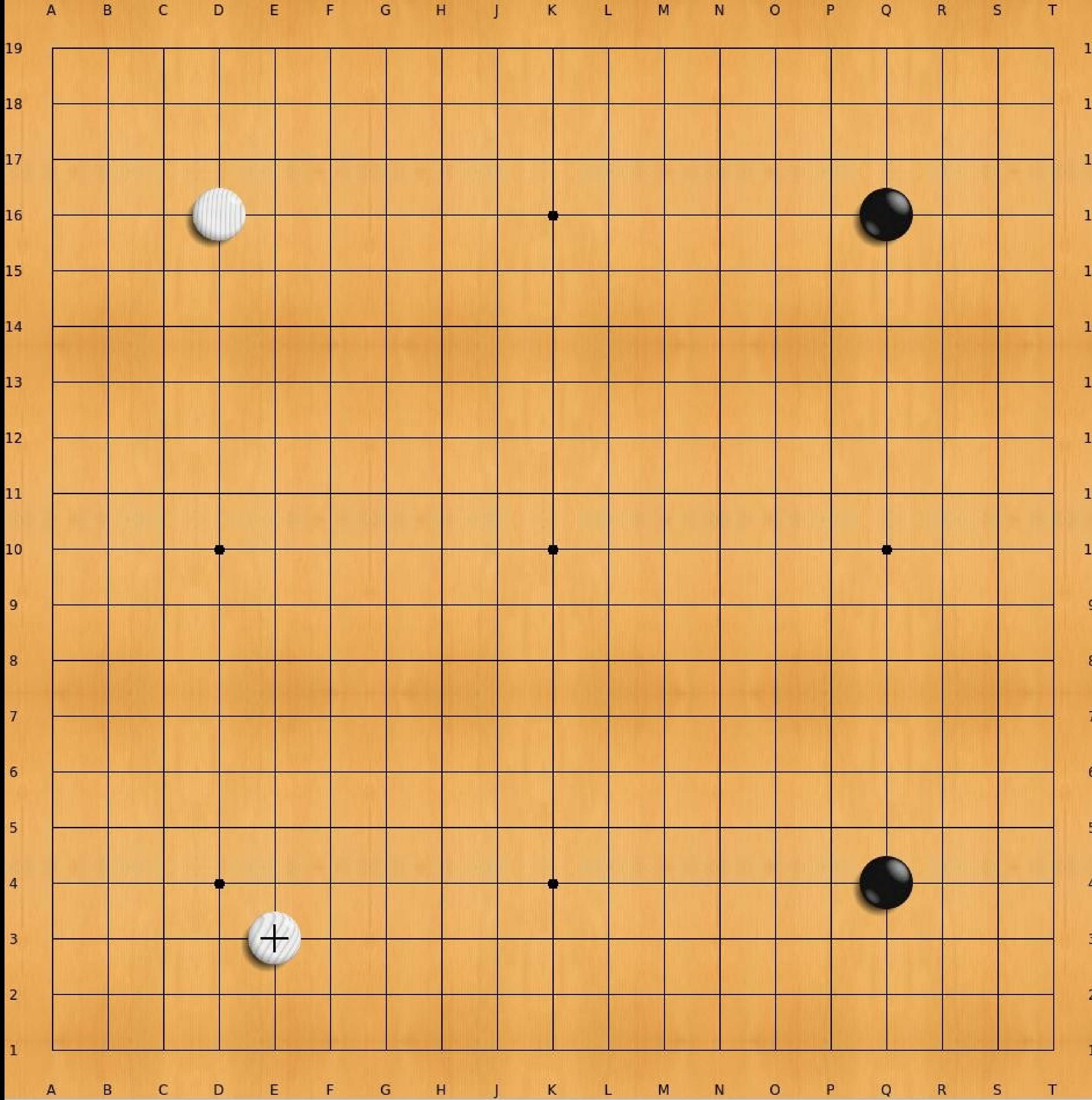
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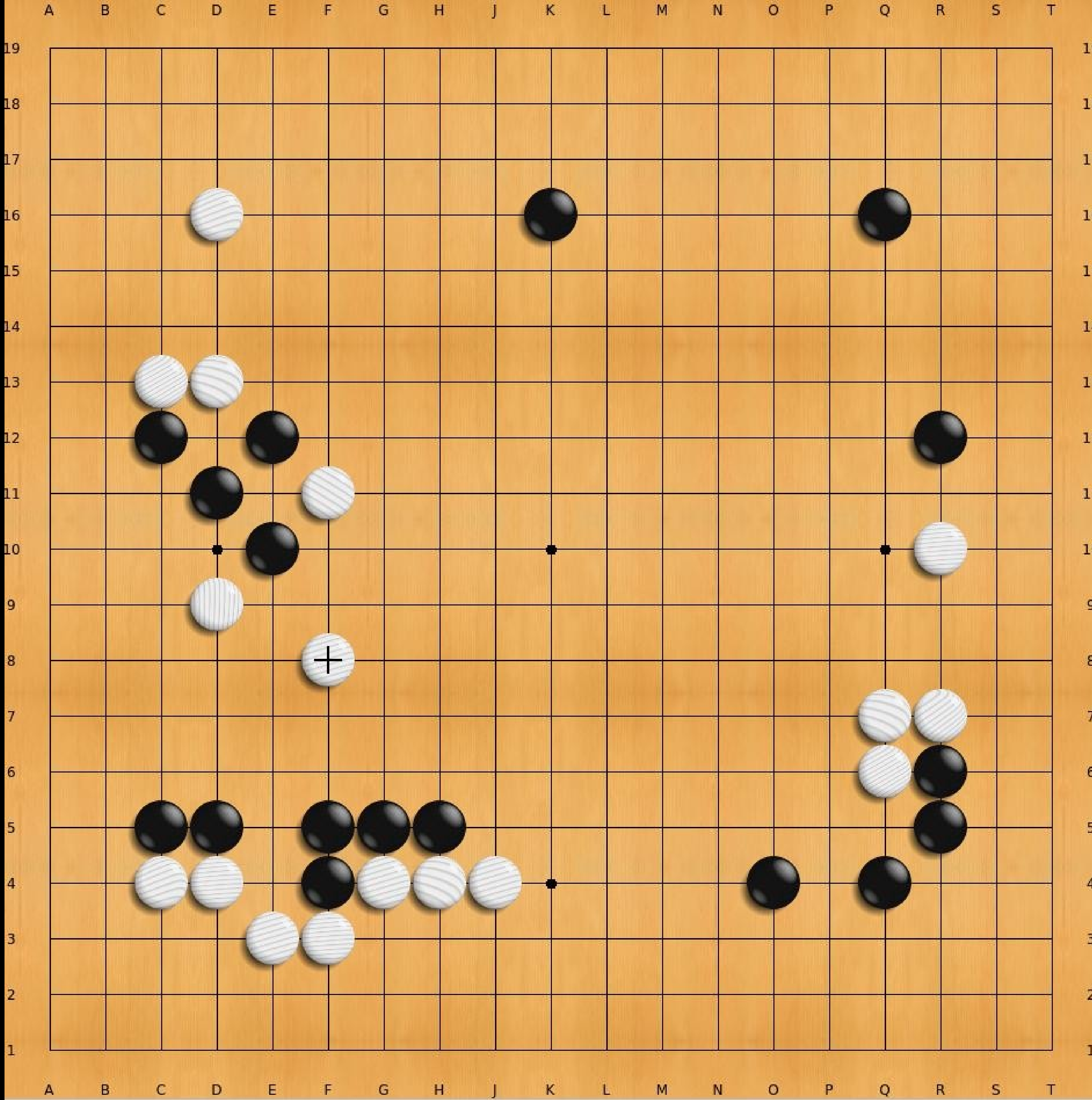
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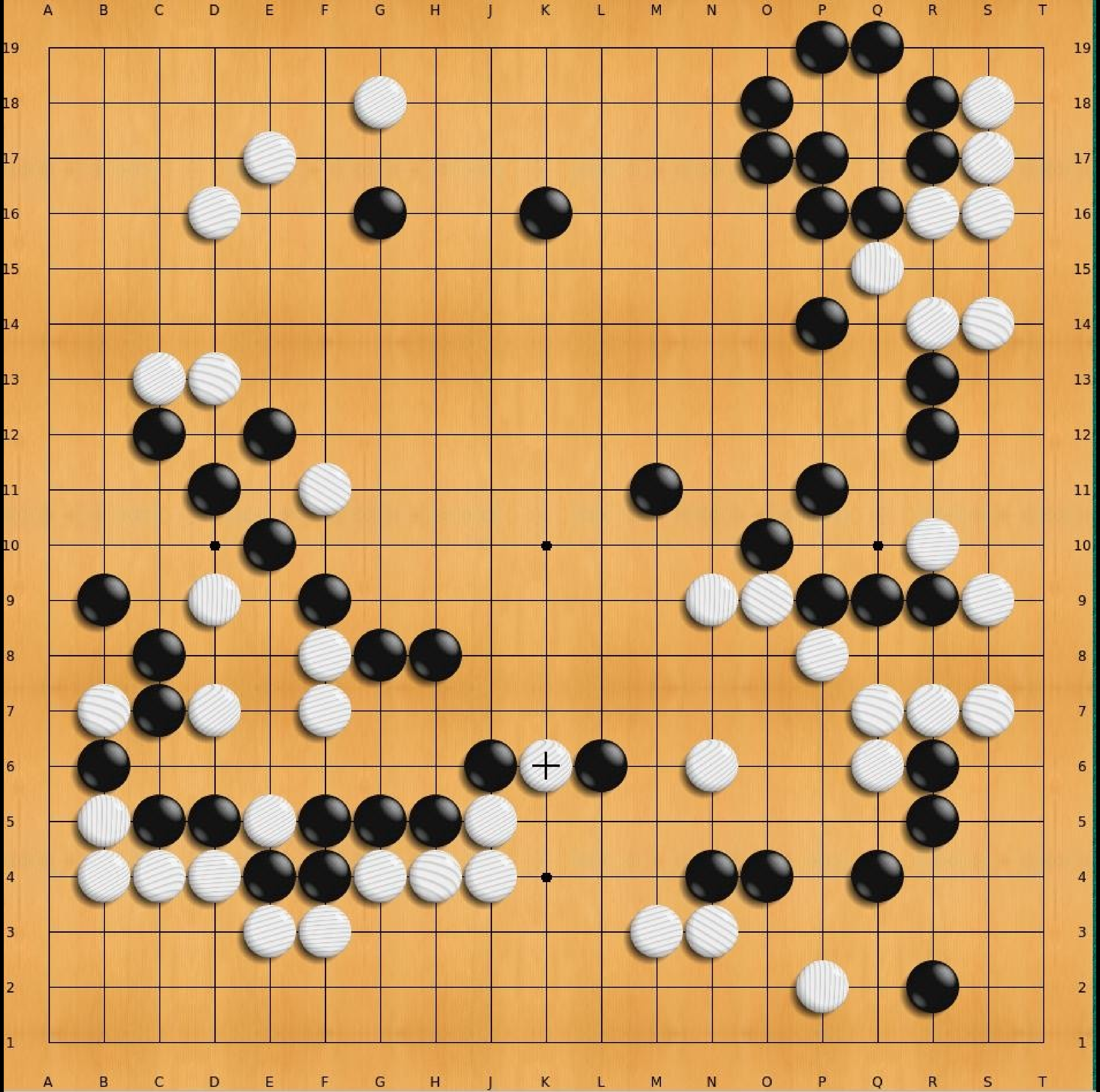
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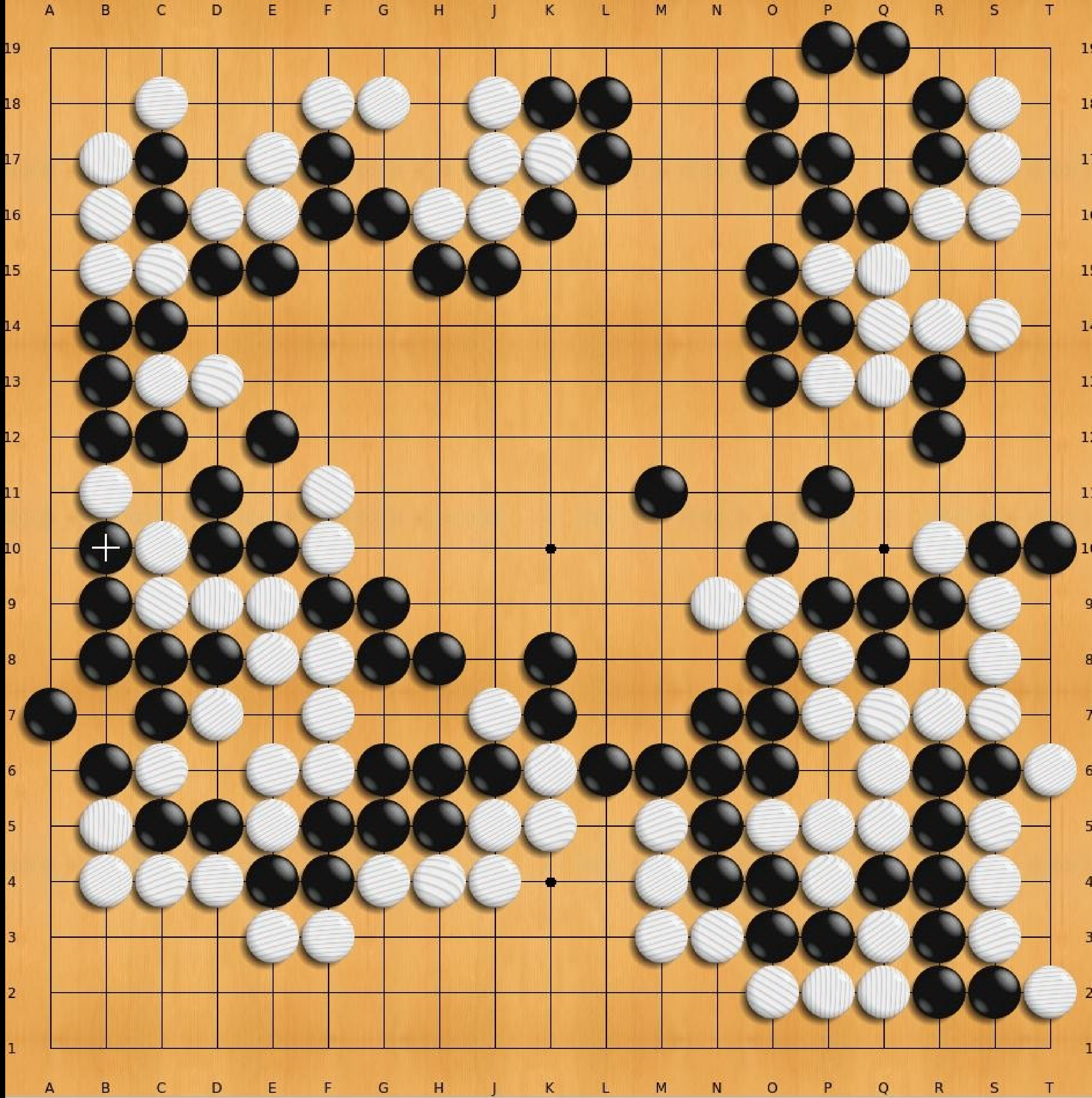

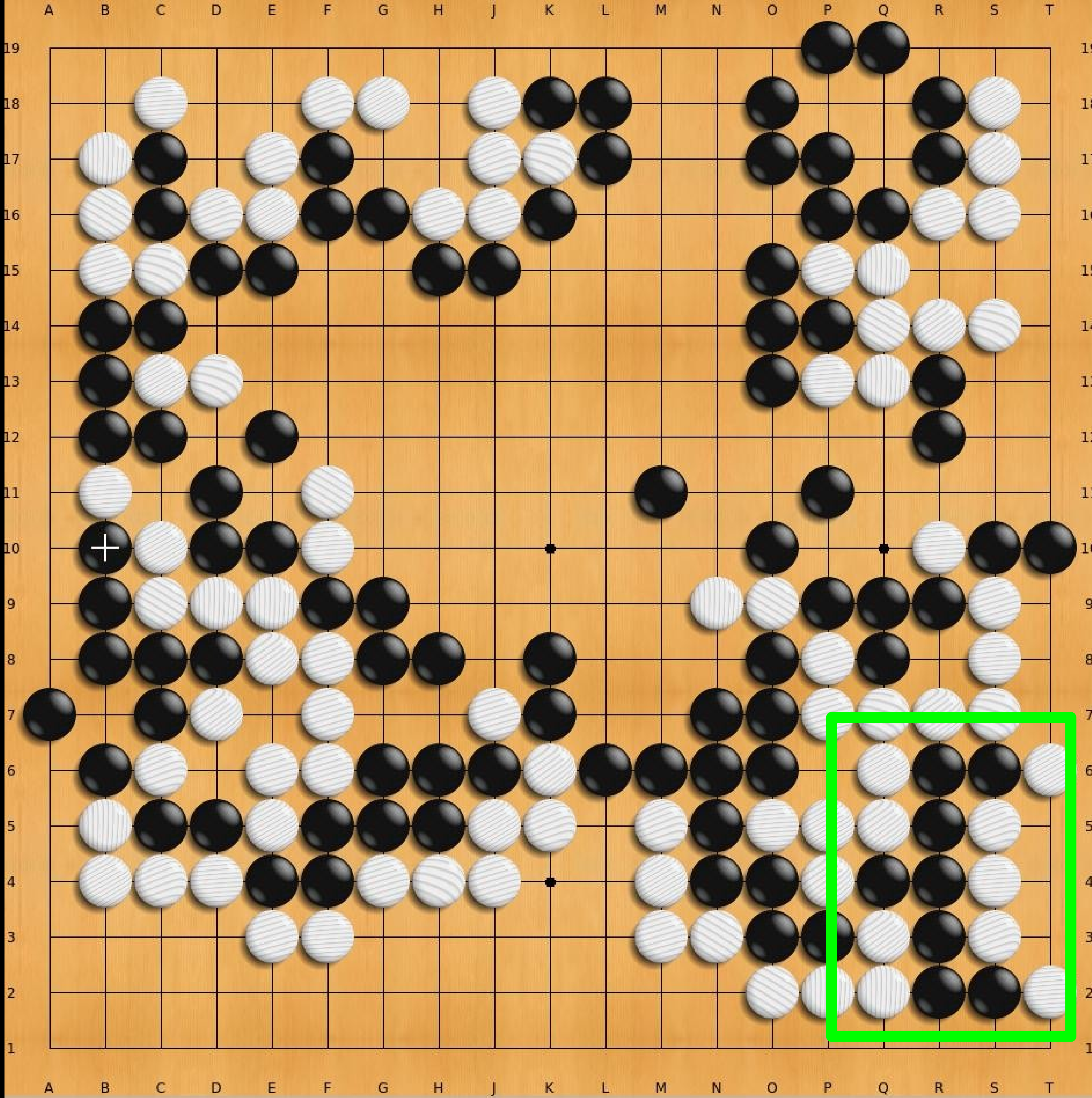
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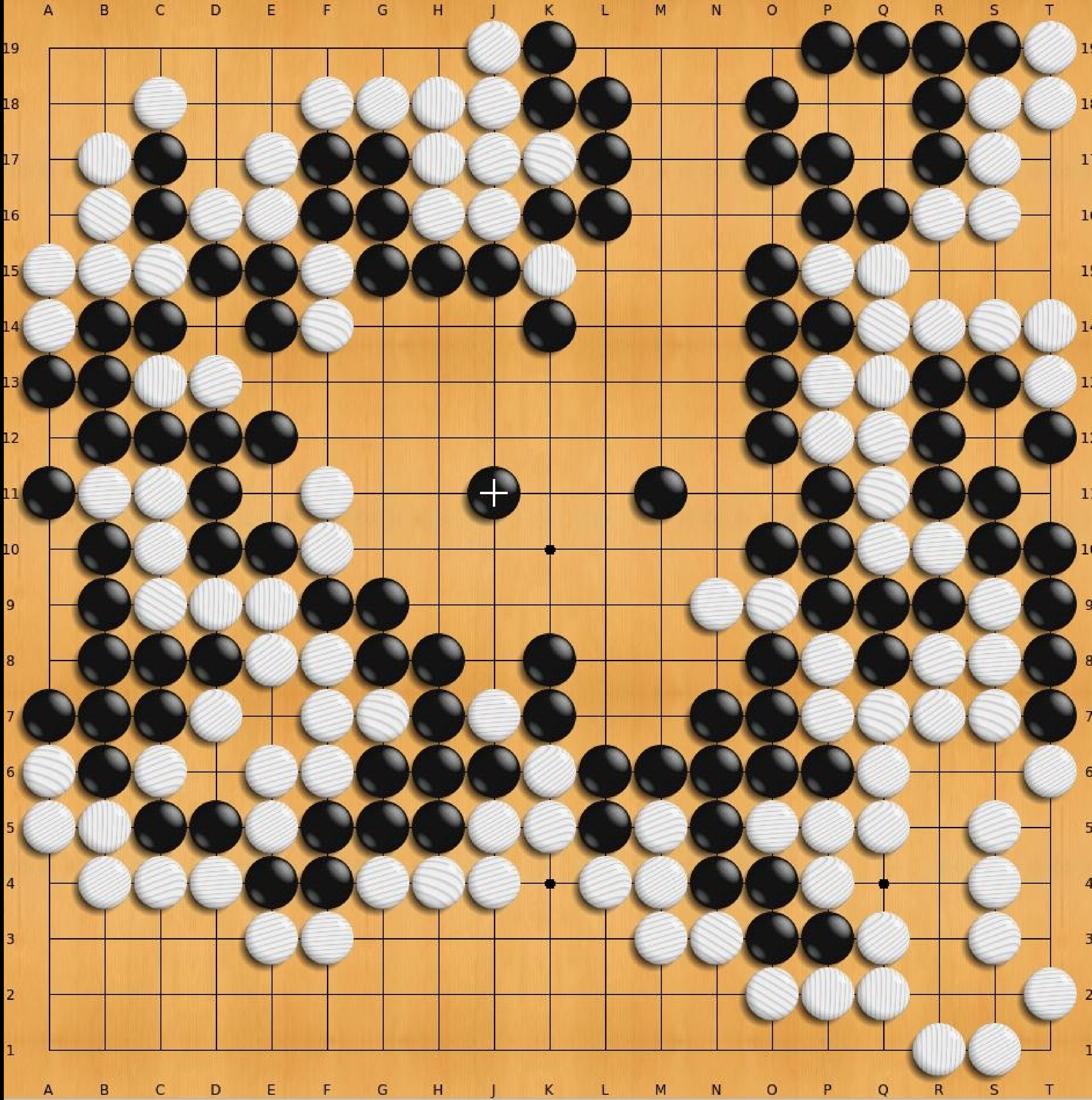

A B C D E F G H J K L M N O P Q R S T
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1


A B C D E F G H J K L M N O P Q R S T
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1


Computational Challenge

Go vs. Chess

Complex vs. Complicated

„While the Baroque rules of ***chess could only have been created by humans****, the rules of* ***go*** *are so elegant, organic, and rigorously logical that* ***if intelligent life forms exist*** *elsewhere in the universe, they almost* ***certainly play go****.“*

Edward Lasker (chess grandmaster)

Larger board

19x19 vs. 8x8

Almost every move is legal

Average branching factor:

250 vs 35

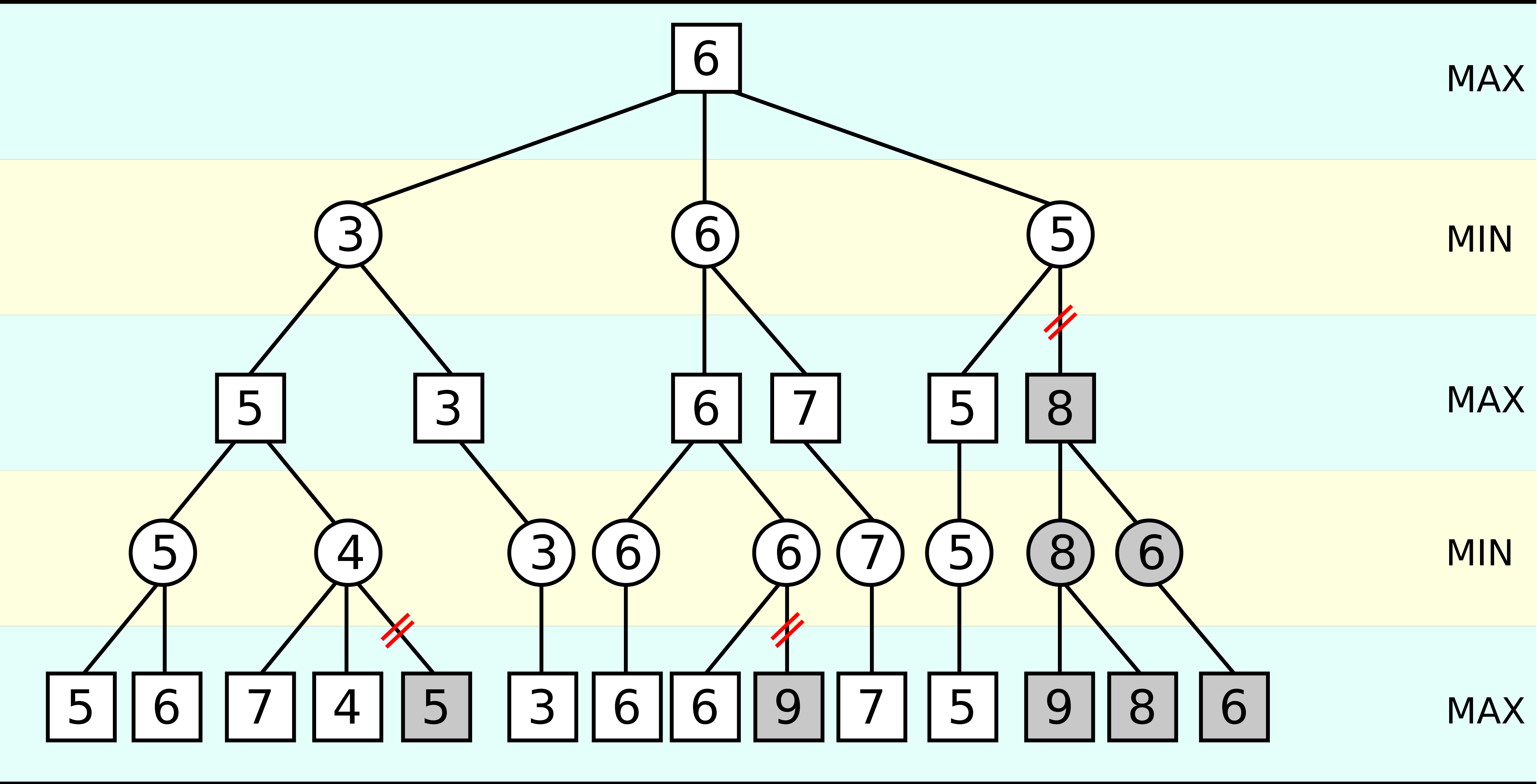
State Space Complexity:

10^{171} vs 10^{47}

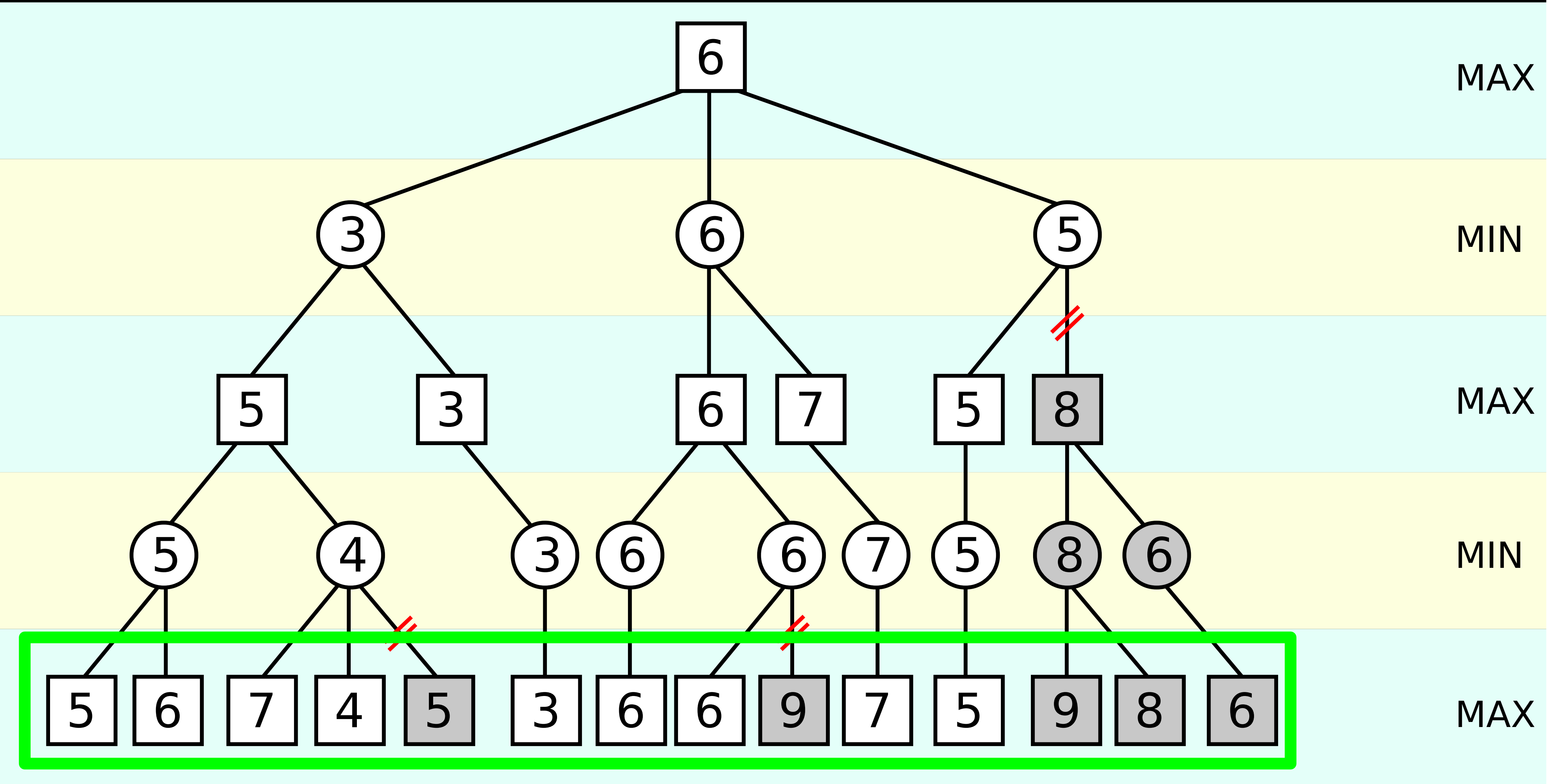

10^{80}

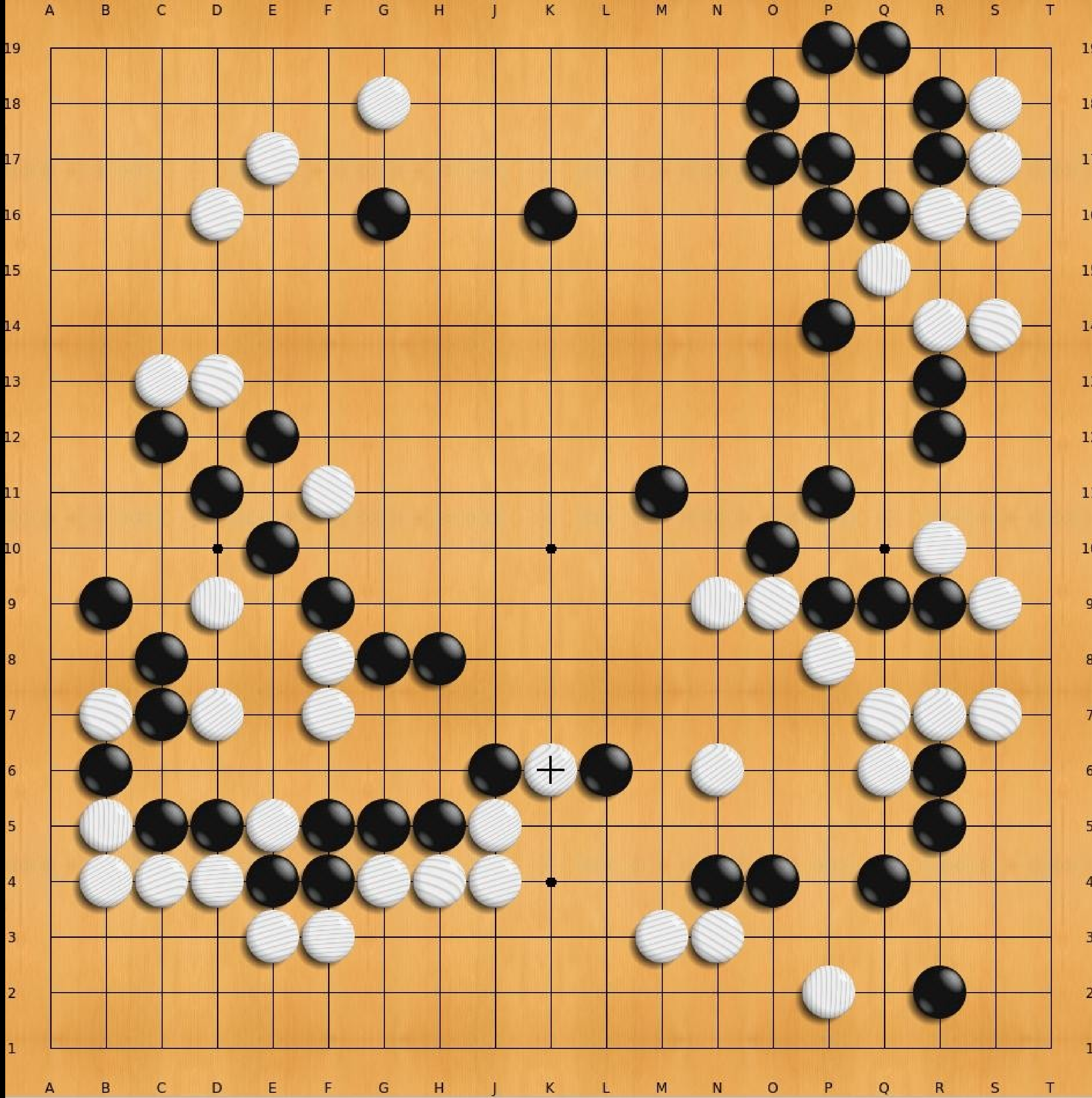
Global impact of moves

Traditional Seach



Evaluation Function

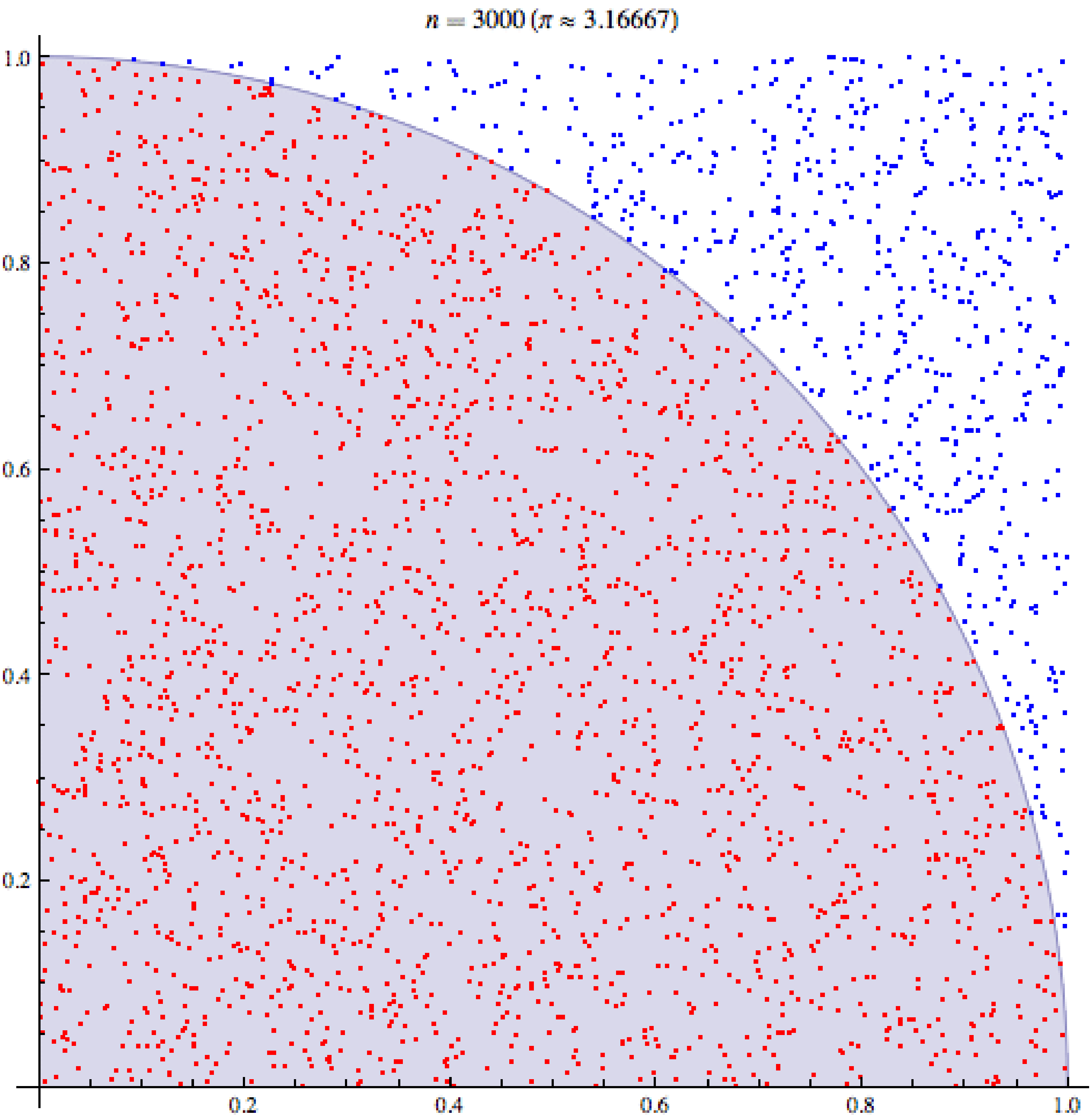



A B C D E F G H J K L M N O P Q R S T
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1


Monte Carlo Method

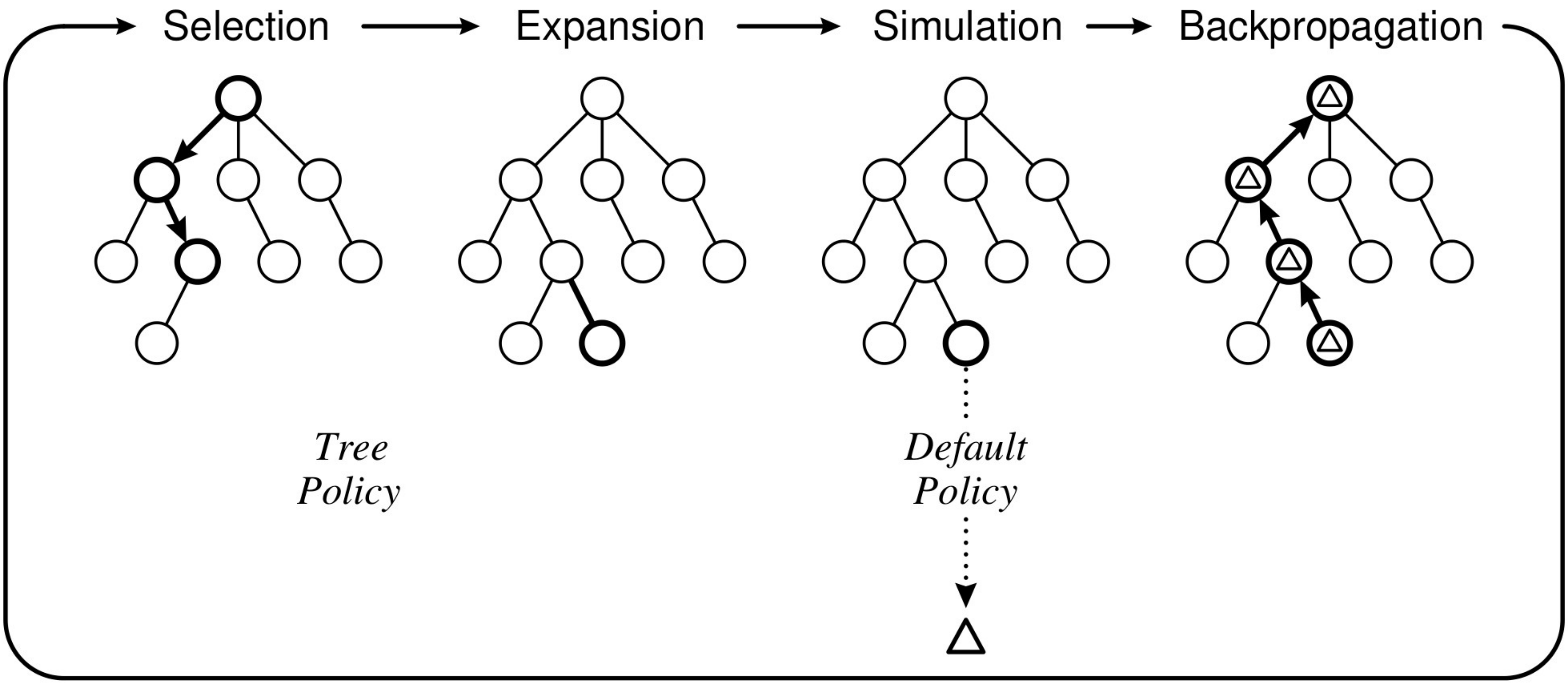
What is Pi?

How do you **determine Pi**?

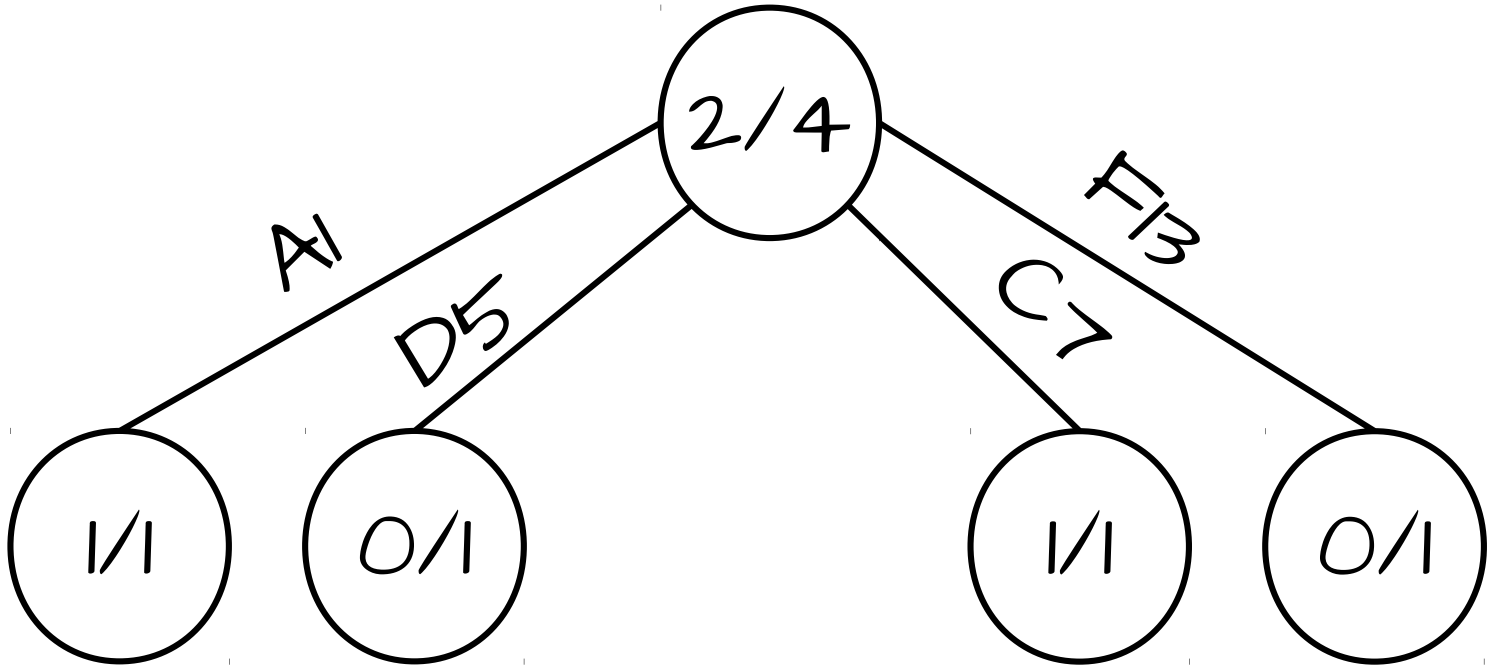


n = 3000 (π ≈ 3.16667)
1.0
0.8
0.6
0.4
0.2
0.2
0.4
0.6
0.8
1.0

2006

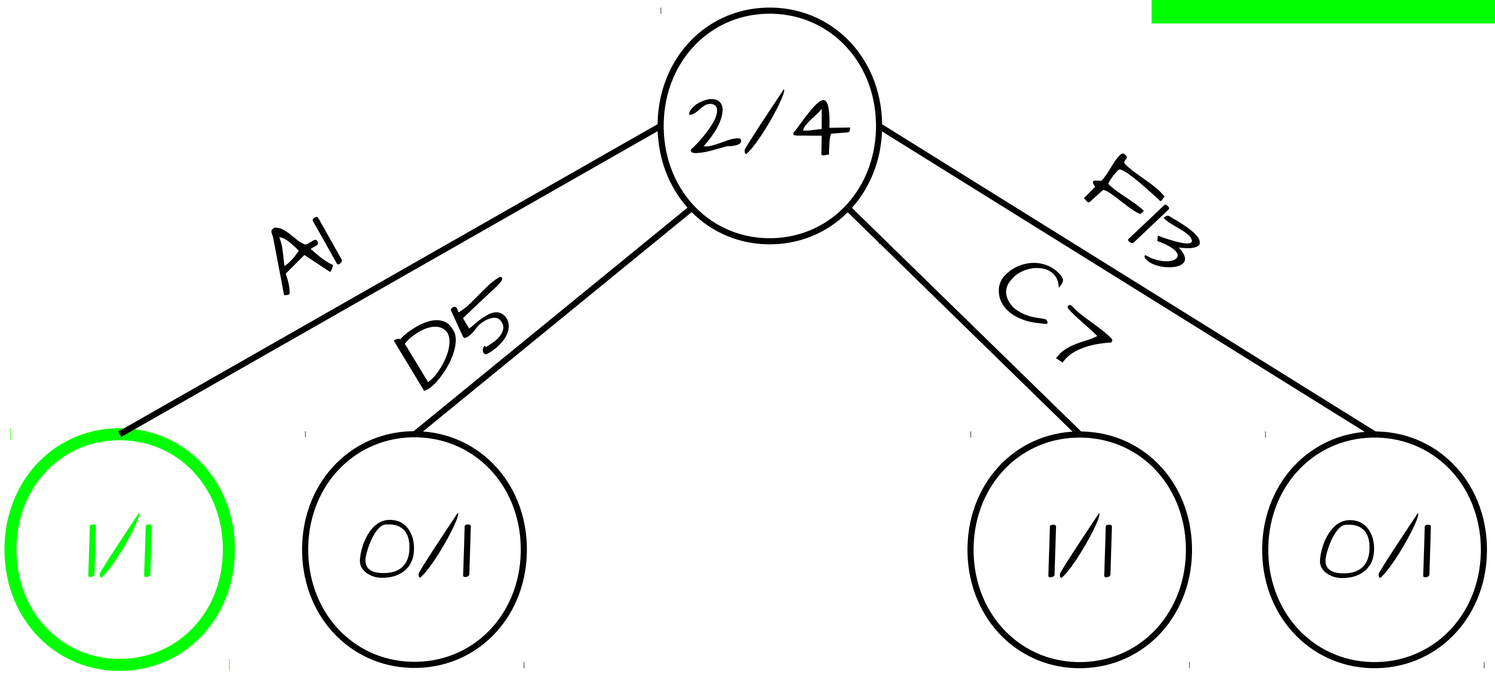


Browne, Cb, and Edward Powley. 2012. A survey of monte carlo tree search methods. Intelligence and AI 4, no. 1: 1-49

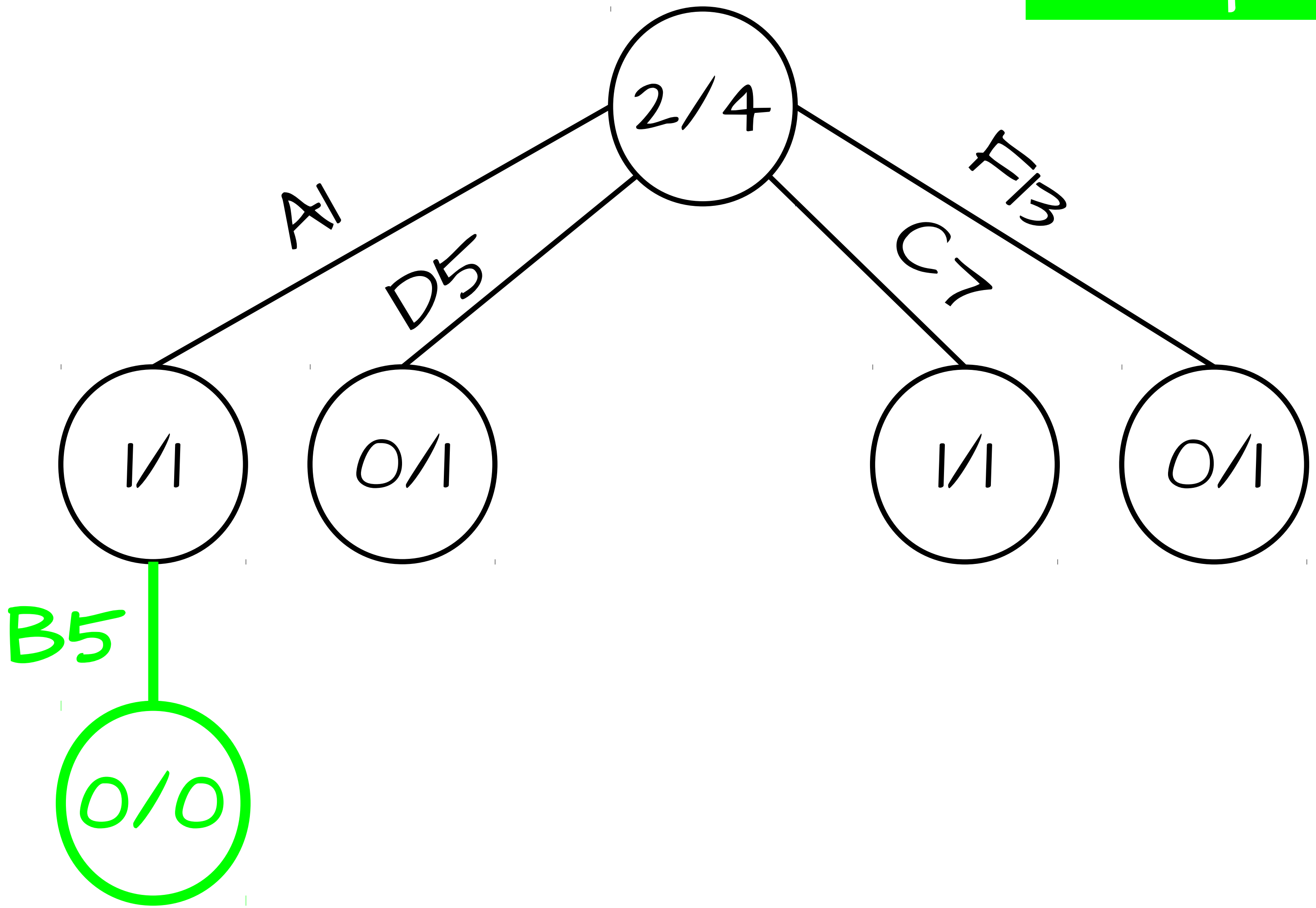


2/4
A1
D5
C7
F13
1/1
0/1
1/1
0/1

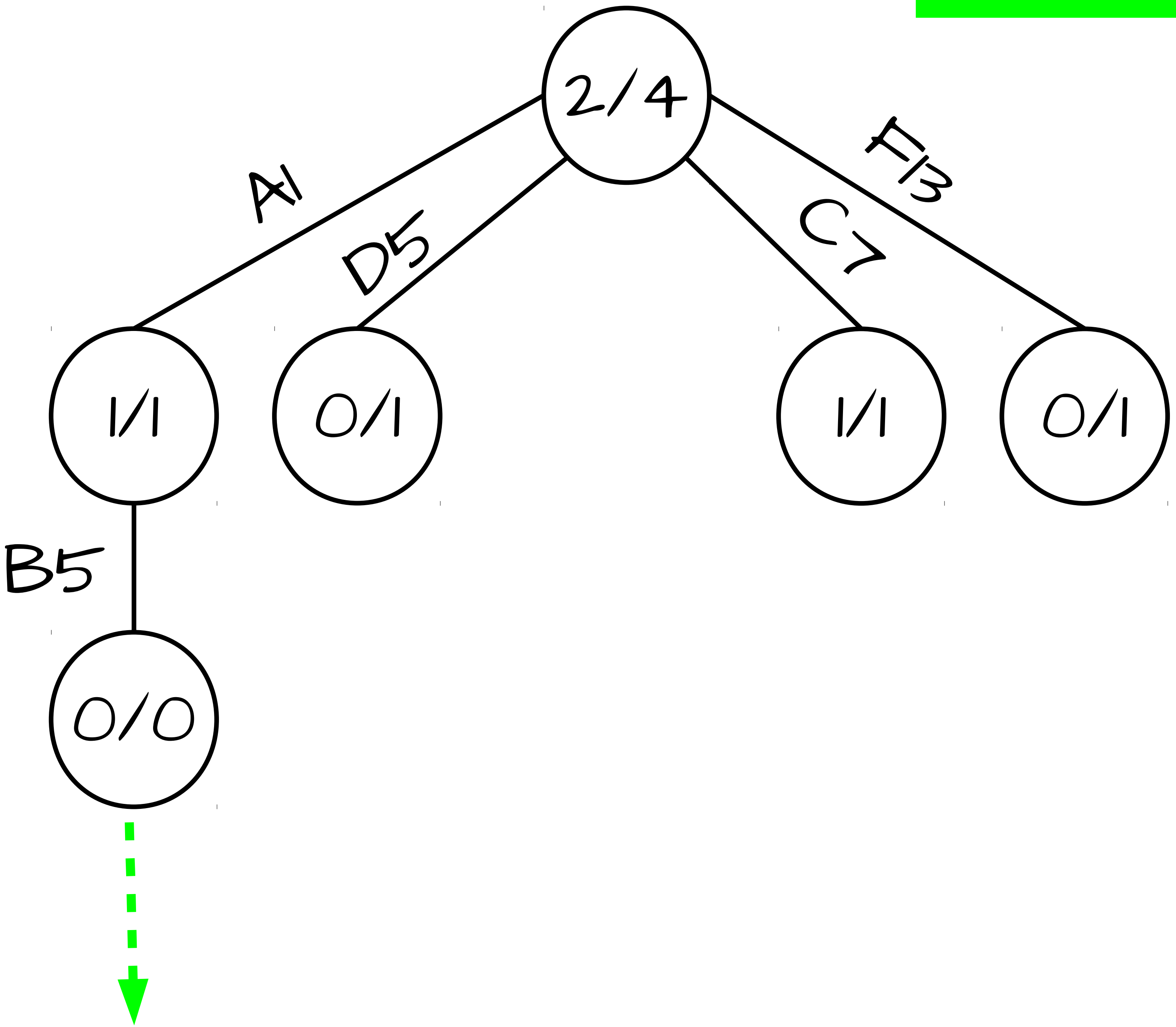
Selection



Expansion



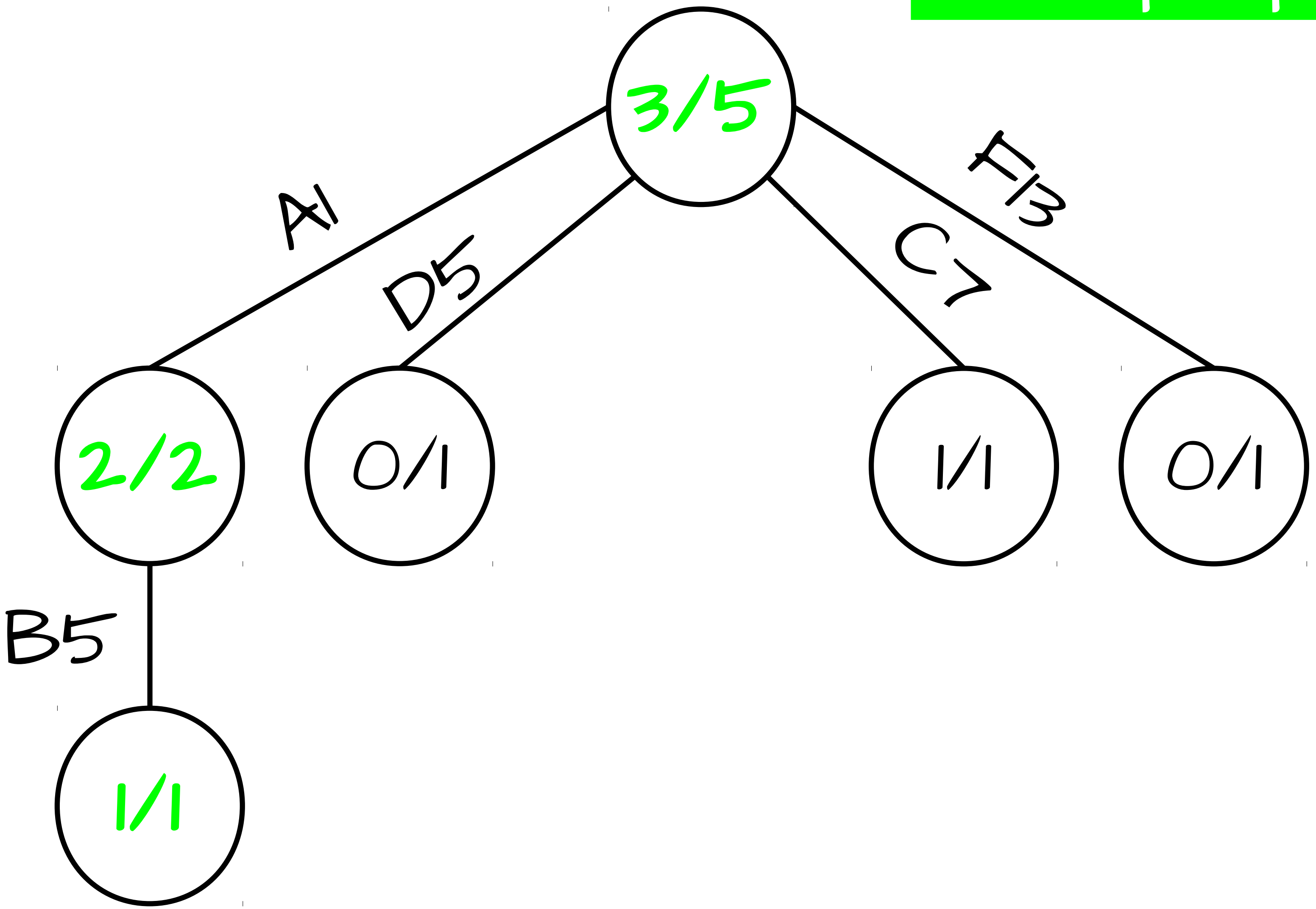
Simulation



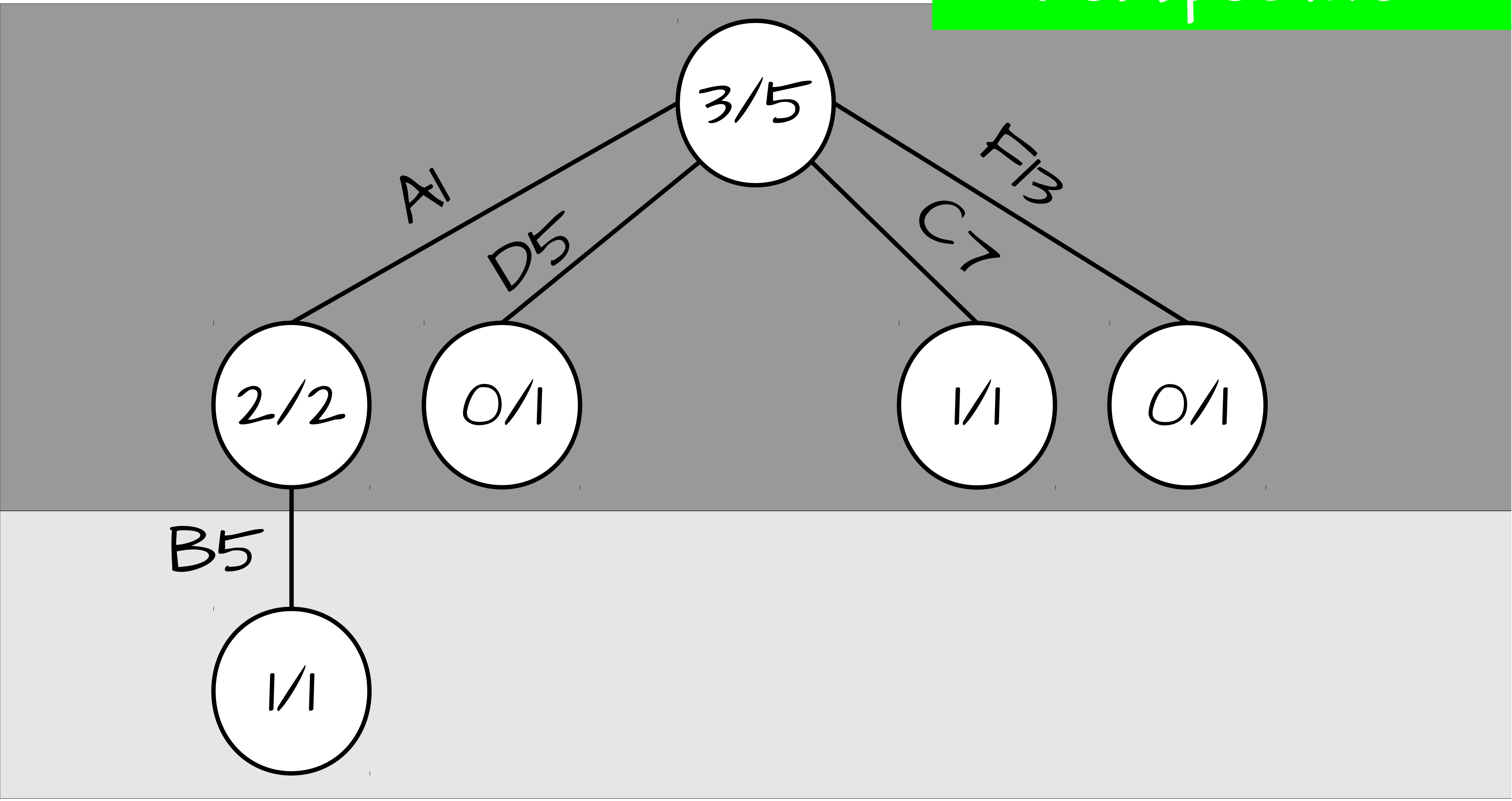
Random


Not Human like?
© H. Michael Miley 2012 | mike@miley.us

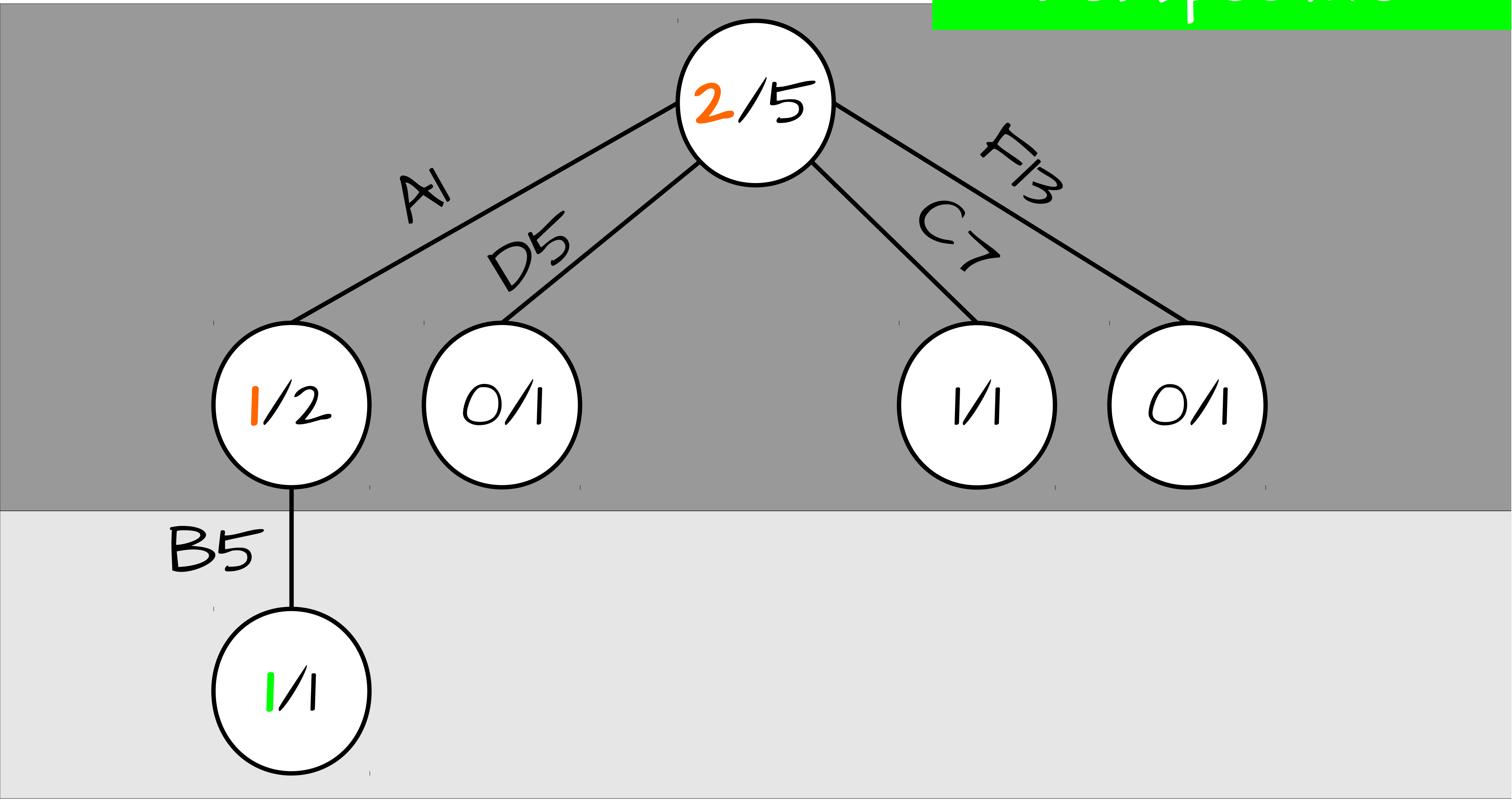
Backpropagation



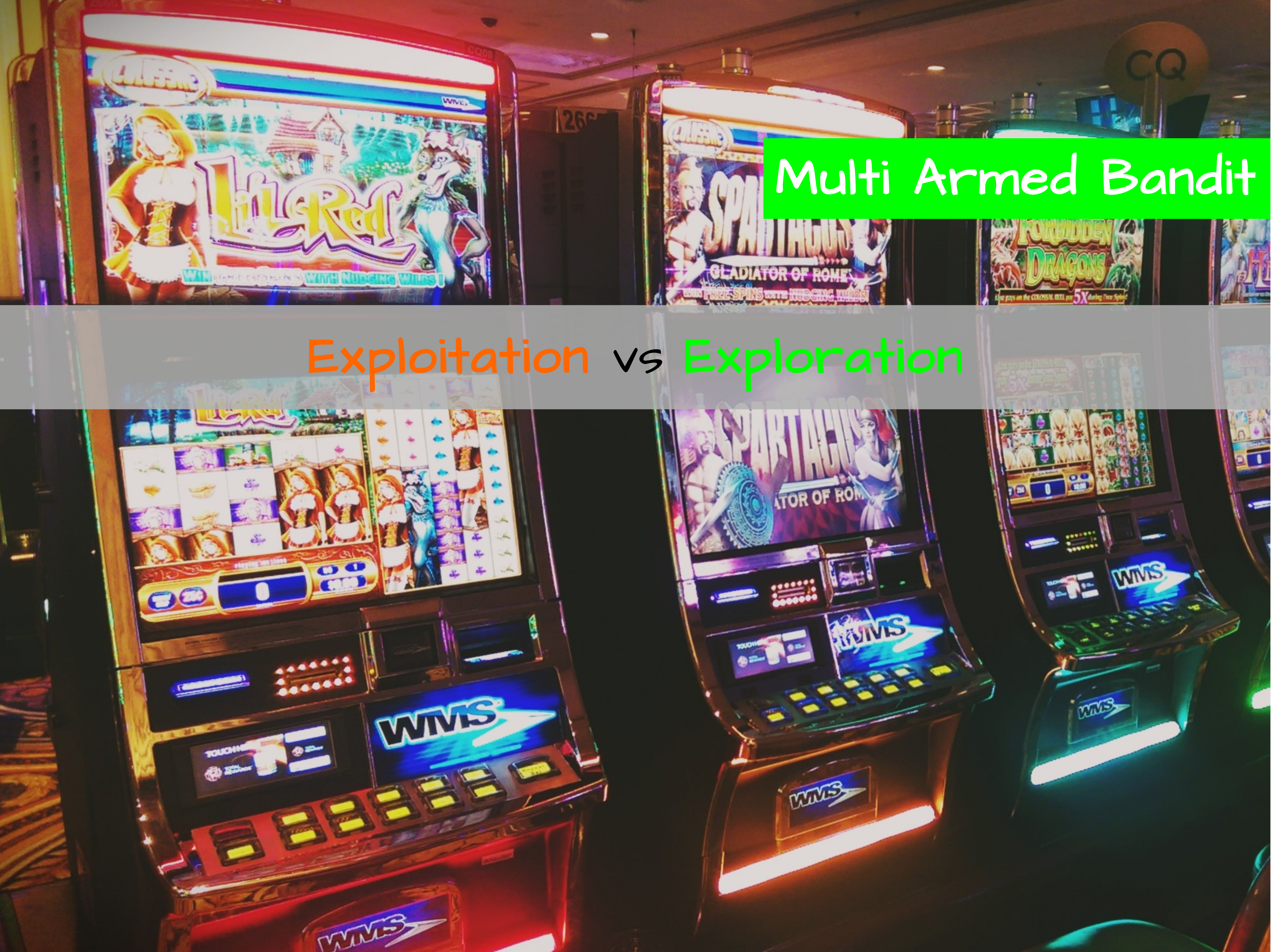
Perspective



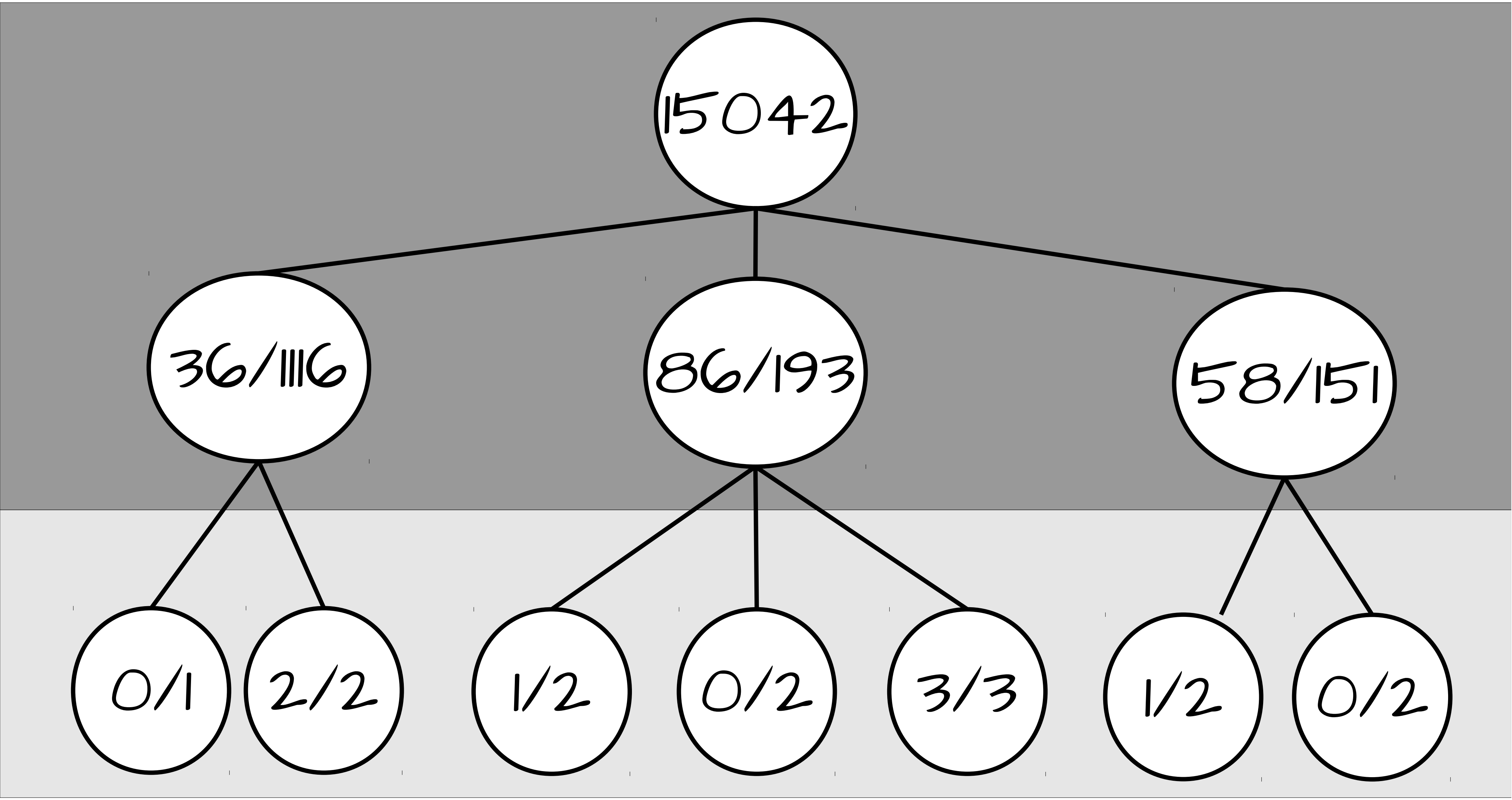
Perspective



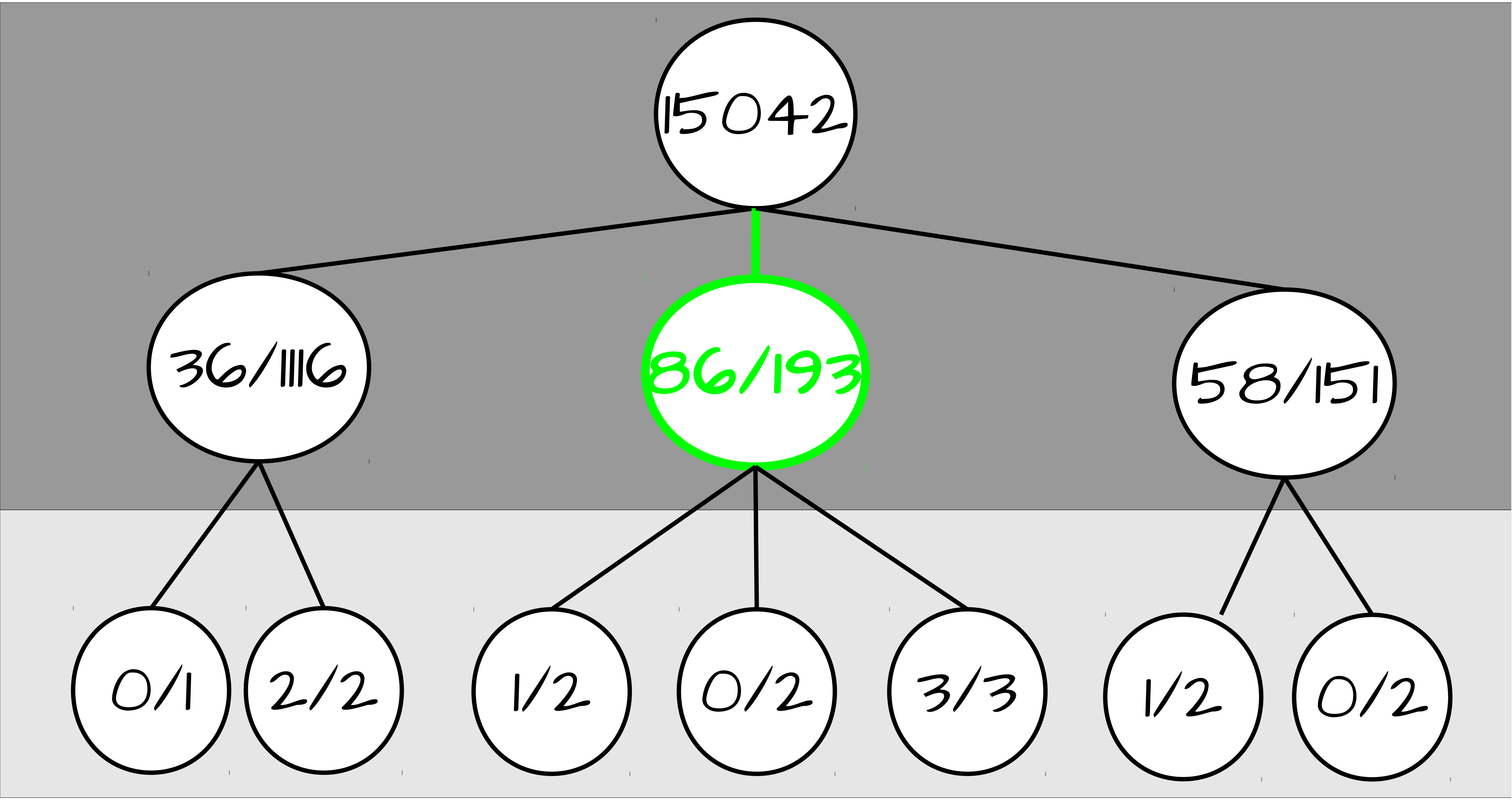

Multi Armed Bandit
Lil Red
SPARTACUS
GLADIATOR OF ROME
FORBIDDEN DRAGONS
WMS
CQ


Multi Armed Bandit
Exploitation vs Exploration
SPARTACUS
GLADIATOR OF ROME
FORBIDDEN DRAGONS
WMS

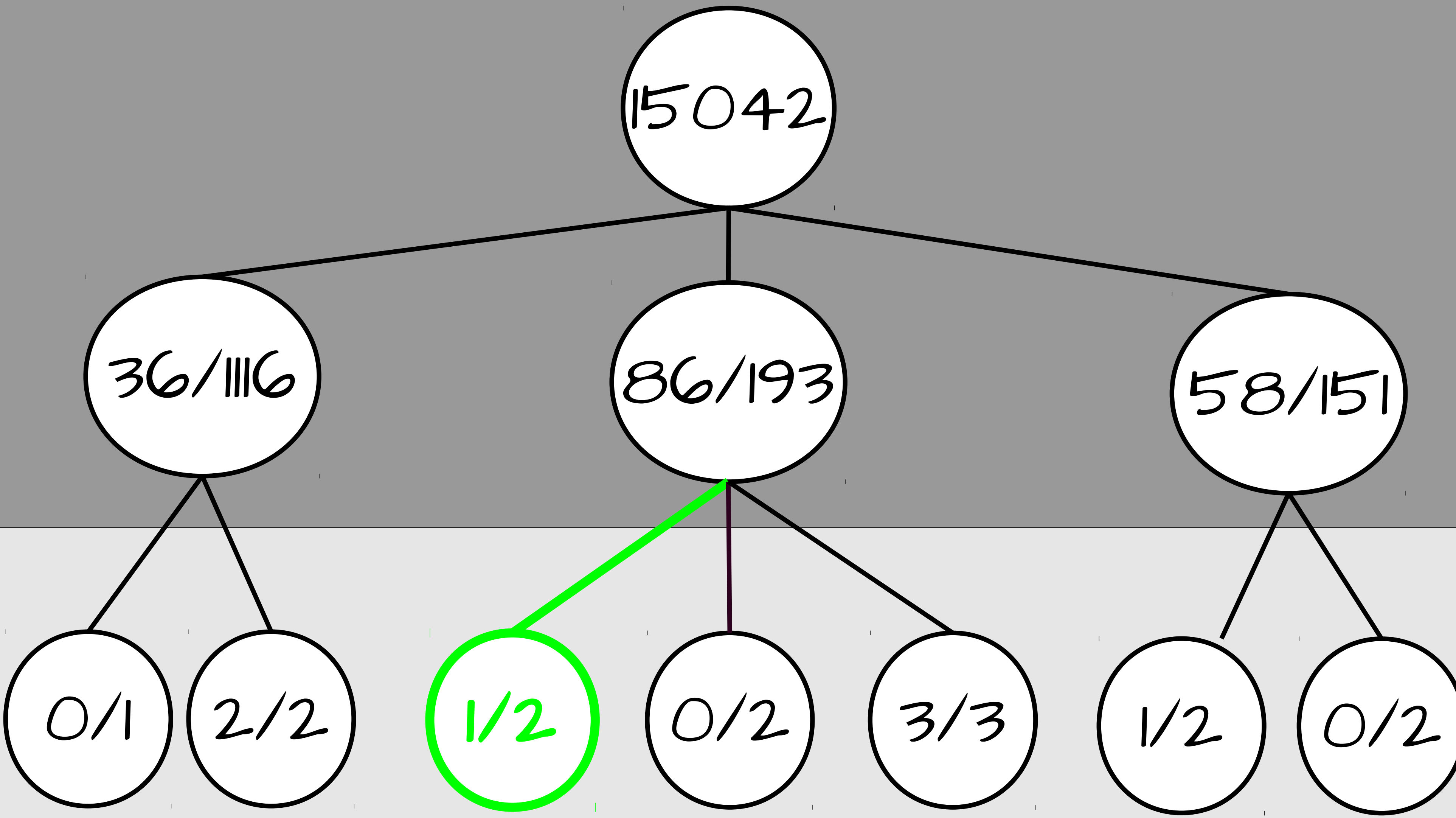
$$\frac{wins}{visits} + explorationFactor\sqrt{\frac{\ln(totalVisits)}{visits}}$$



15042
36/1116
86/193
58/151
0/1
2/2
1/2
0/2
3/3
1/2
0/2



15042
36/1116
86/193
58/151
0/1
2/2
1/2
0/2
3/3
1/2
0/2


15042
36/1116
86/193
58/151
0/1
2/2
1/2
0/2
3/3
1/2
0/2

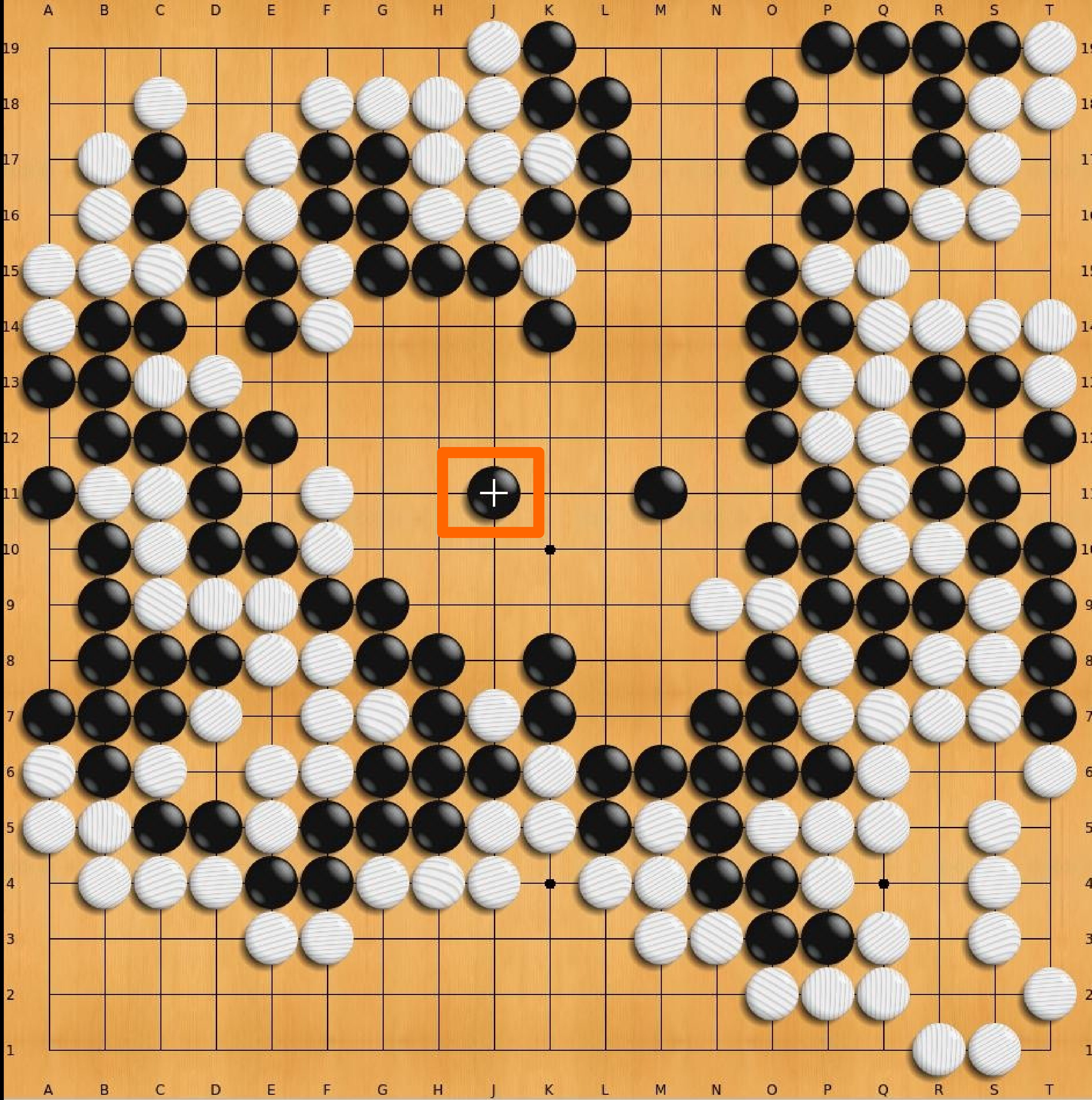
Generate a valid random move

Who has won?

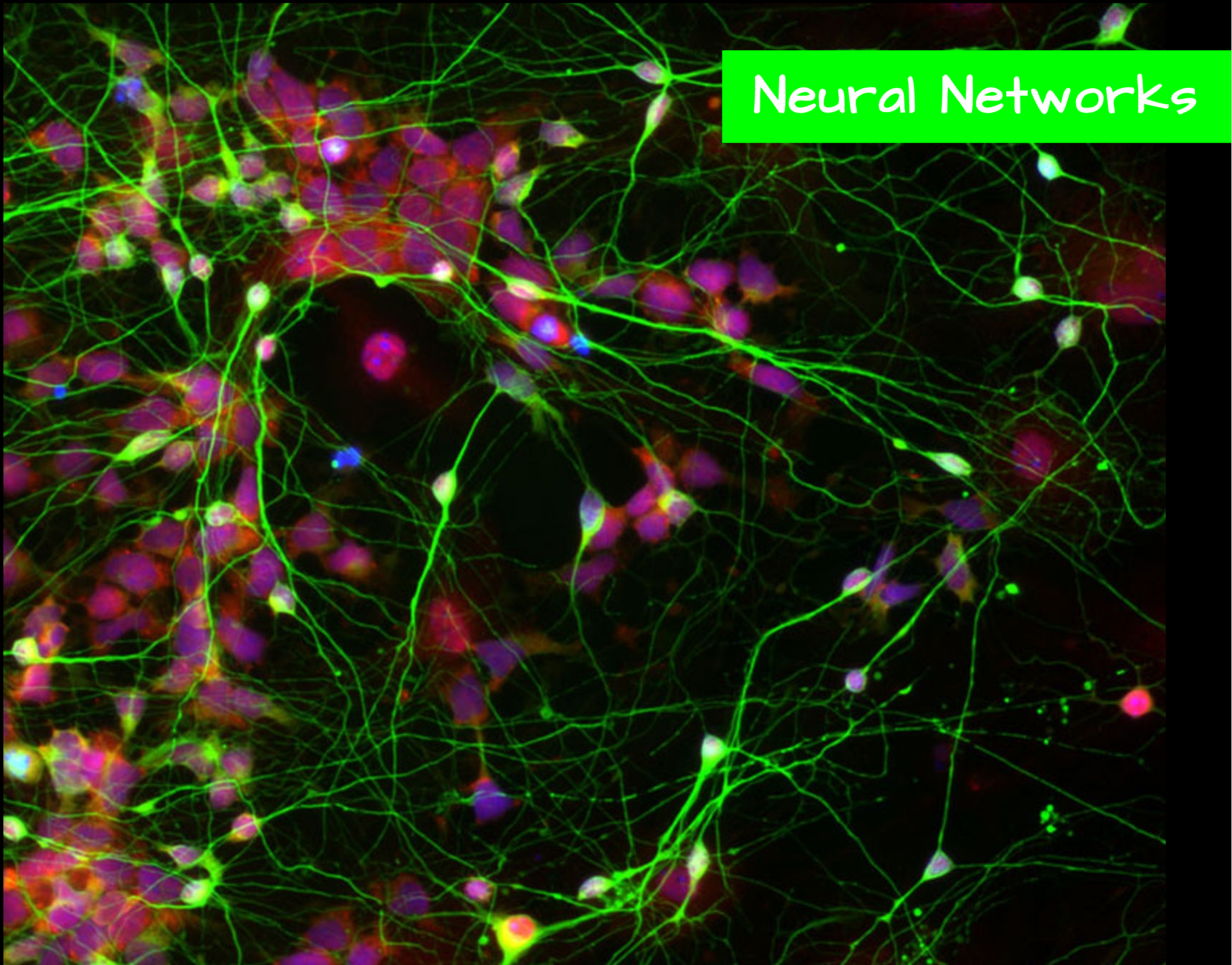
General Game Playing

Anytime


Lazy


A B C D E F G H J K L M N O P Q R S T
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Expert Knowledge


Neural Networks

MOVE EVALUATION IN GO USING DEEP CONVOLUTIONAL NEURAL NETWORKS

2014

Chris J. Maddison
University of Toronto
cmaddis@cs.toronto.edu

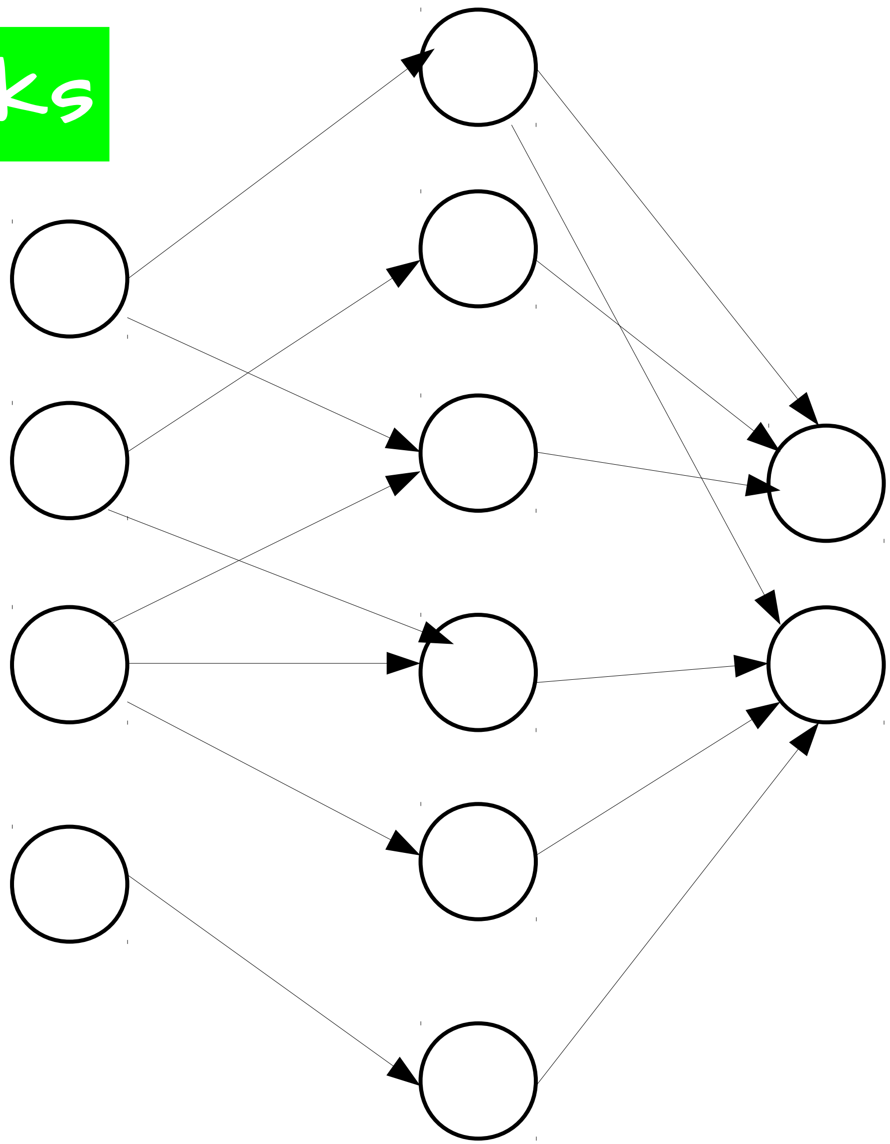
Aja Huang[1], Ilya Sutskever[2], David Silver[1]
Google DeepMind[1], Google Brain[2]
{ajahuang,ilyasu,davidsilver}@google.com

ABSTRACT

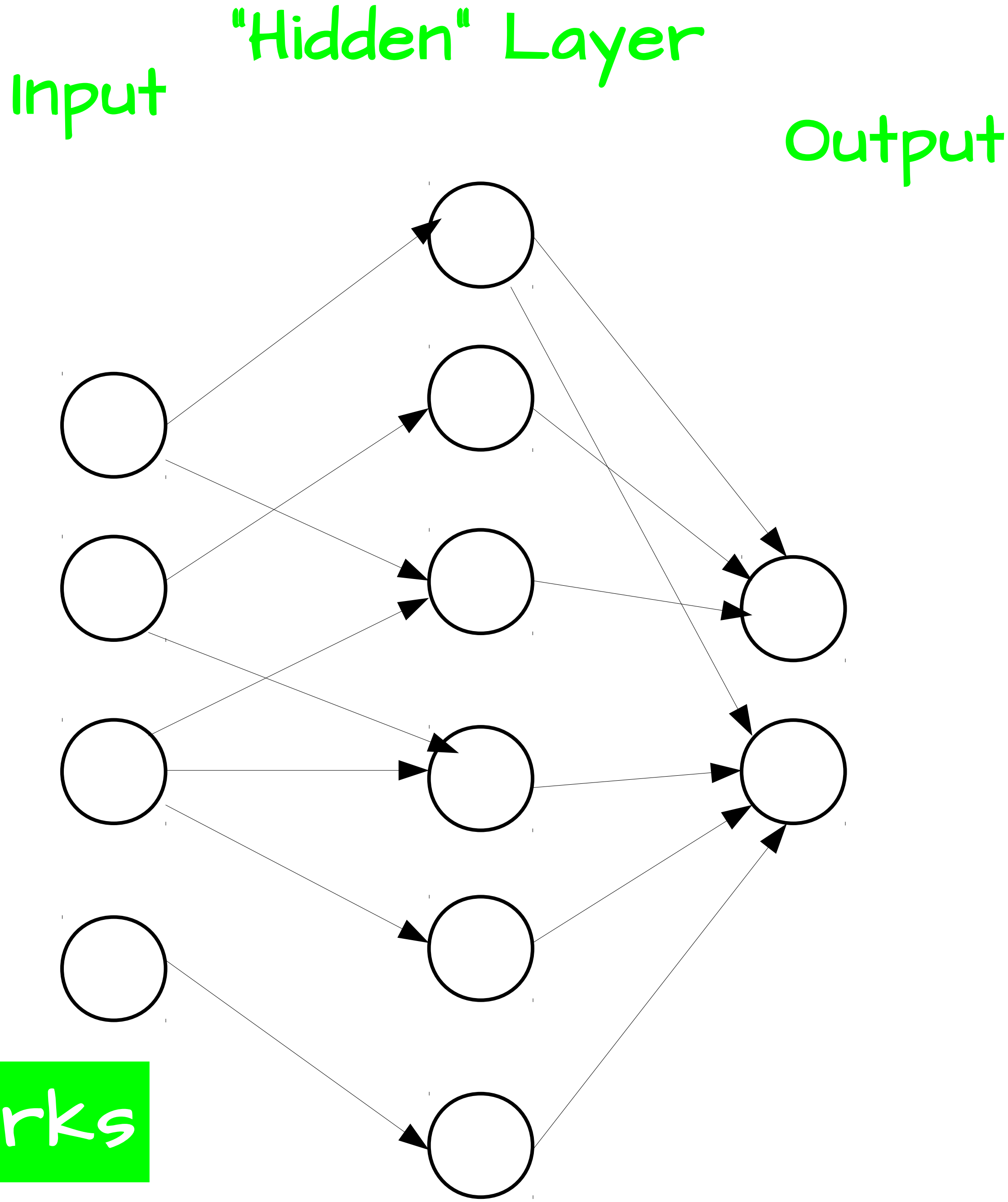
The game of Go is more challenging than other board games, due to the difficulty of constructing a position or move evaluation function. In this paper we investigate whether deep convolutional networks can be used to directly represent and learn this knowledge. We train a large 12-layer convolutional neural network by supervised learning from a database of human professional games. The network correctly predicts the expert move in 55% of positions, equalling the accuracy of a 6 dan human player. When the trained convolutional network was used di-

What does this even mean?

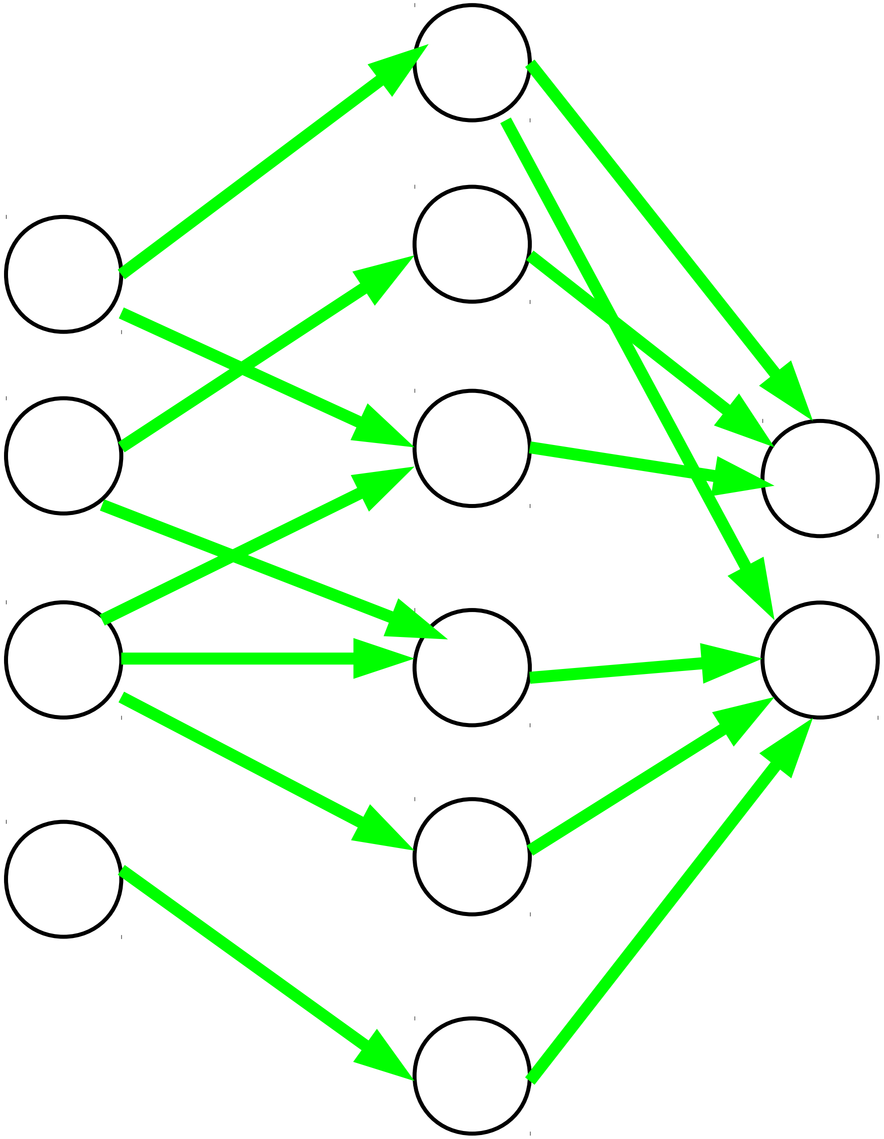
Neural Networks



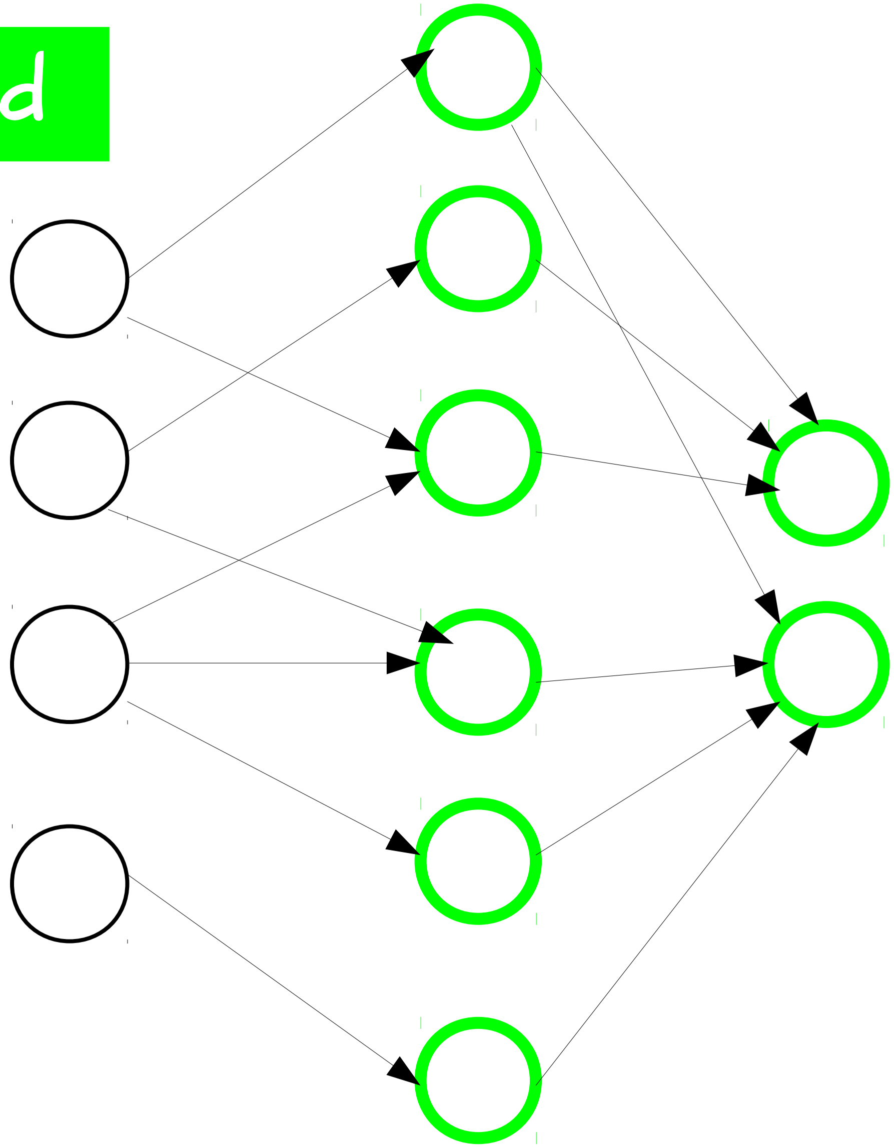
Neural Networks



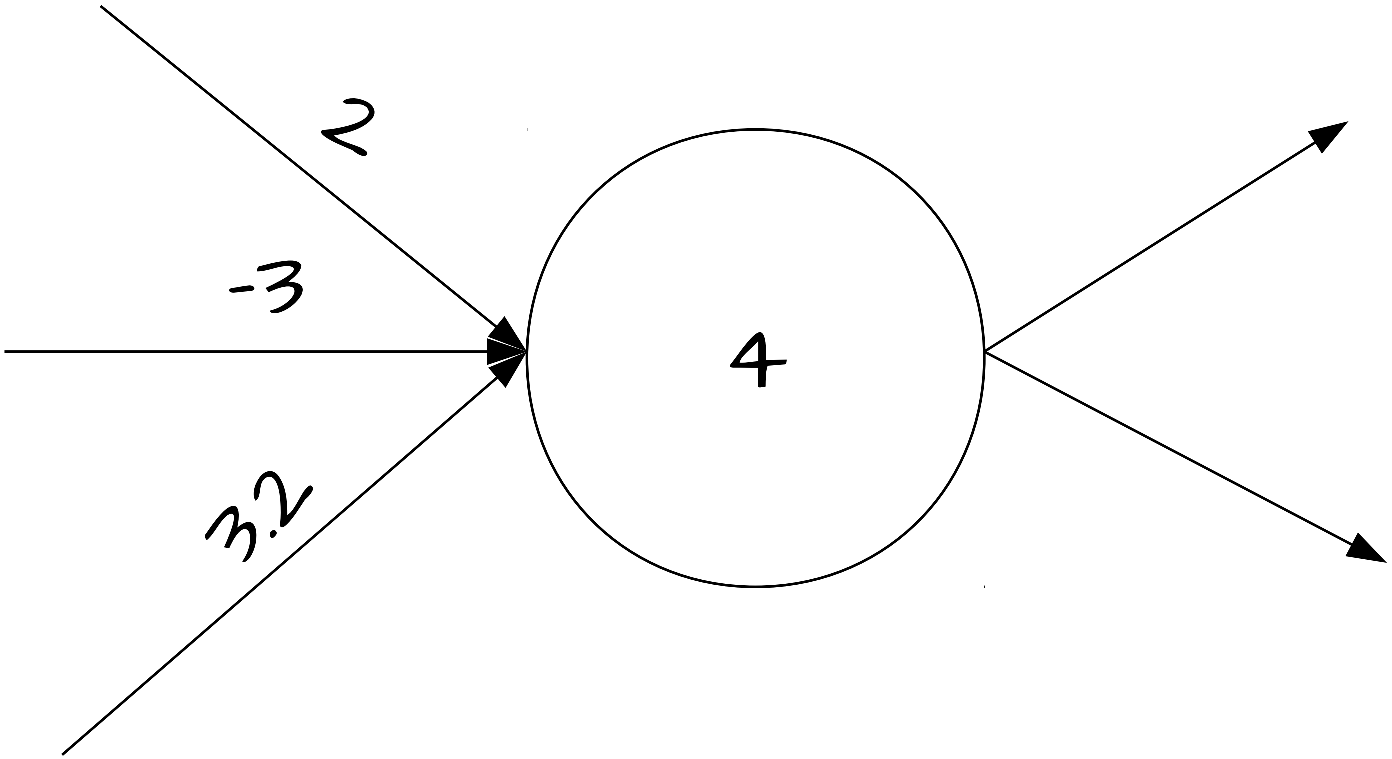
Weights



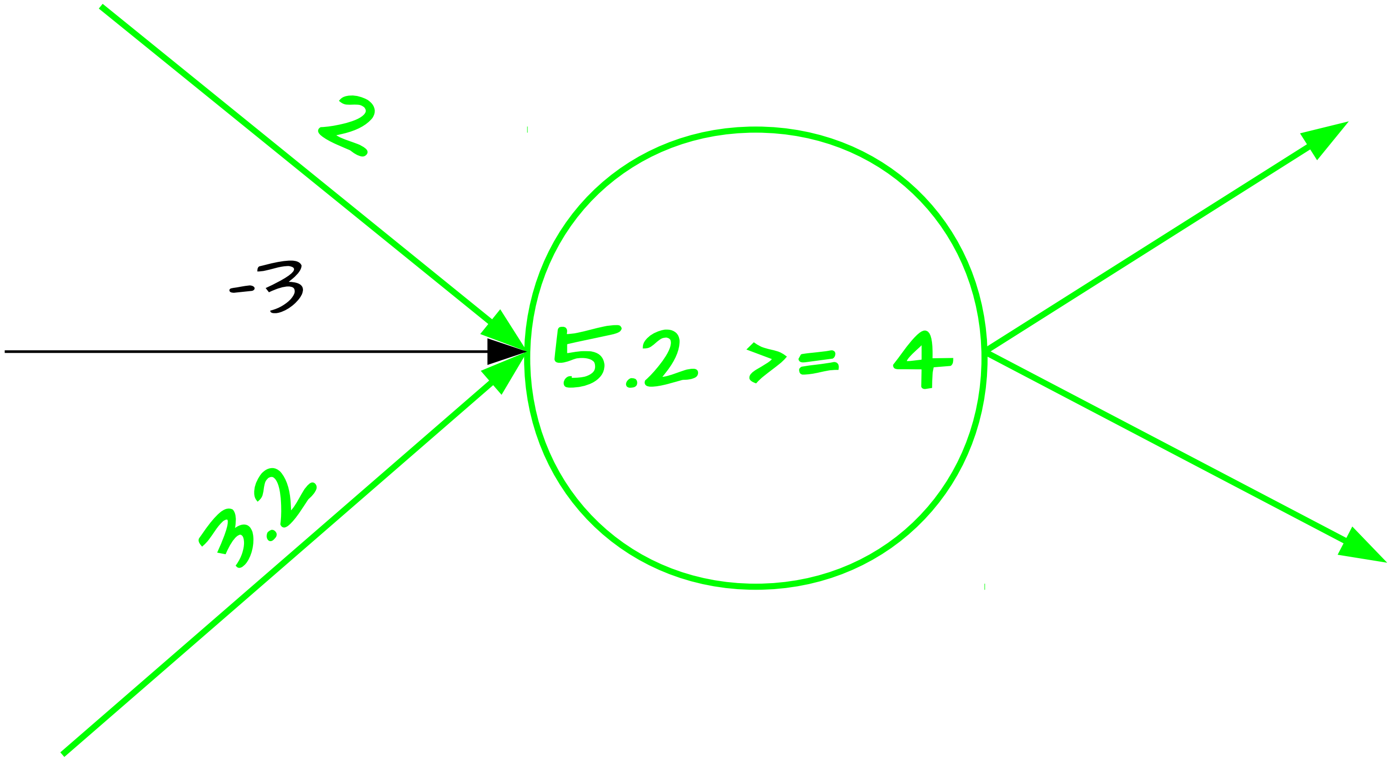
Bias/Threshold



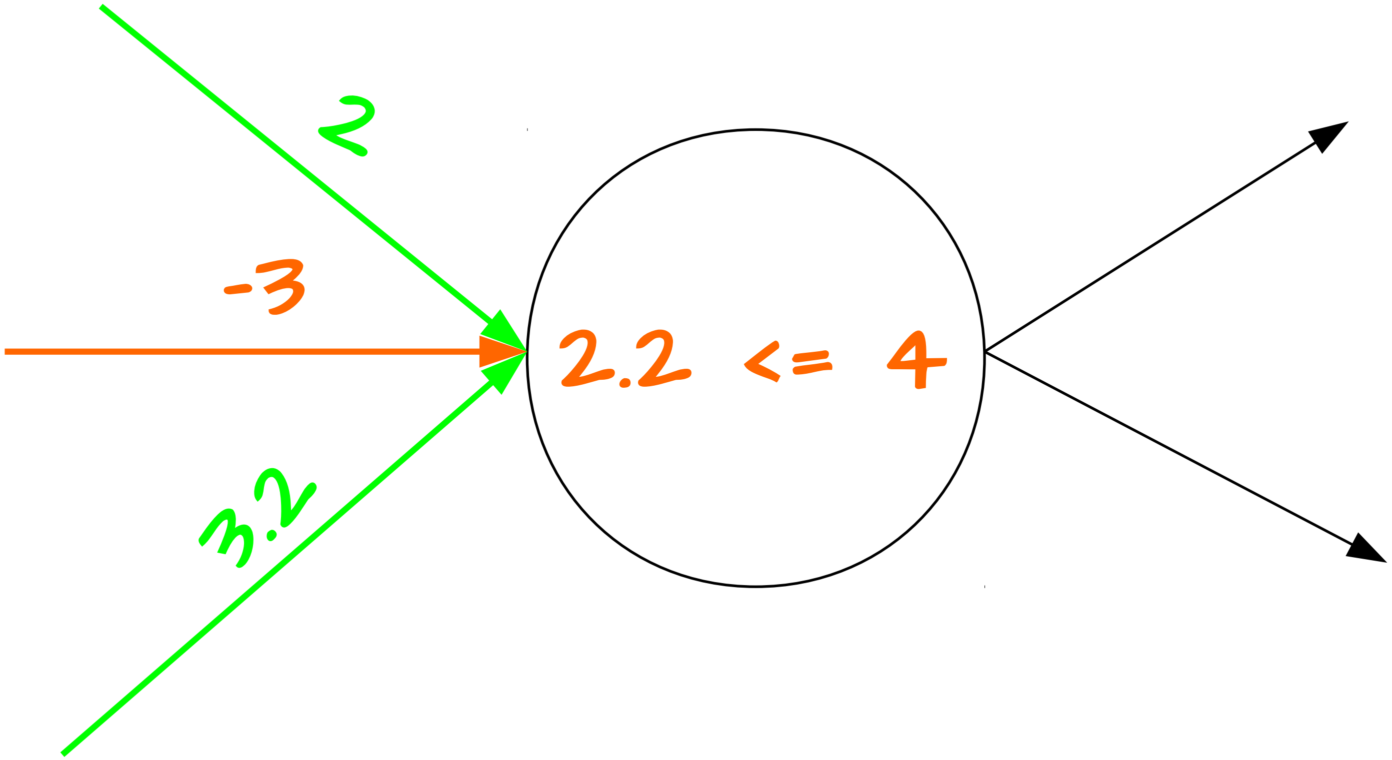
Activation



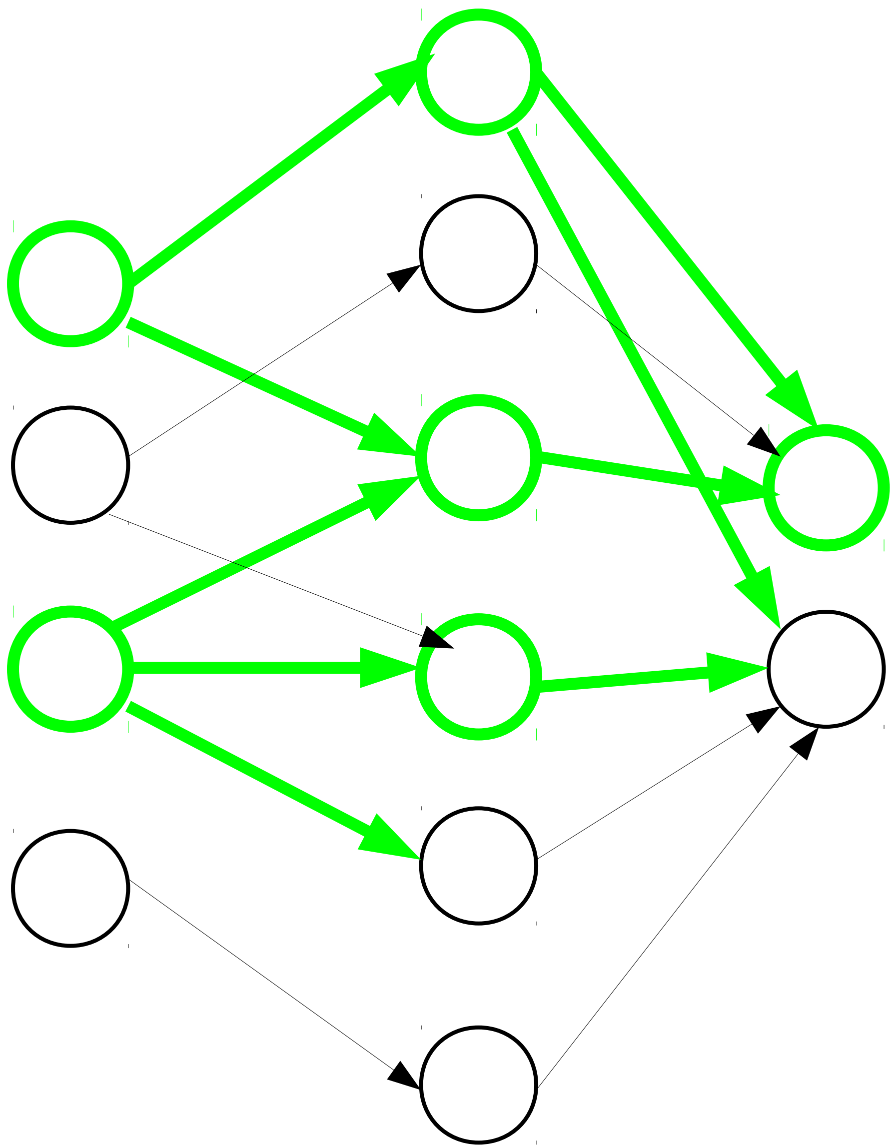
Activation



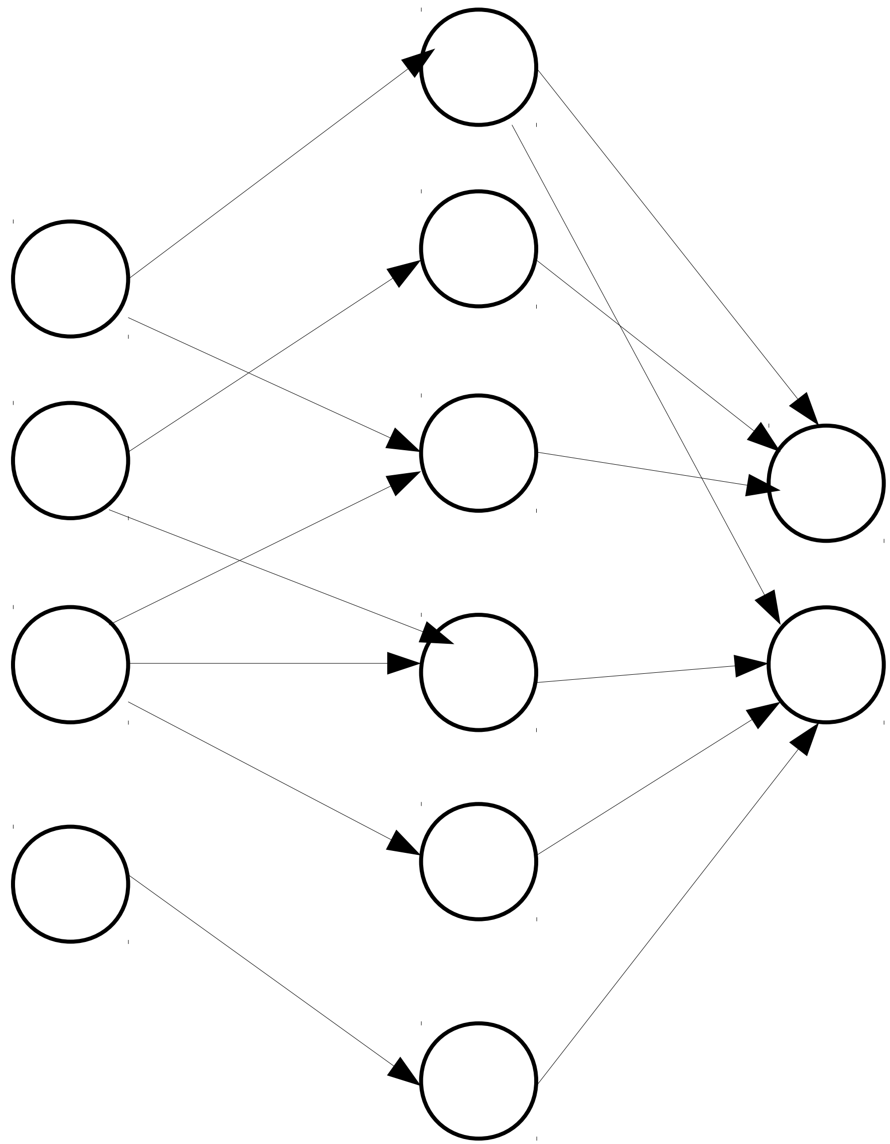
Activation



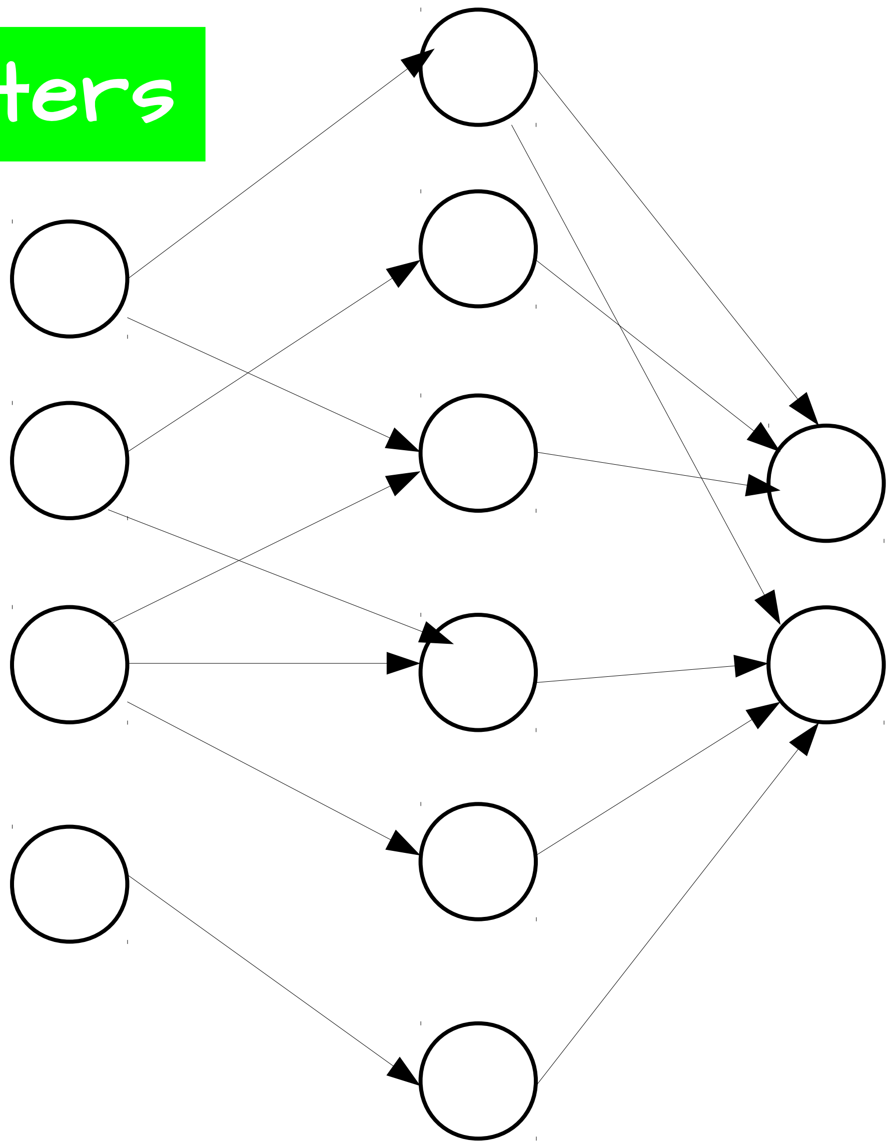
Activation



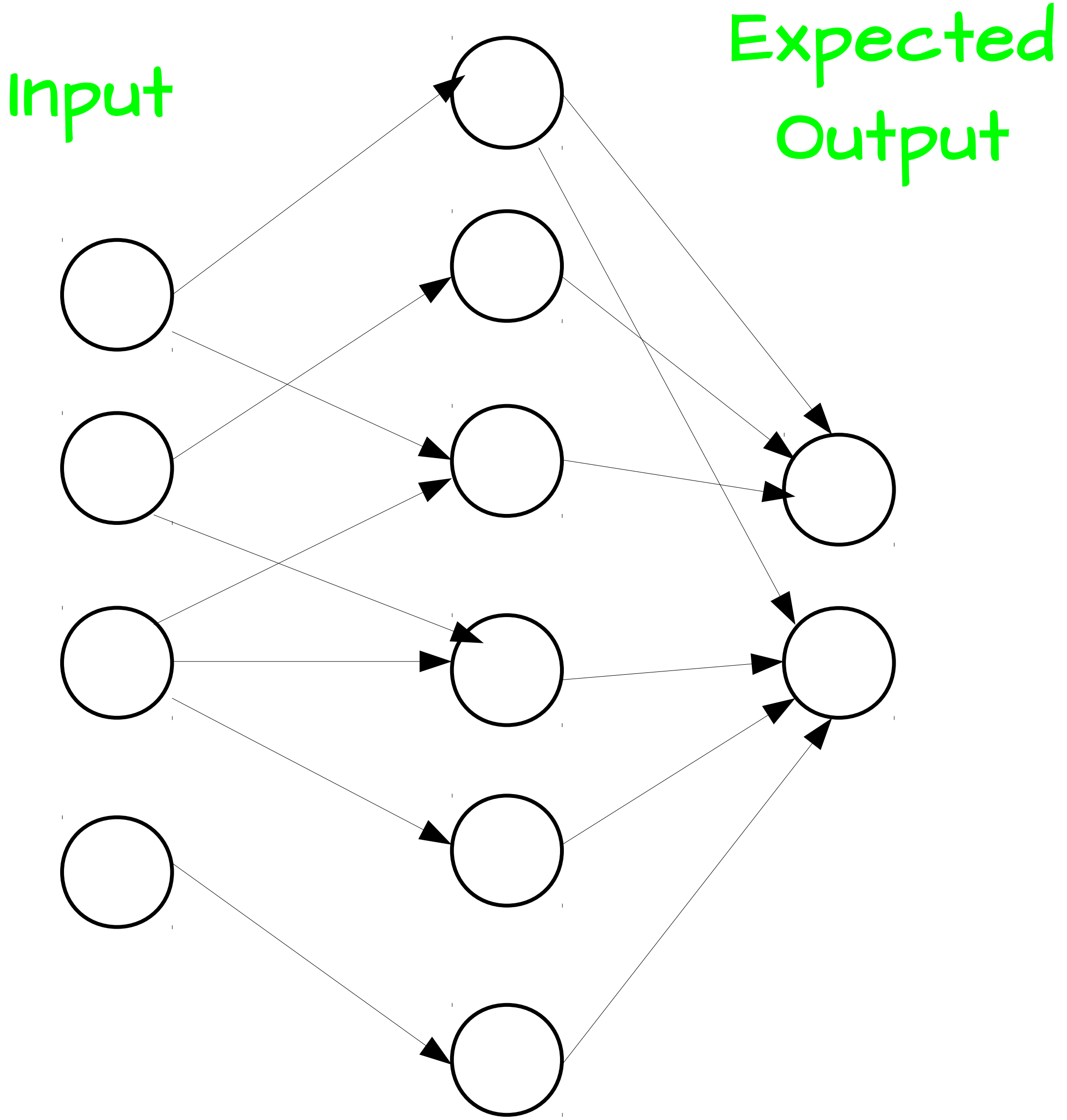
Training



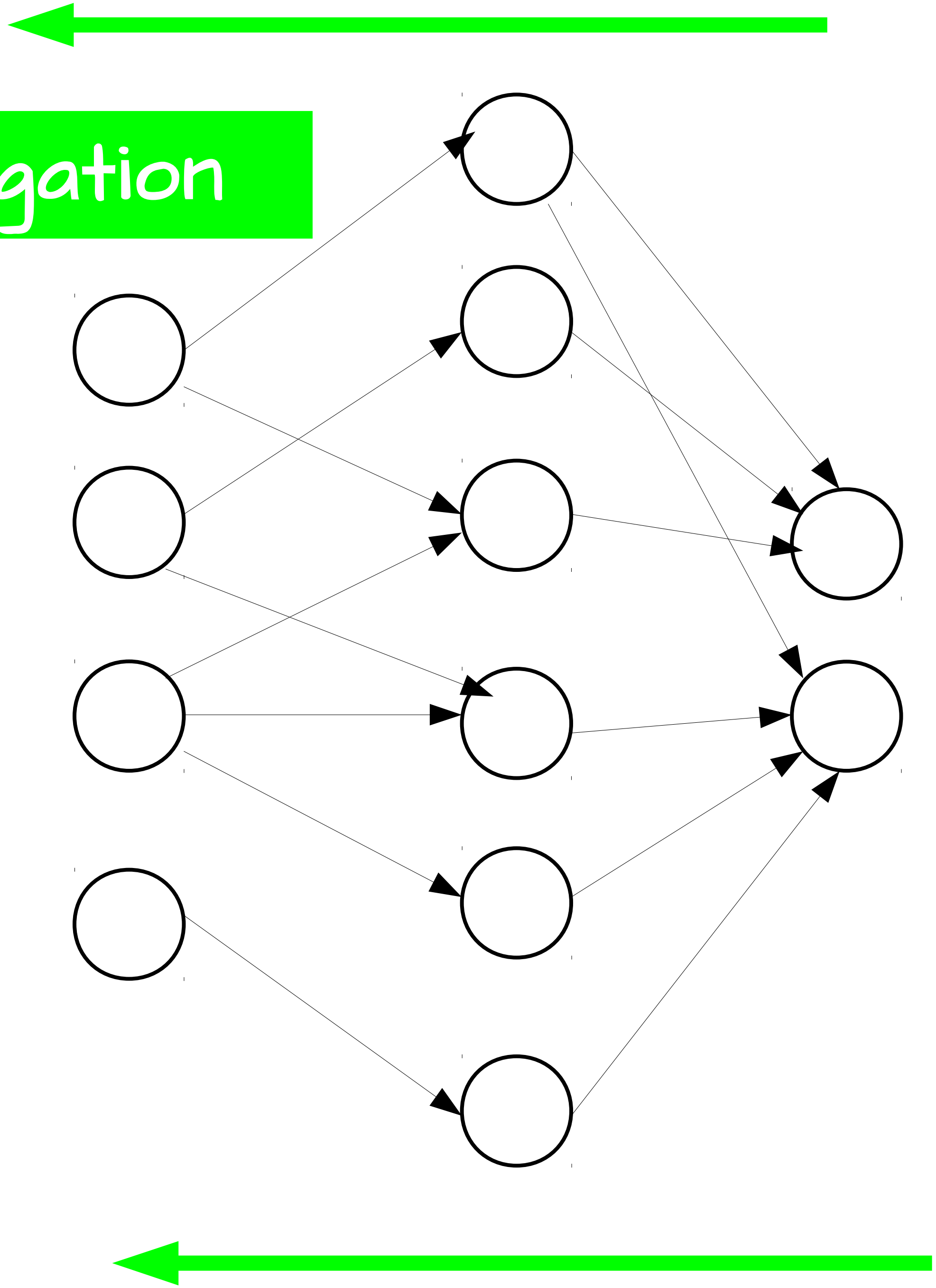
Adjust parameters



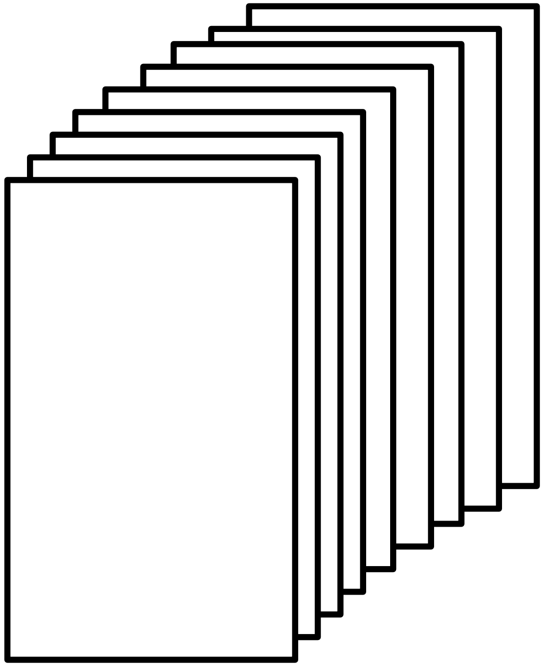
Supervised Learning



Backpropagation



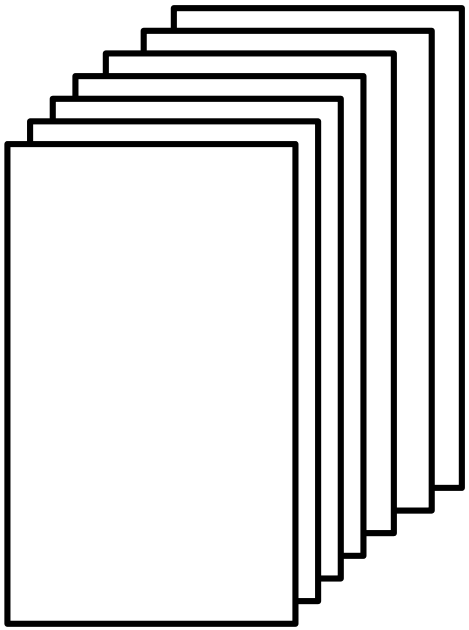
Data set

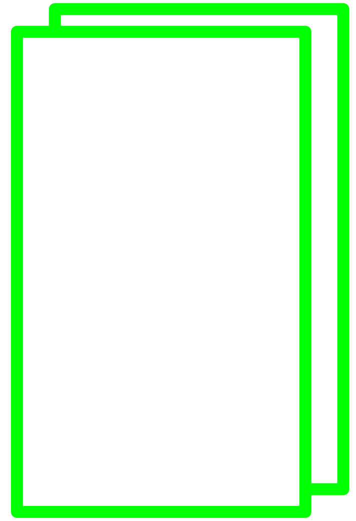


Training data + test data

Training

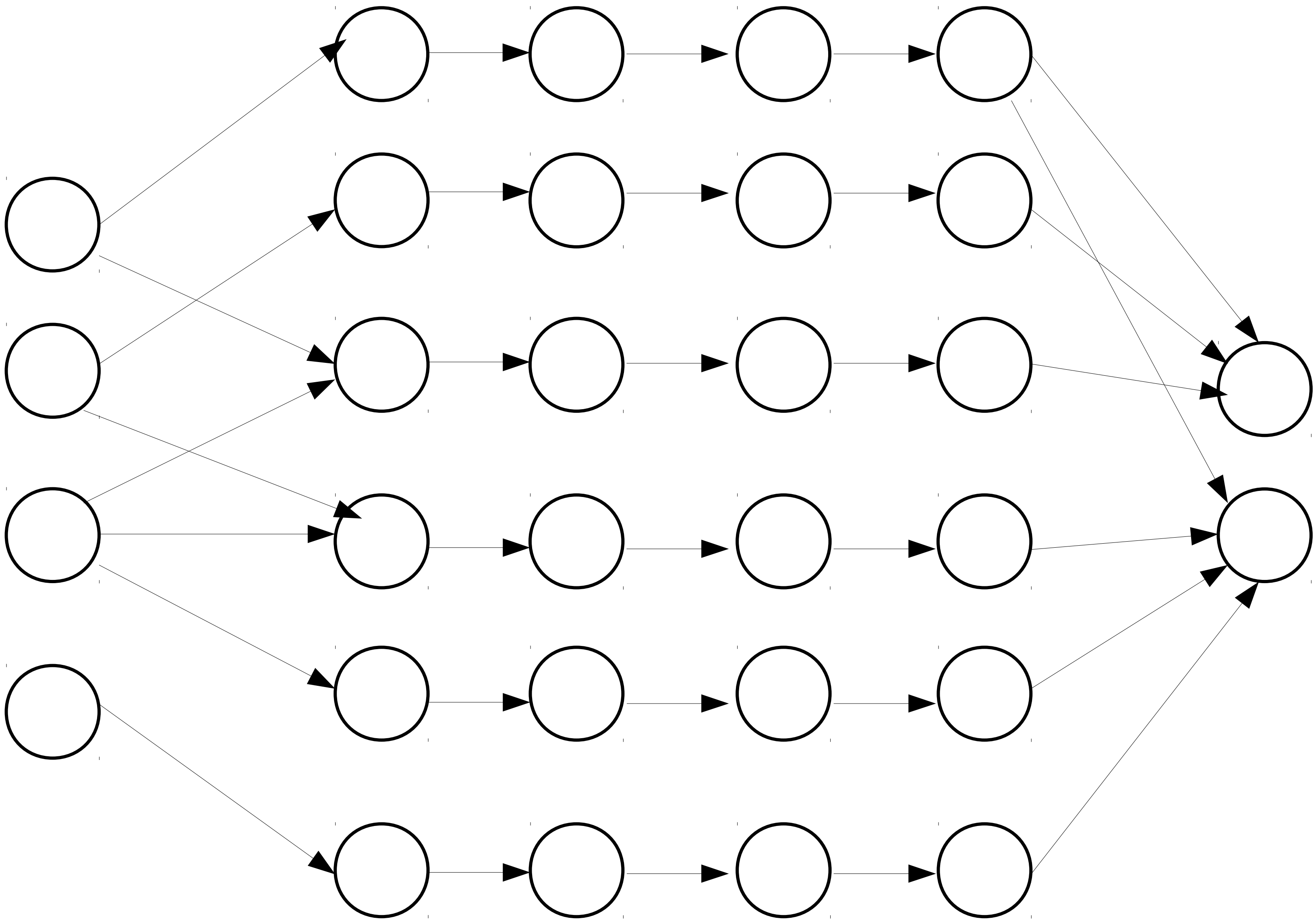
Verify



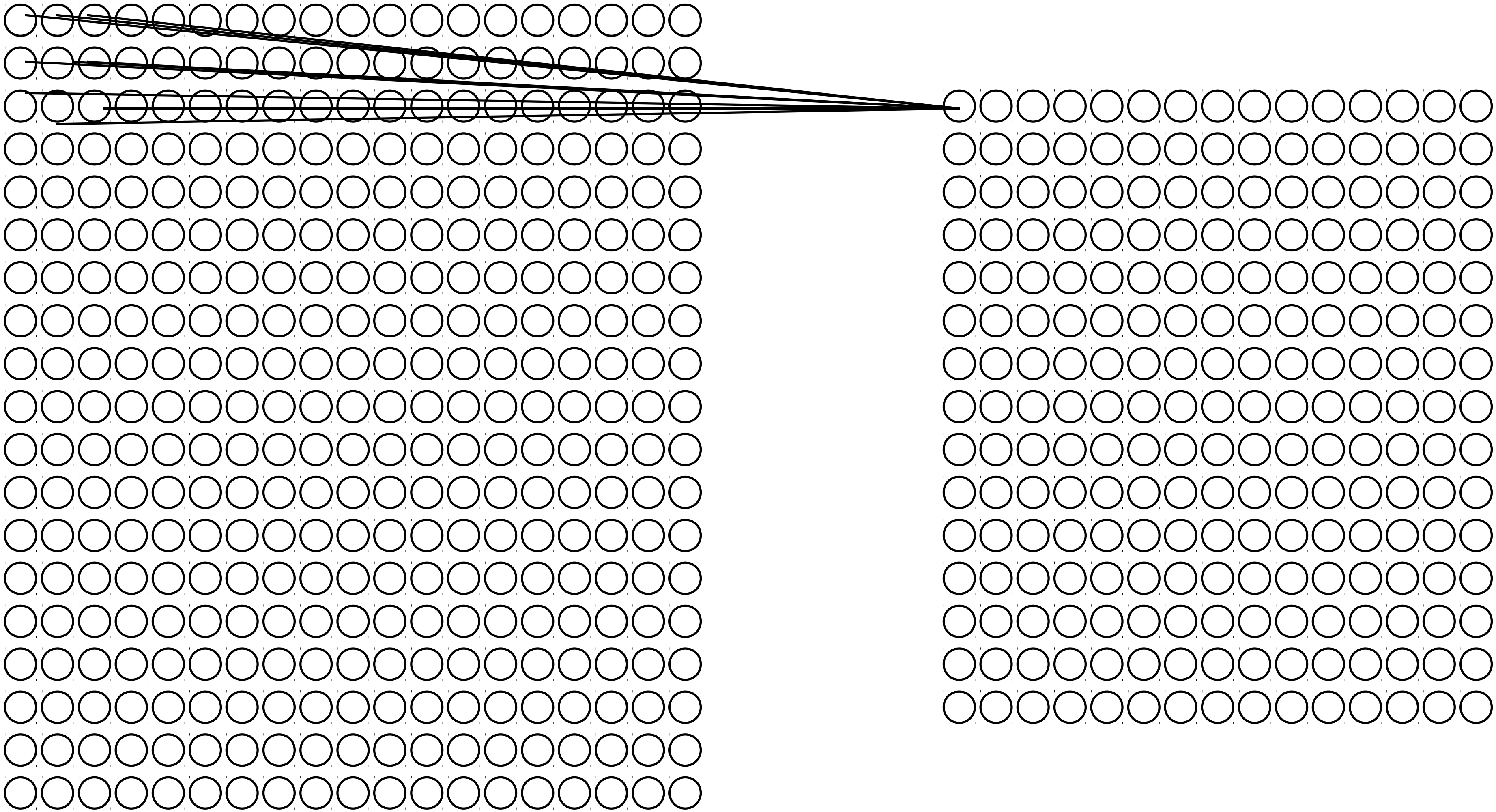


Overfitting

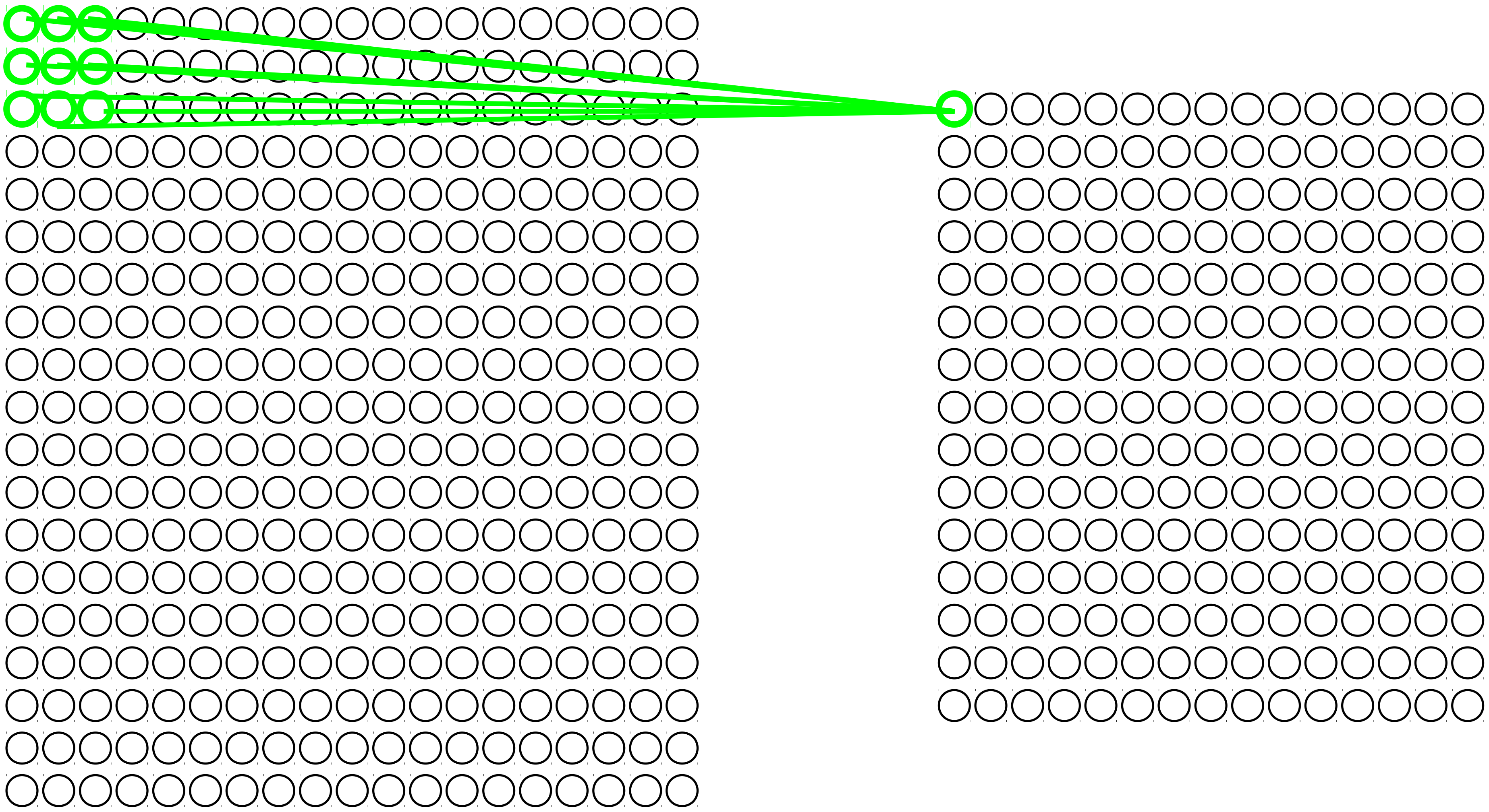
Deep Neural Networks



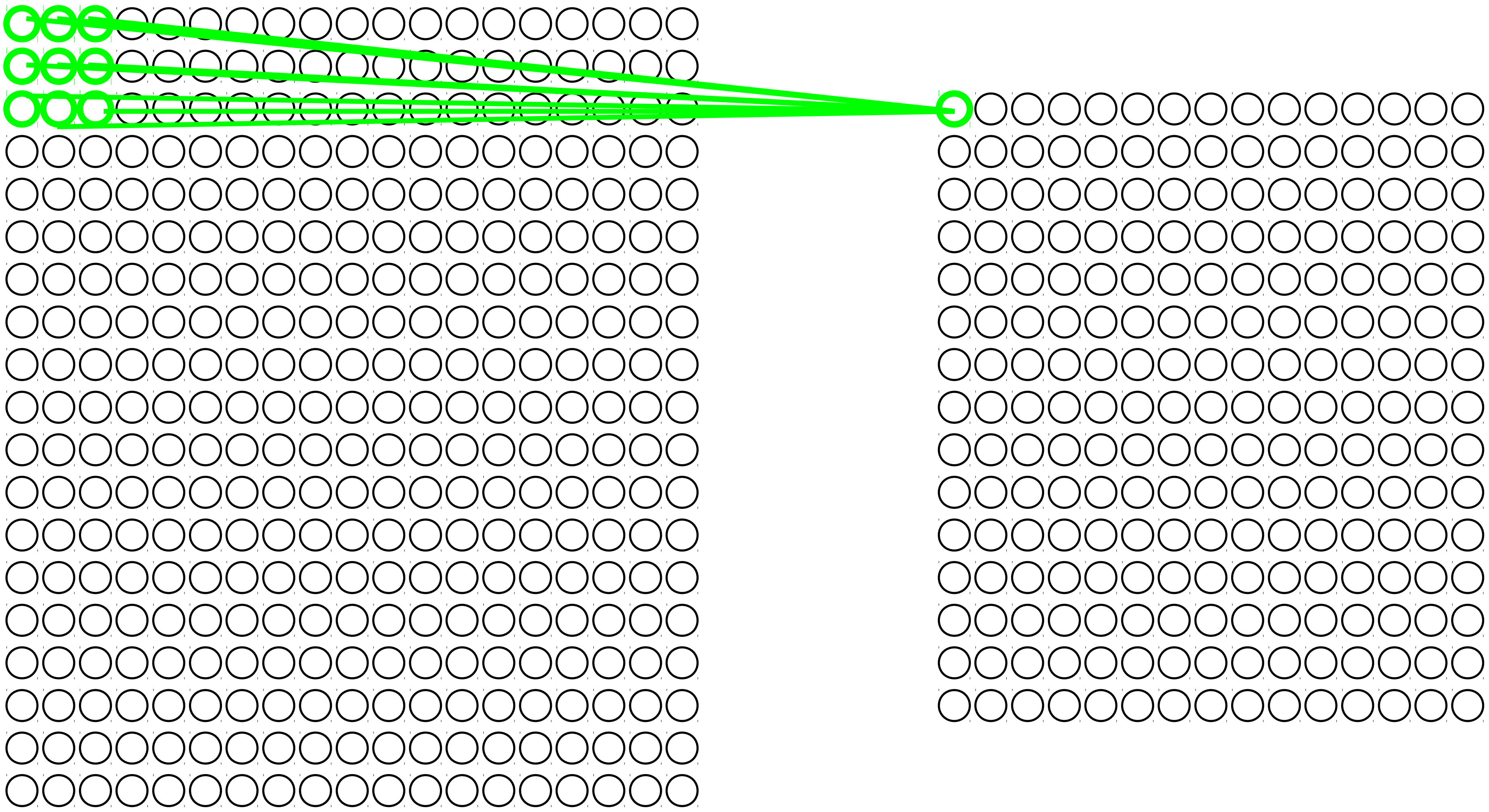
Convolutional Neural Networks



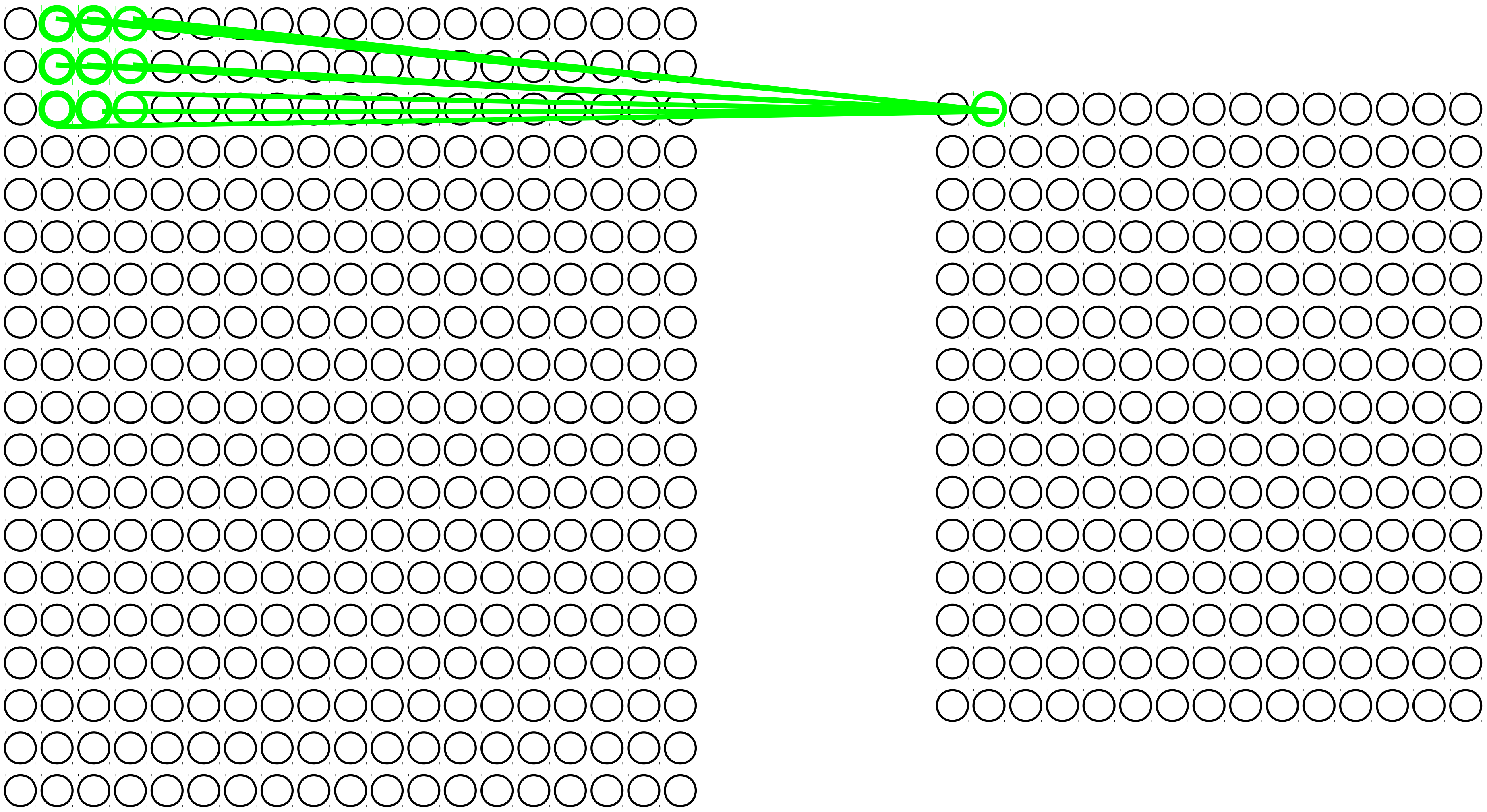
Local Receptive Field



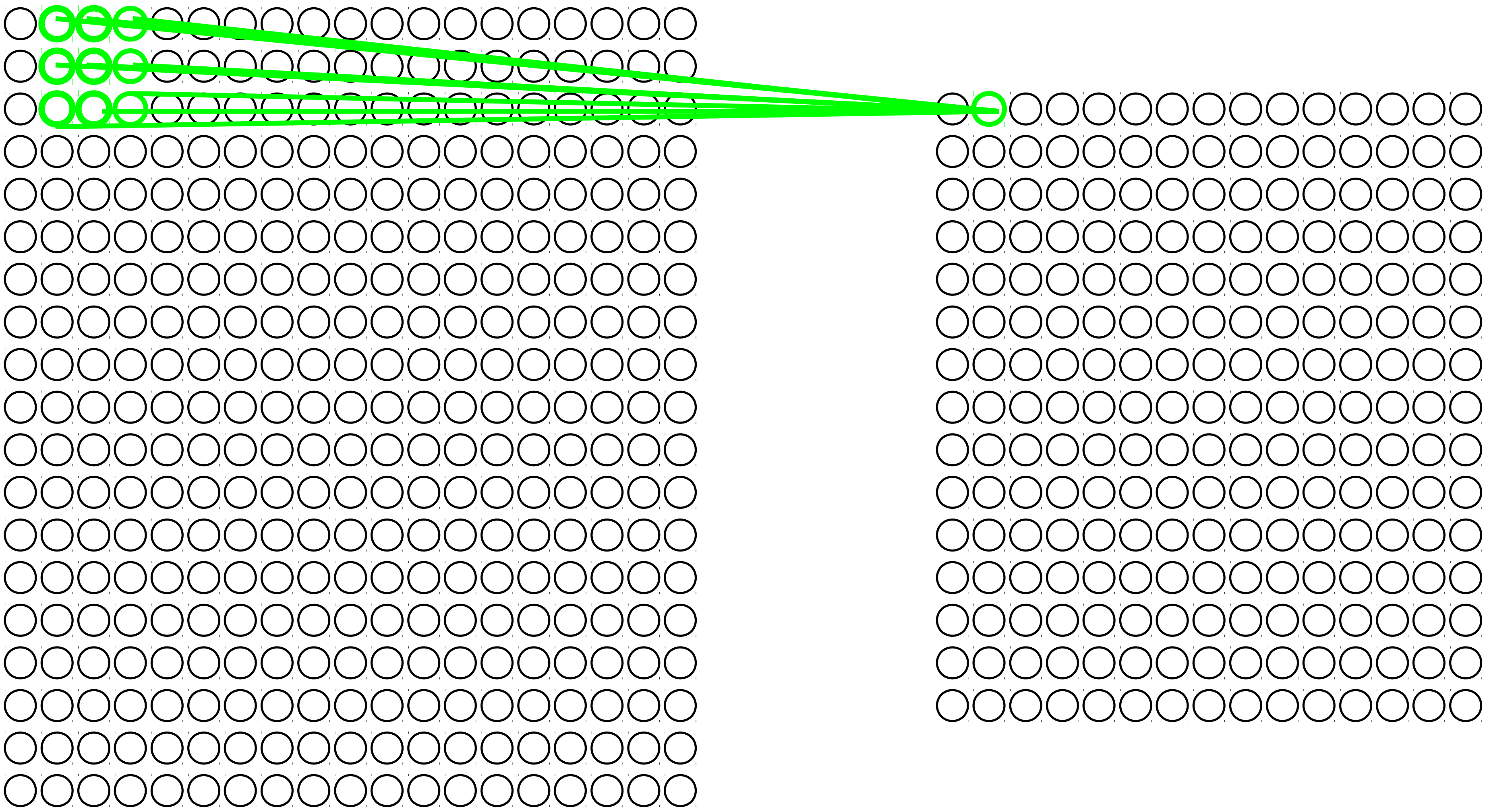
Feature Map



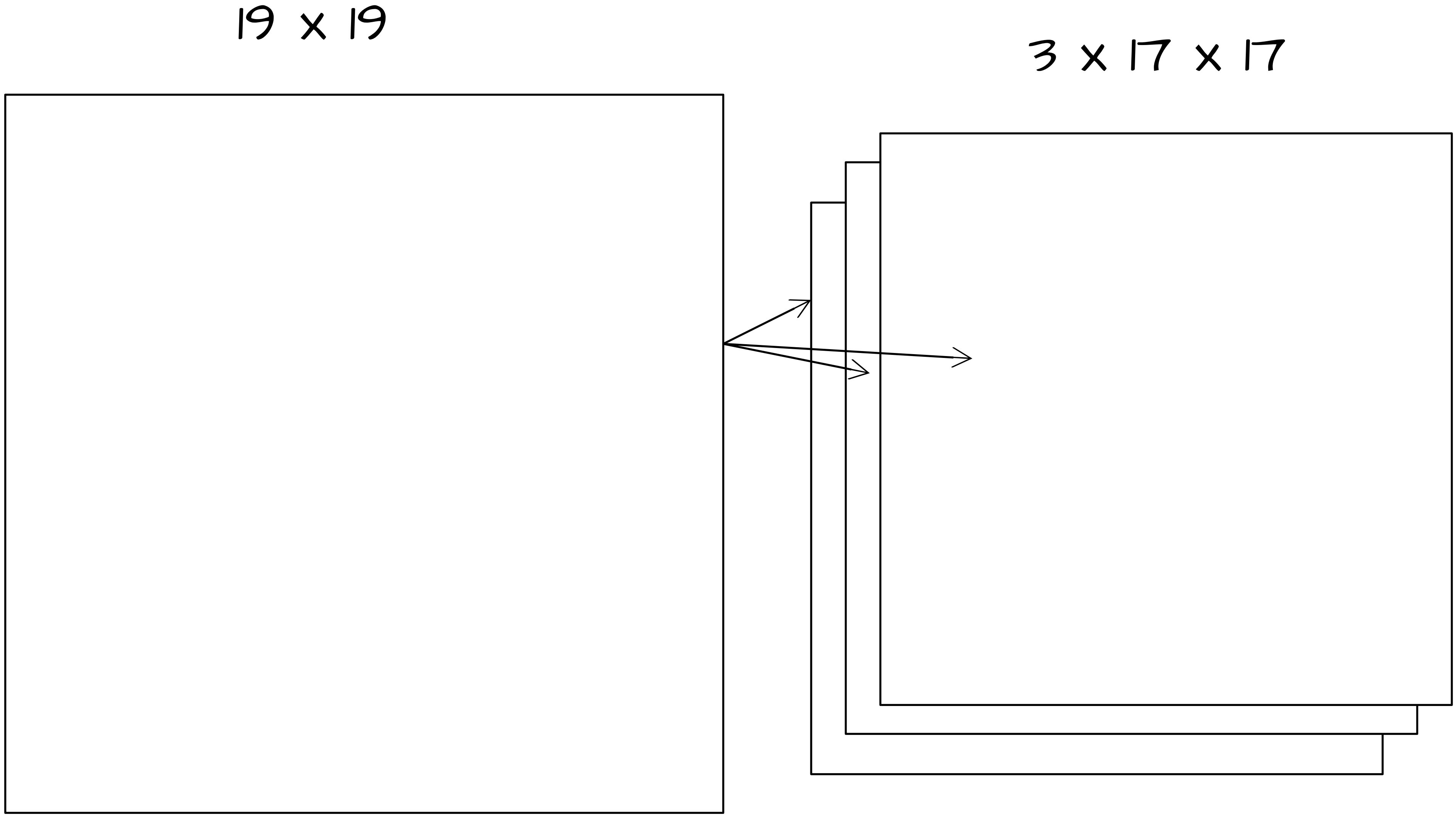
Stride



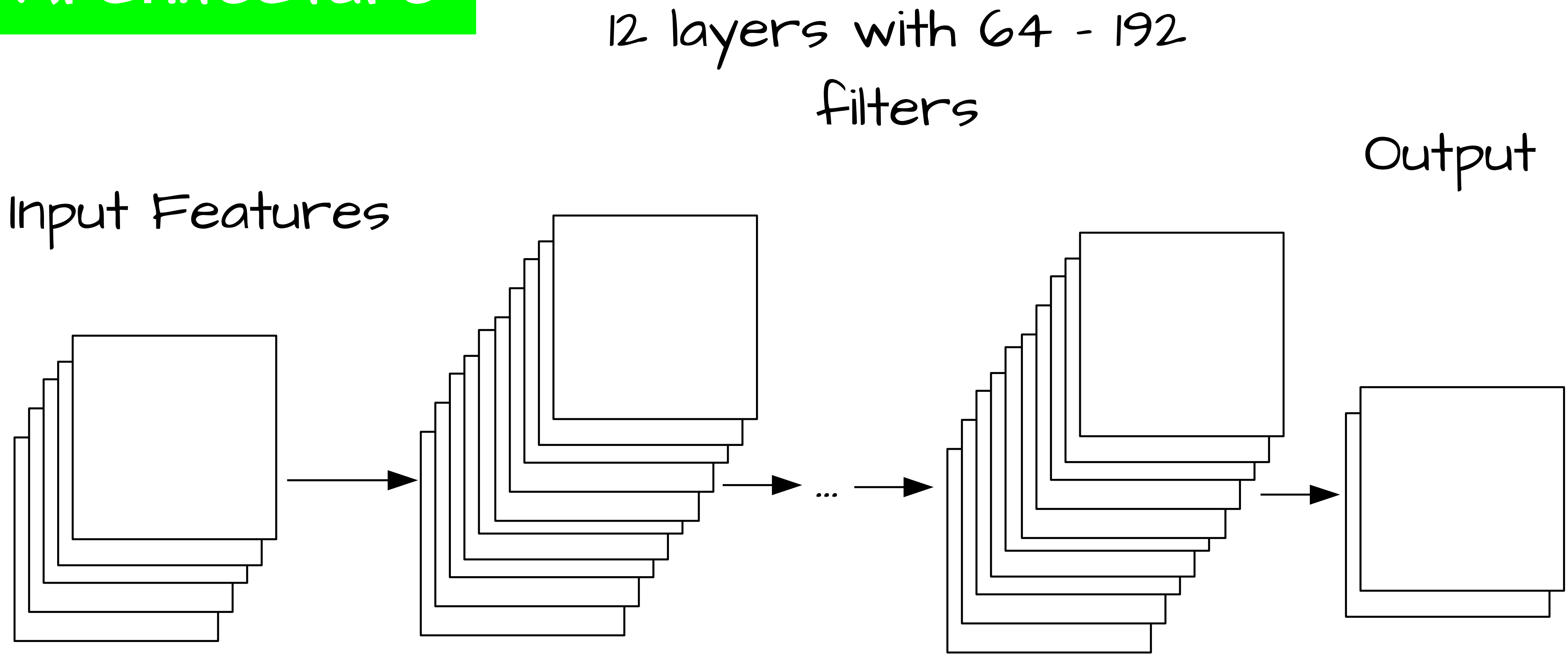
Shared weights and biases



Multiple Feature maps/filters

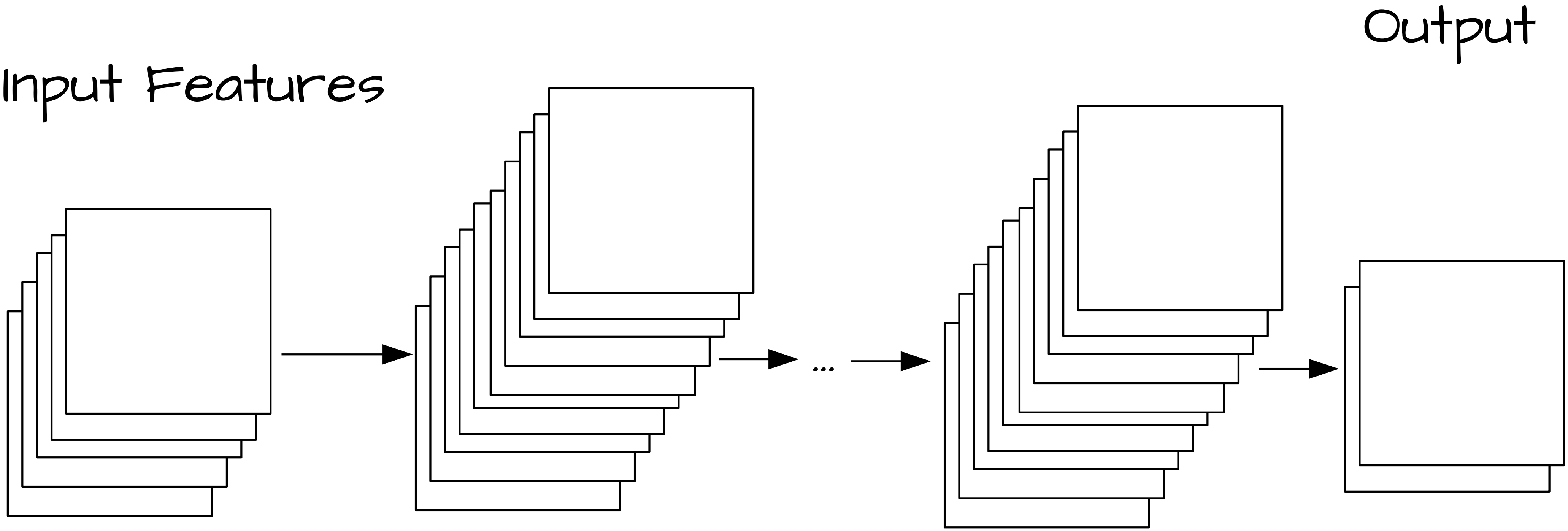


Architecture

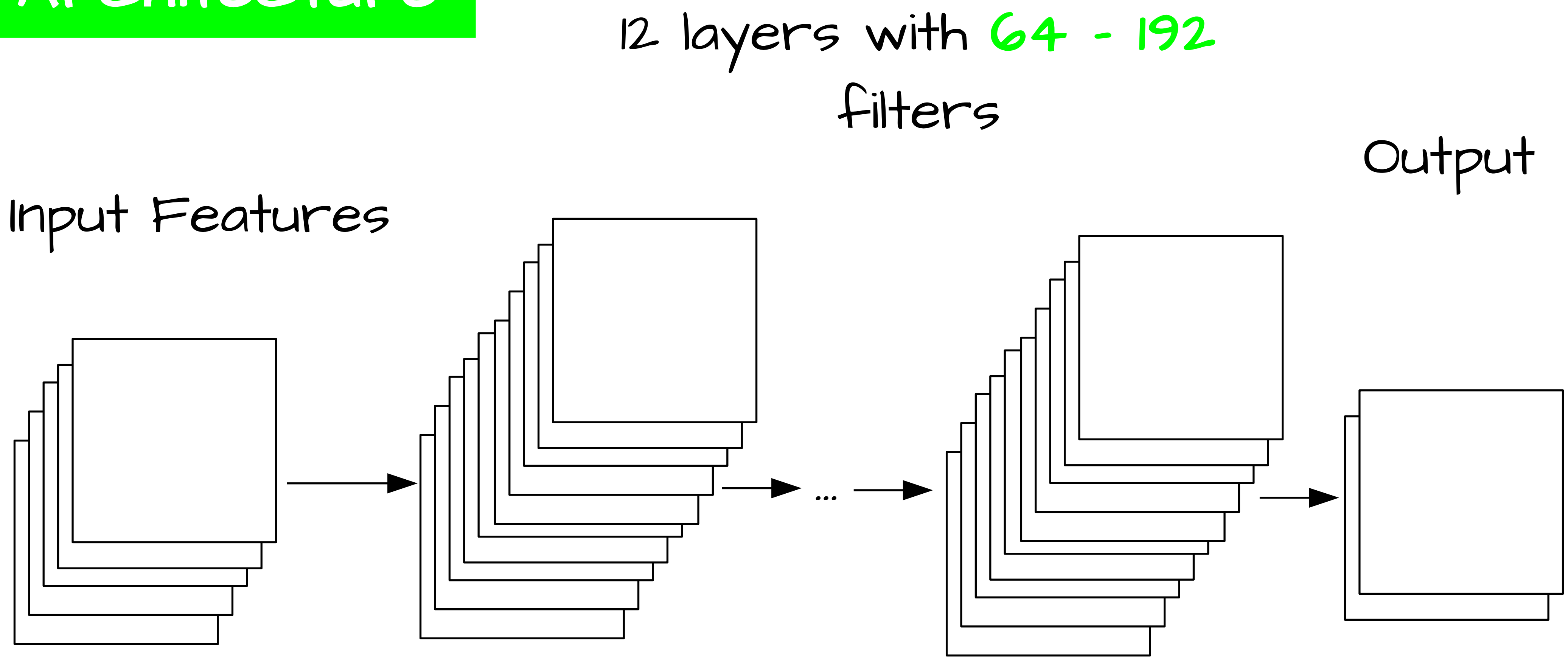


Architecture

12 layers with 64 - 192 filters



Architecture



2.3 million parameters
630 million connections

Input Features

- Stone Colour x 3
- Liberties x 4
- Liberties after move played x 6
- Legal Move x 1
- Turns since x 5
- Capture Size x 7
- Ladder Move x 1
- KGS Rank x 9

Training on game data predicting the next move

55% Accuracy

Mostly beats GnuGo

Combined with MCTS in the

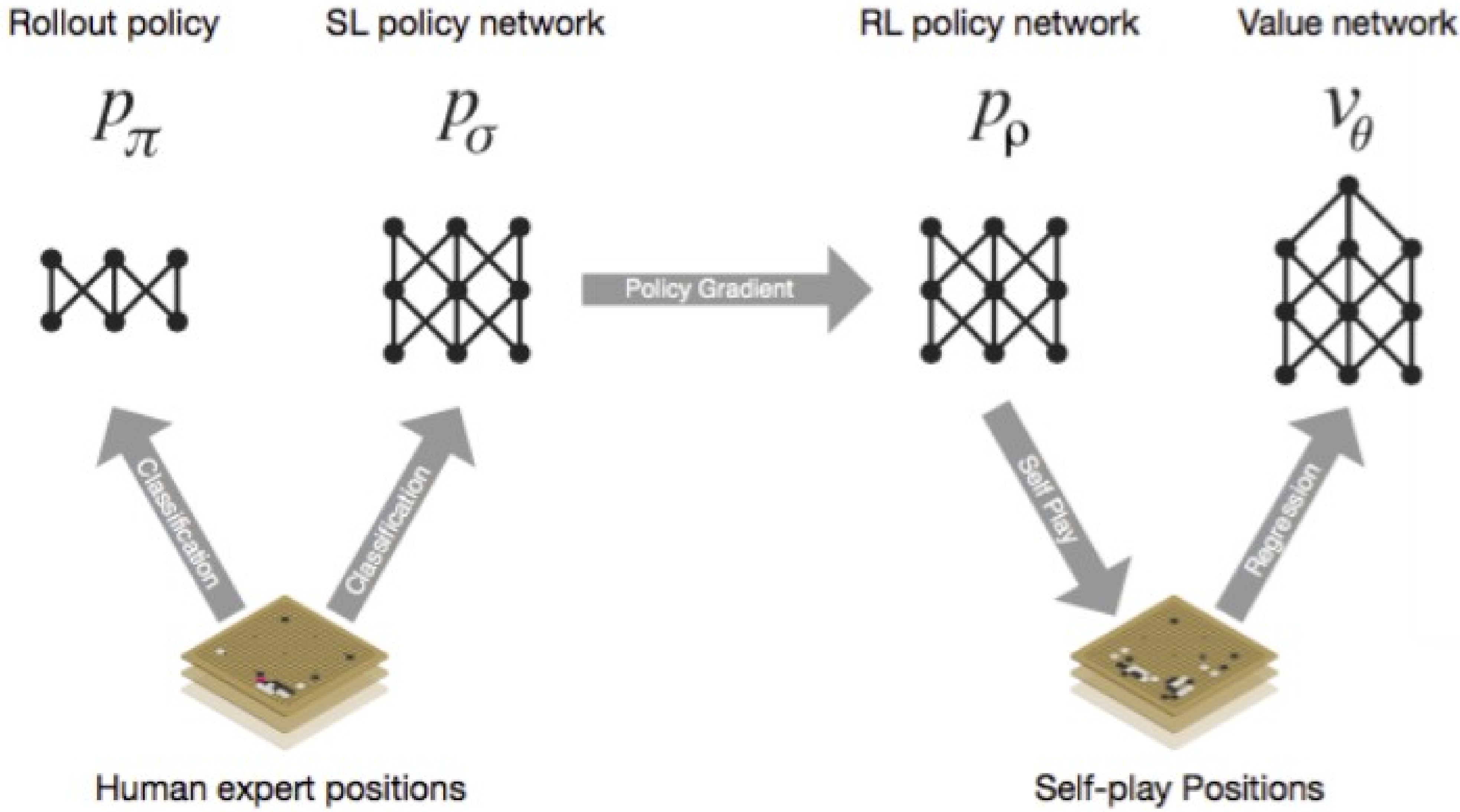
Selection

Asynchronous GPU Power

Revolution

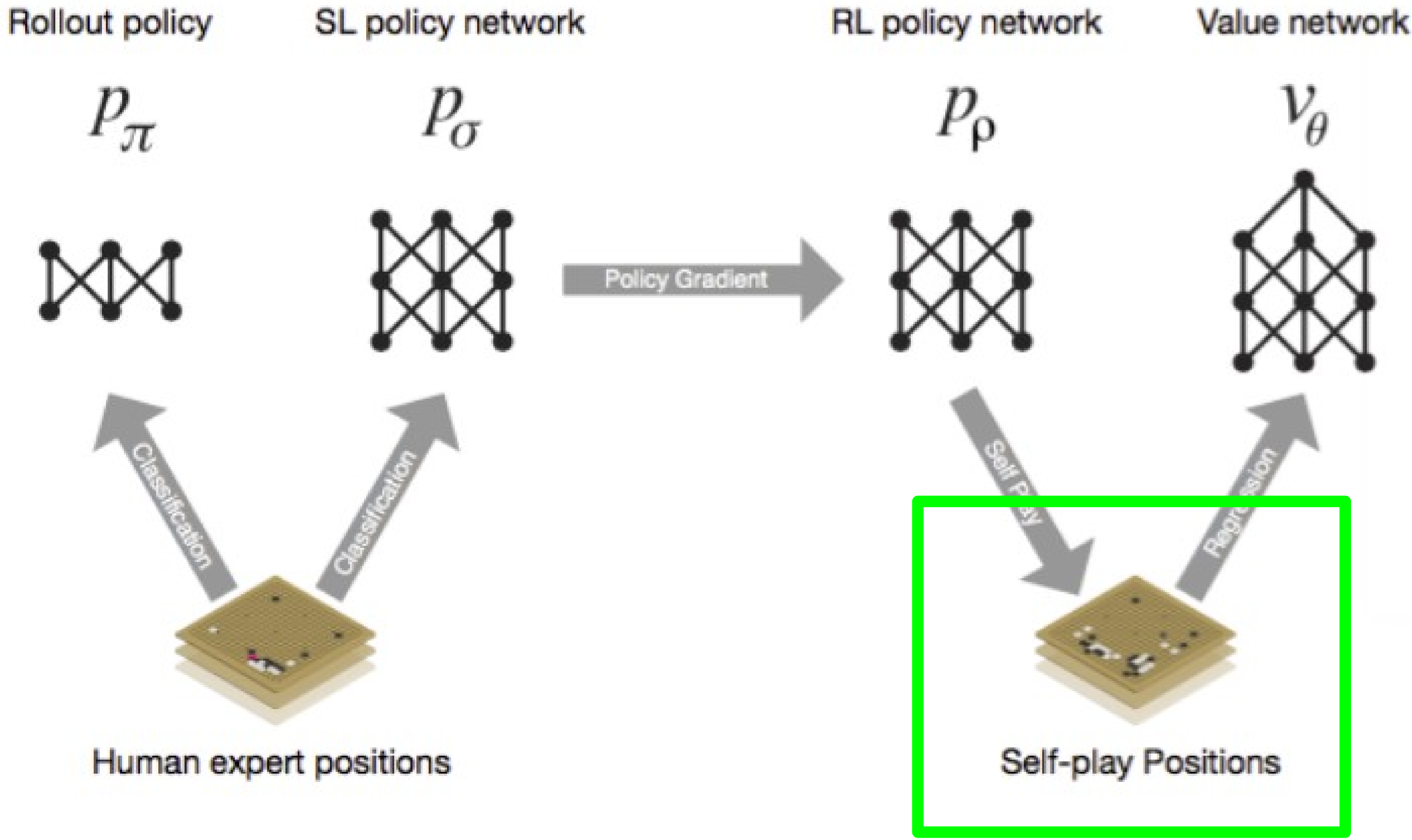
AlphaGo

Networks in Training



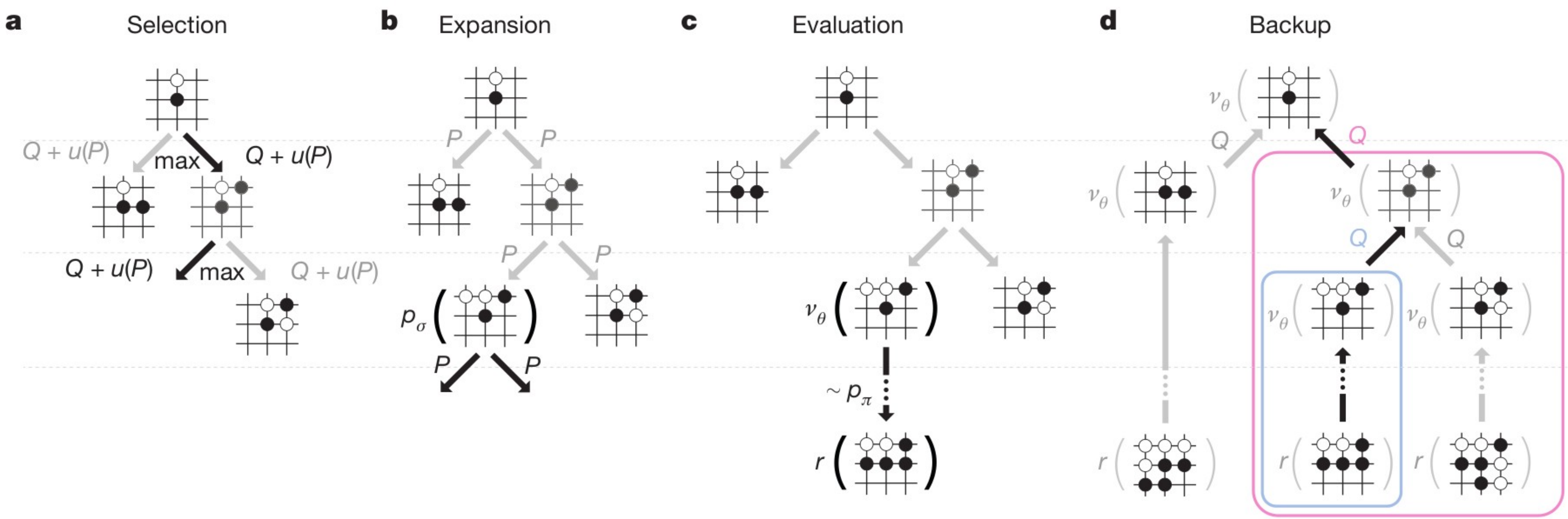
Silver, D. et al., 2016. Mastering the game of Go with deep neural networks and tree search. Nature, 529(7587), p.484-489.

Networks in Training



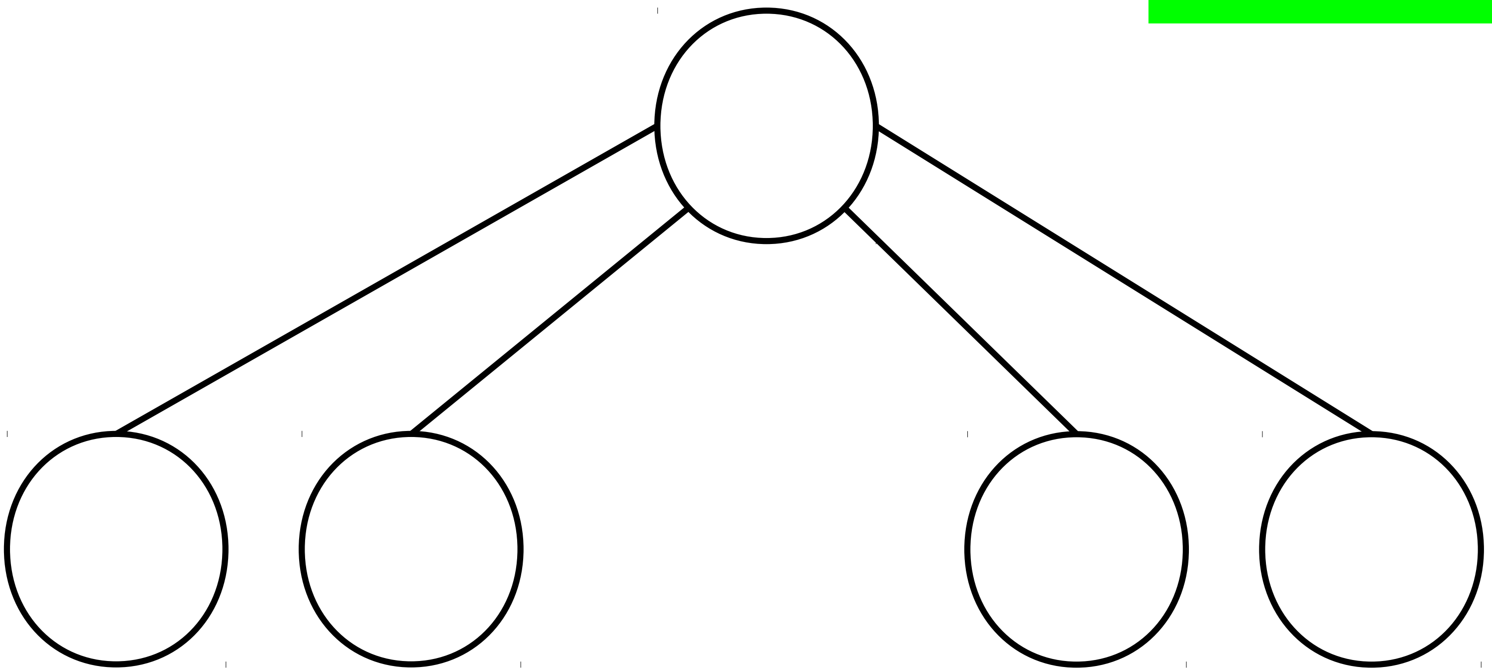
Silver, D. et al., 2016. Mastering the game of Go with deep neural networks and tree search. Nature, 529(7587), p.484-489.

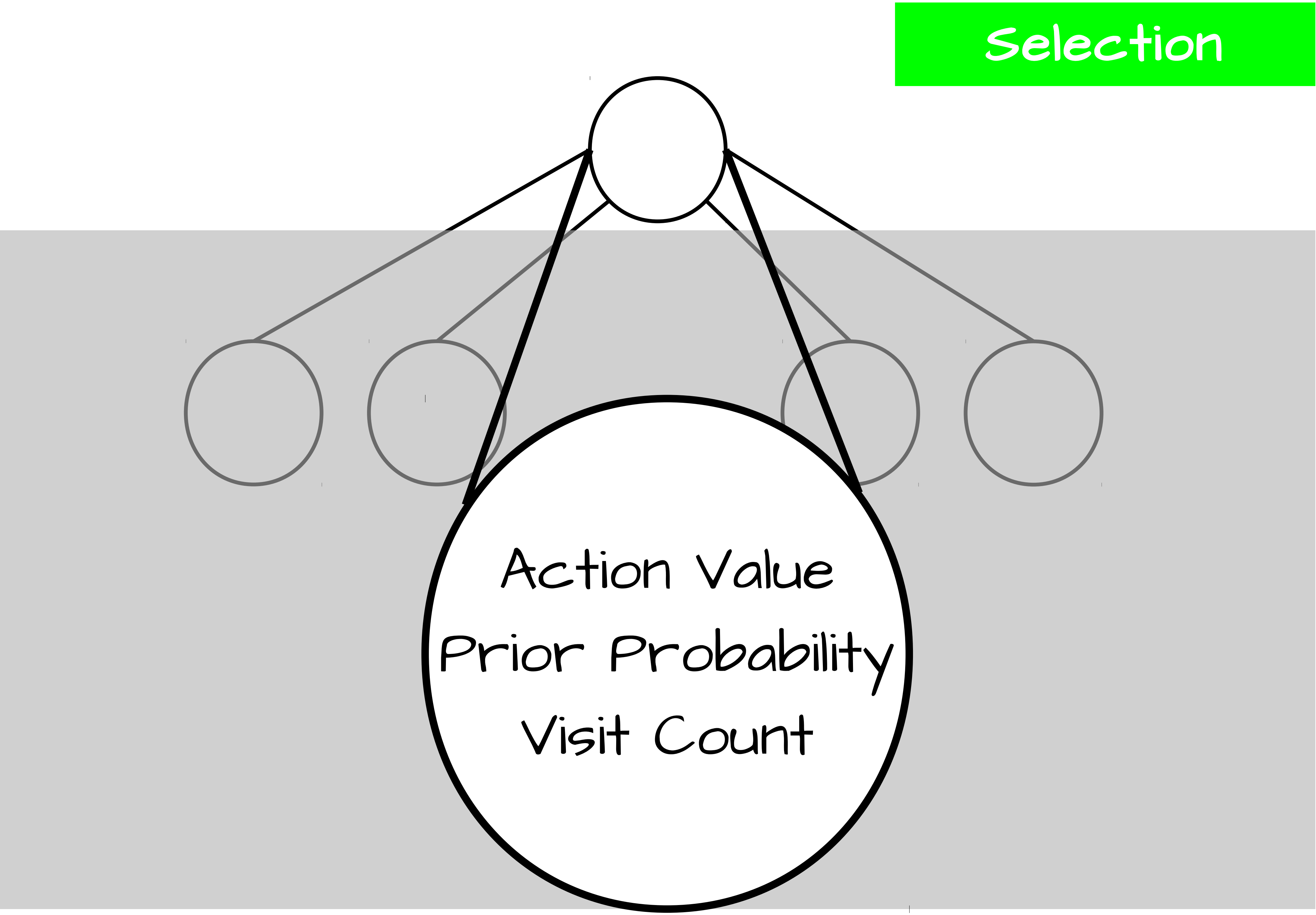
AlphaGo Search

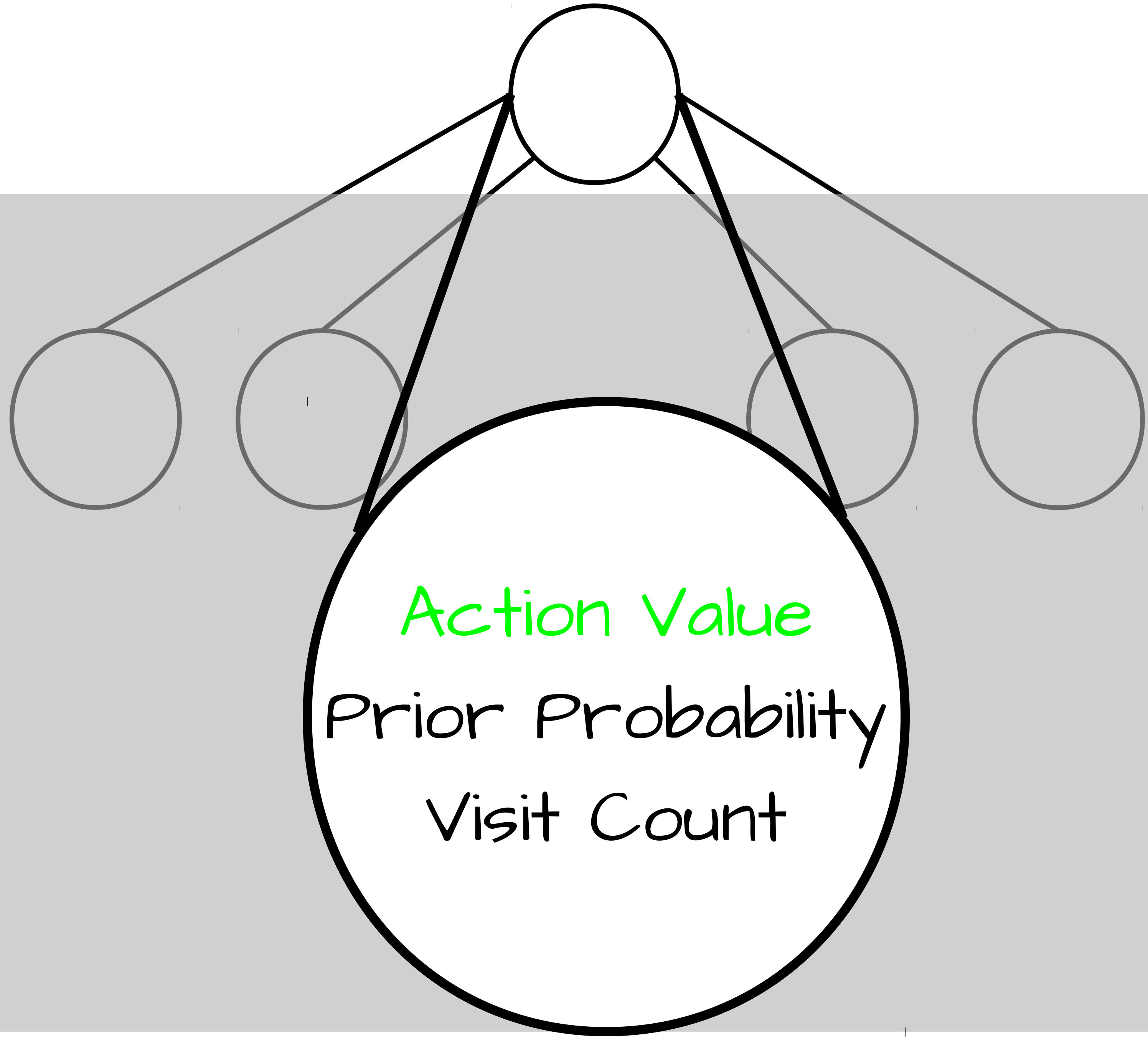


Silver, D. et al., 2016. Mastering the game of Go with deep neural networks and tree search. Nature, 529(7587), p.484-489.

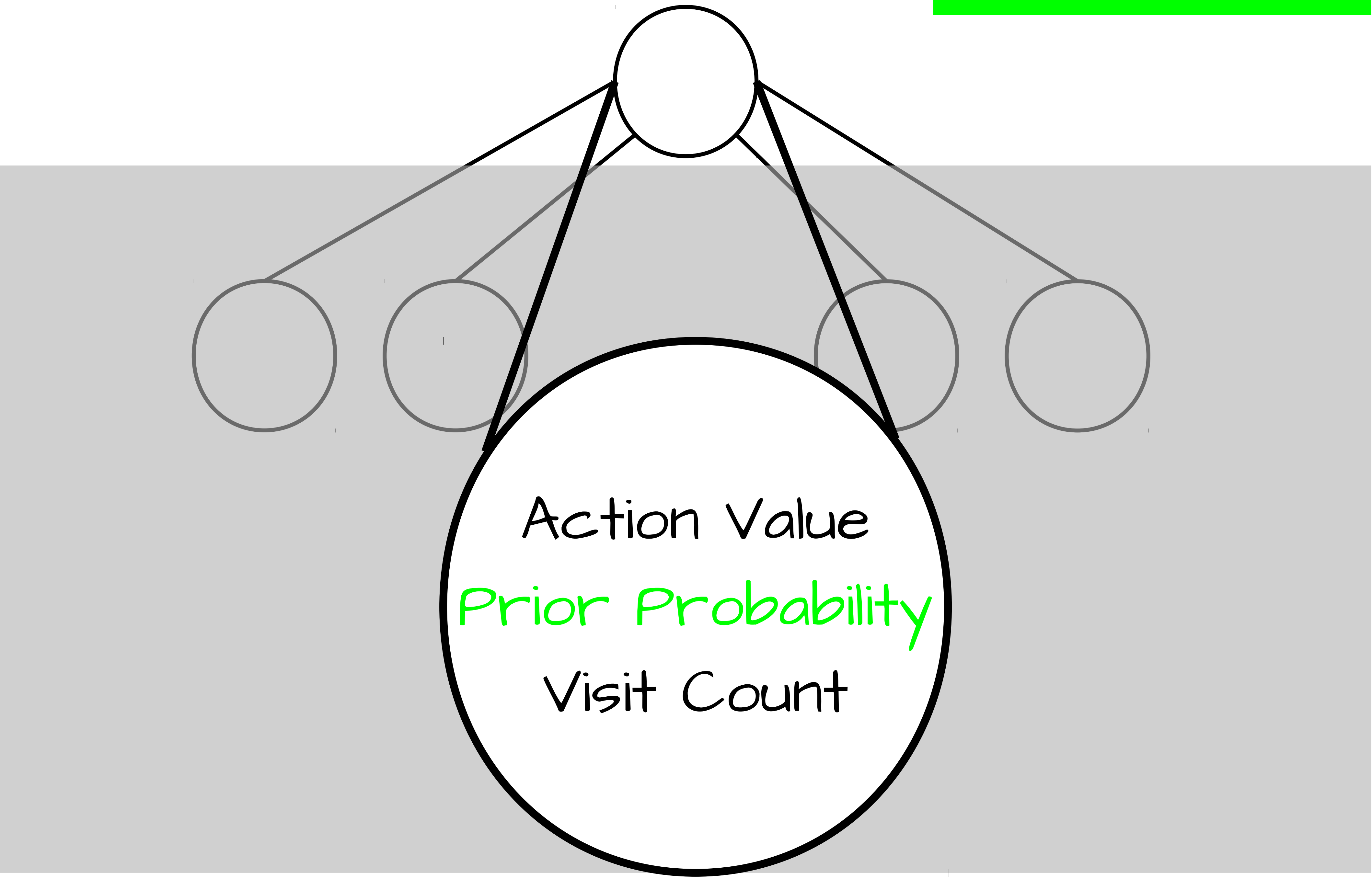
Selection



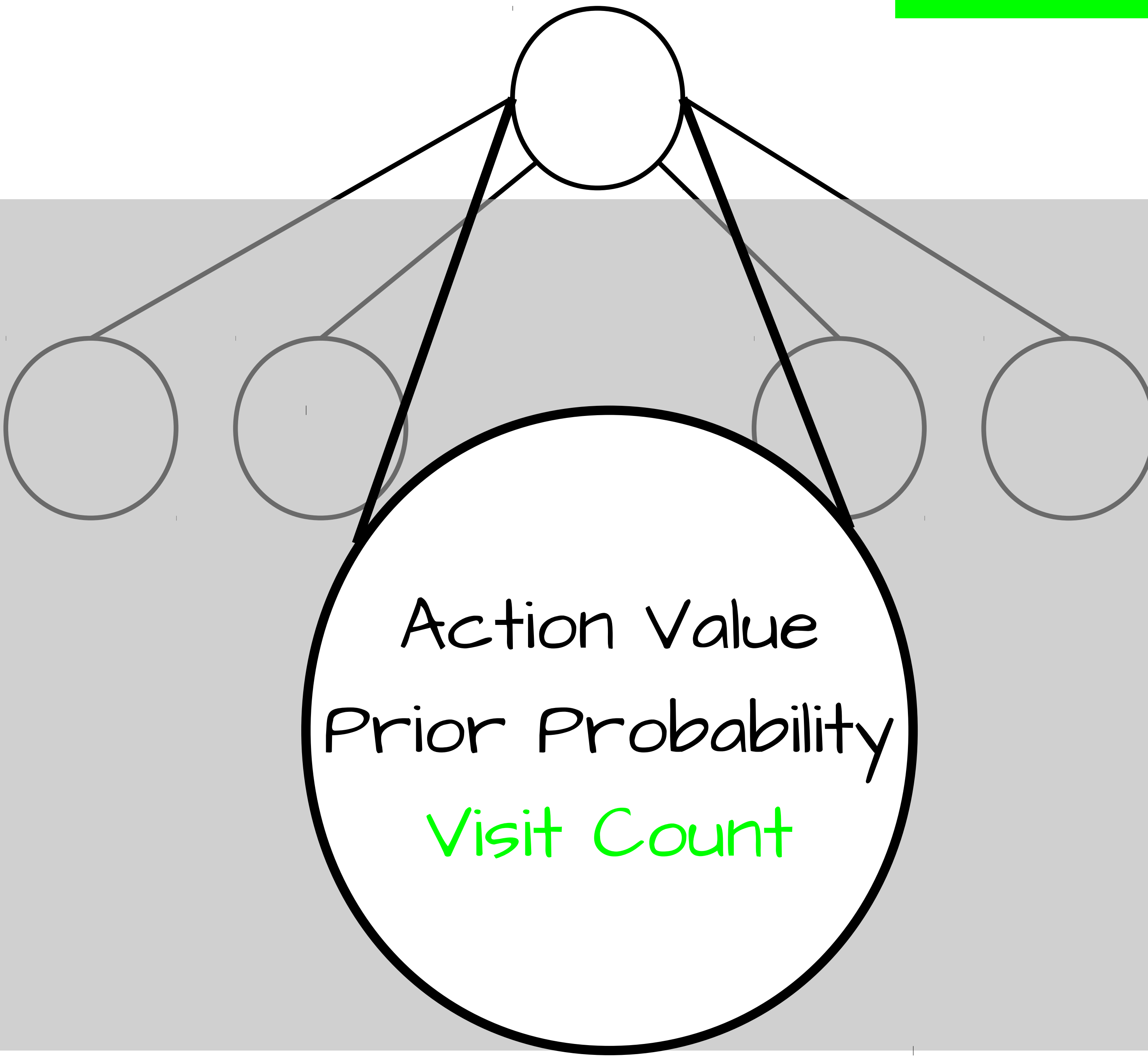

Selection
Action Value
Prior Probability
Visit Count


Action Value
Prior Probability
Visit Count

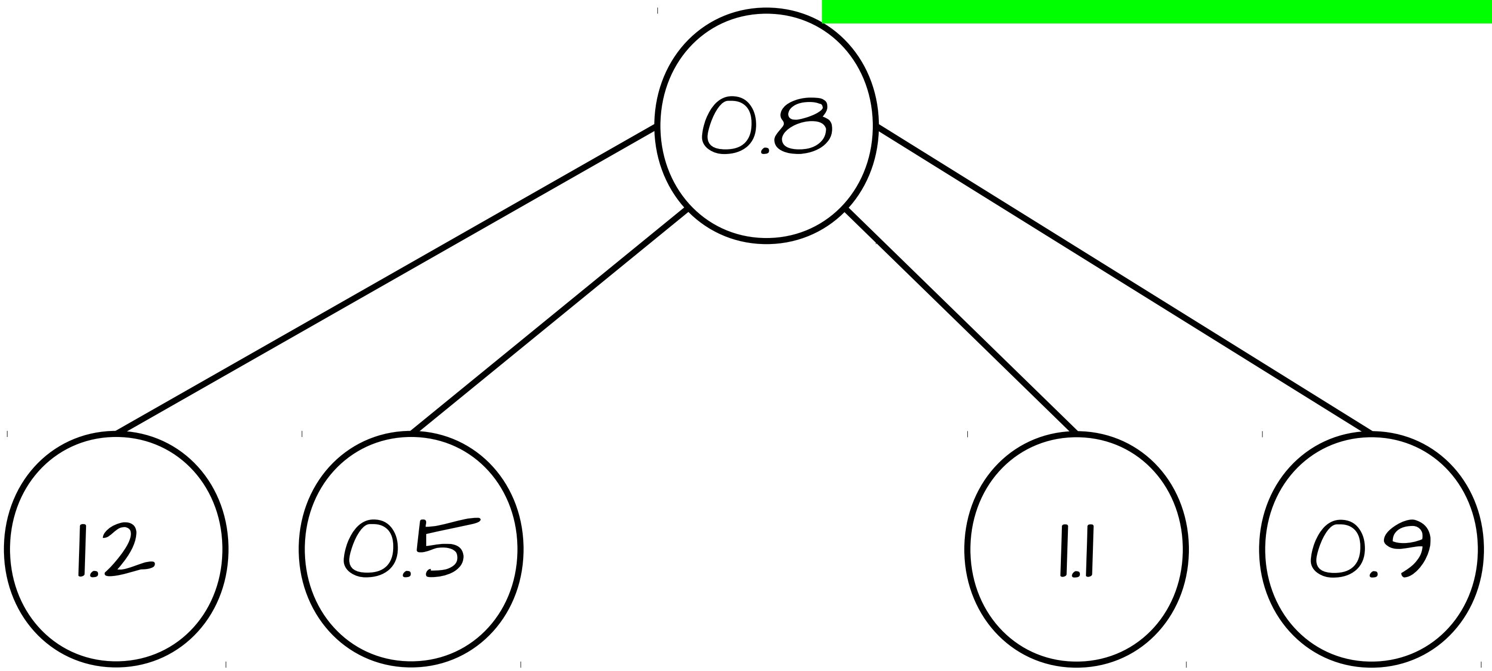
Selection



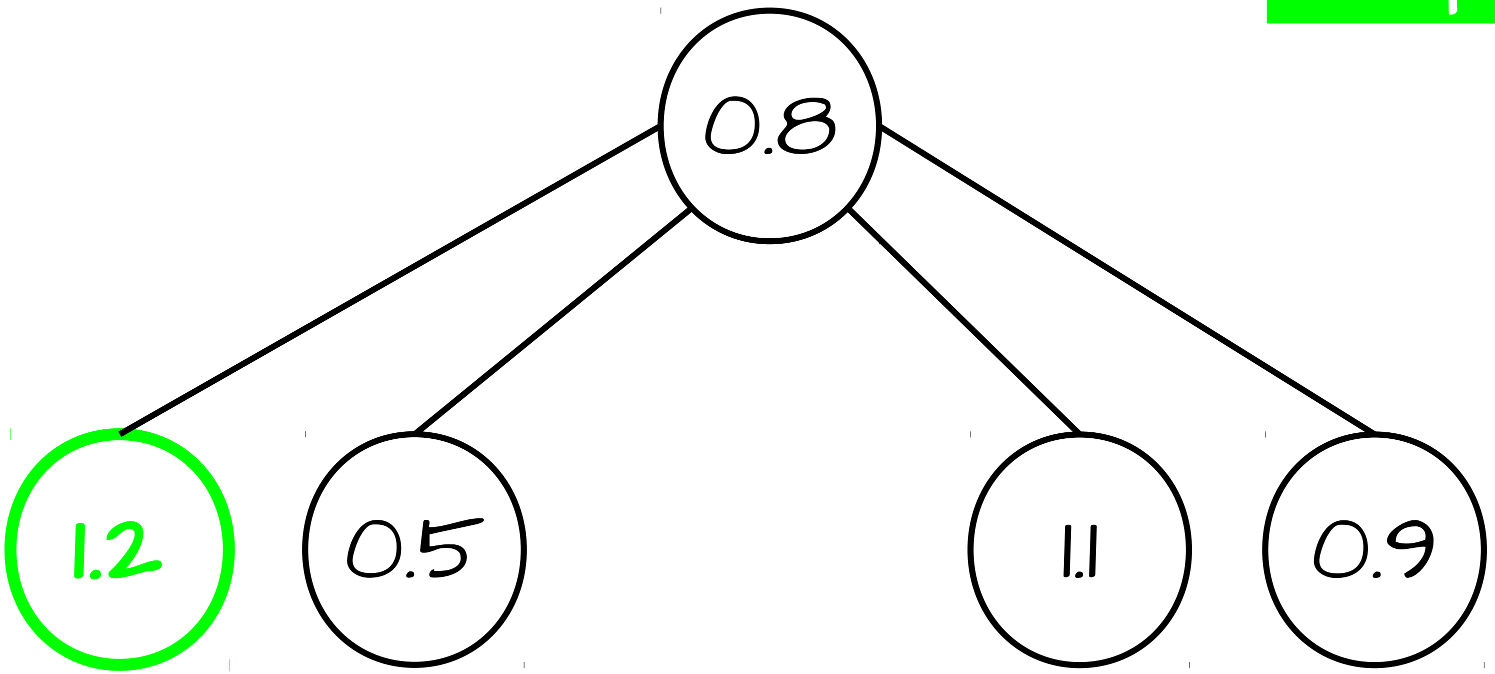
Selection



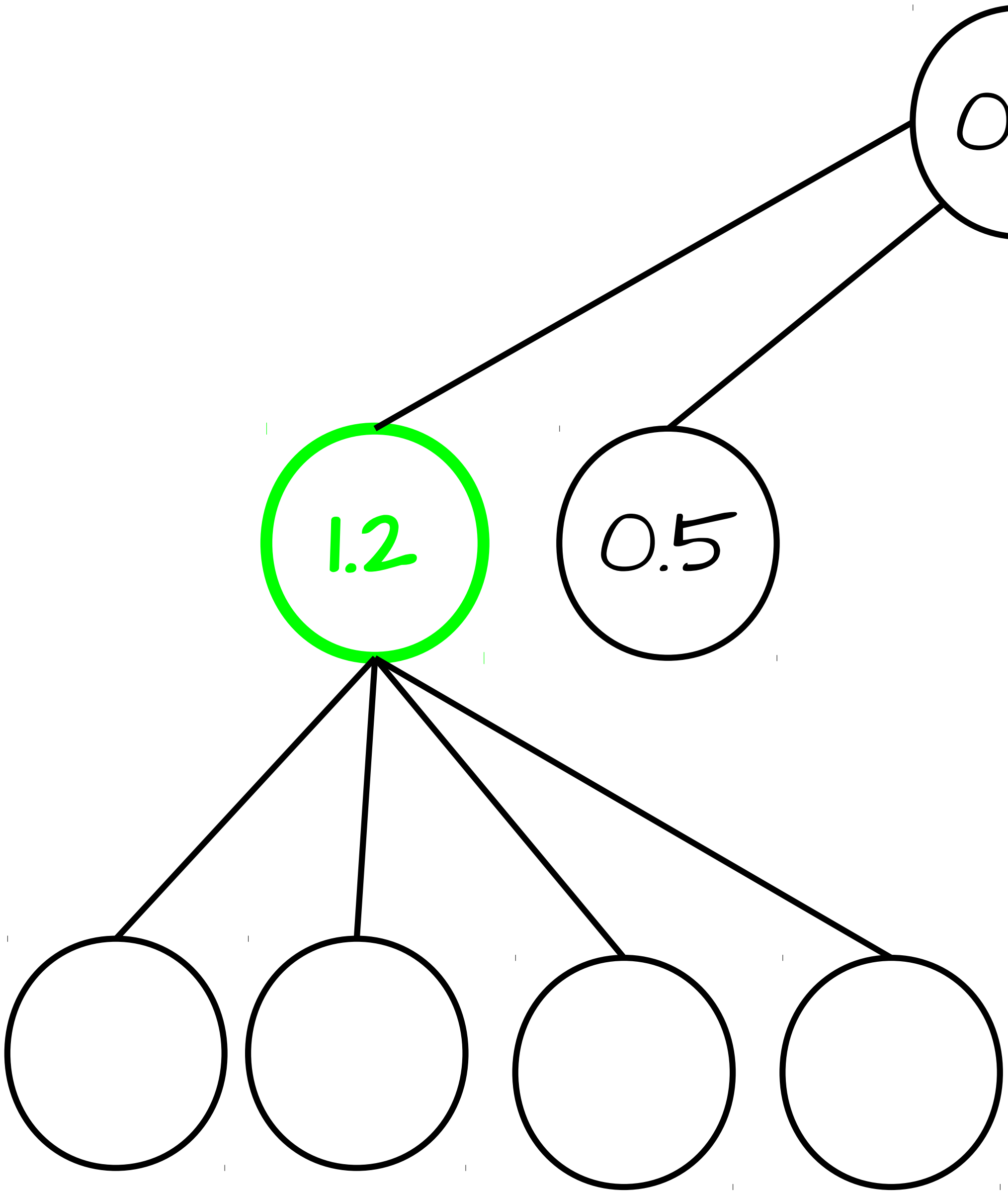
Action Value + Bonues



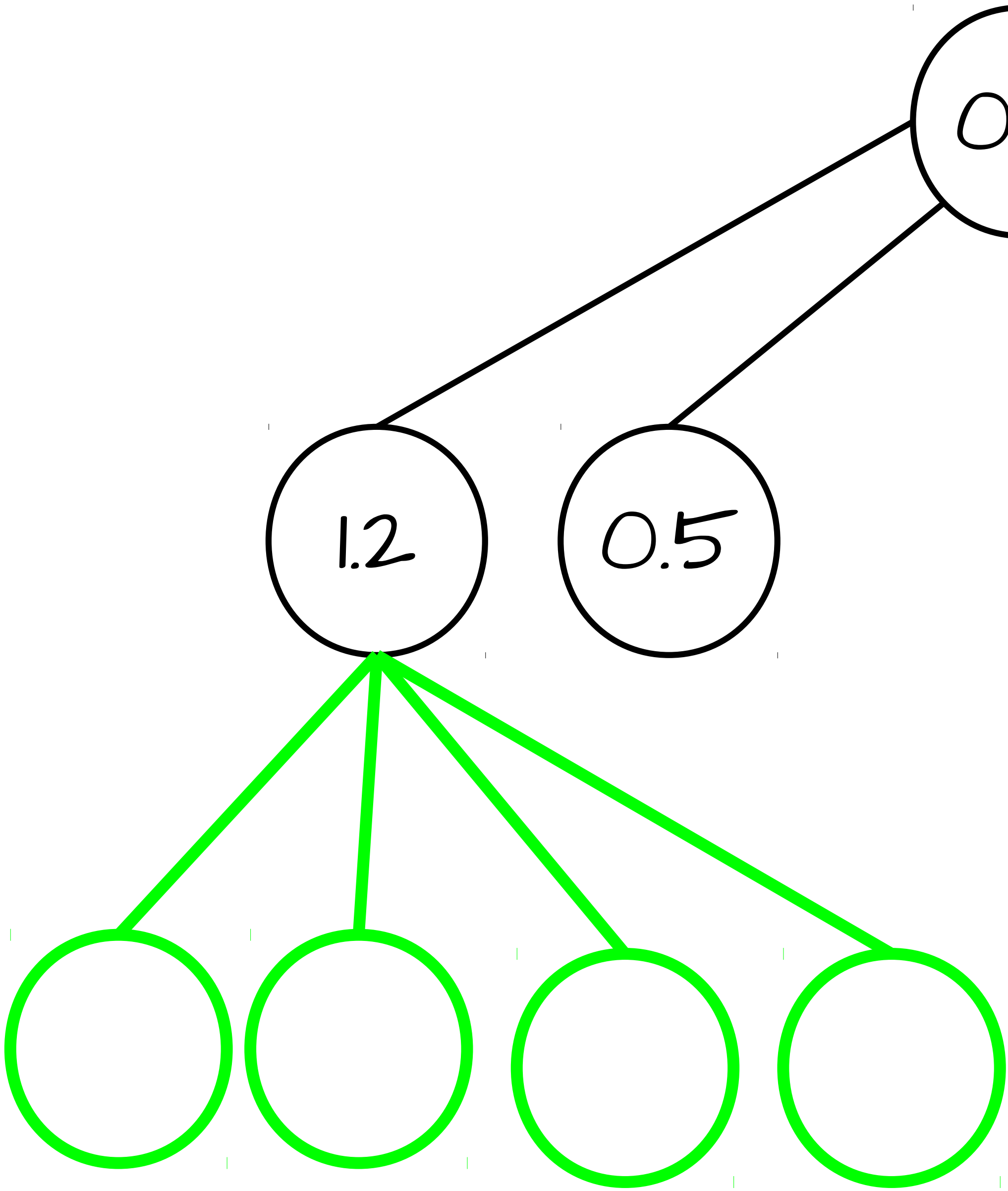
Expansion



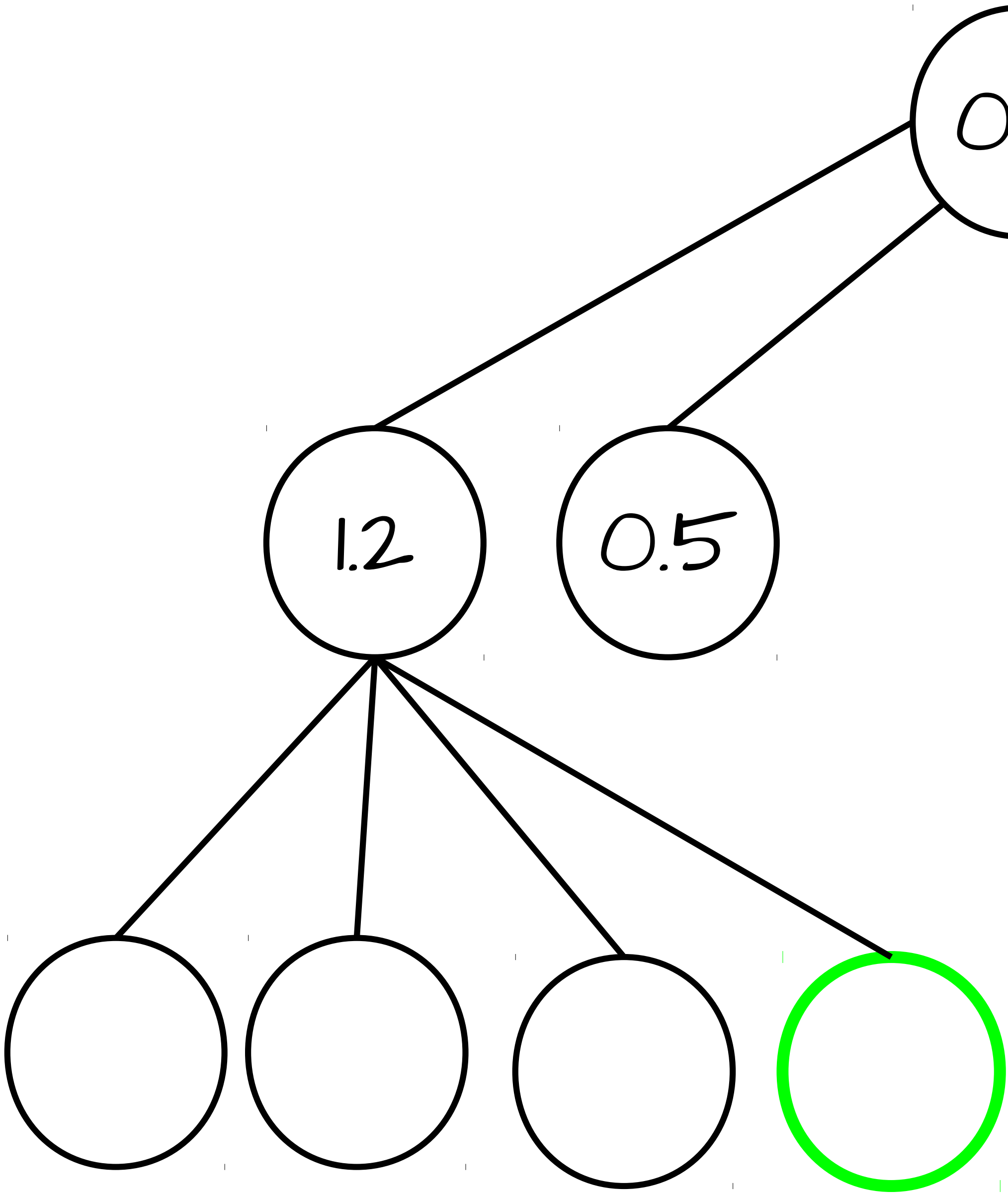
Expansion

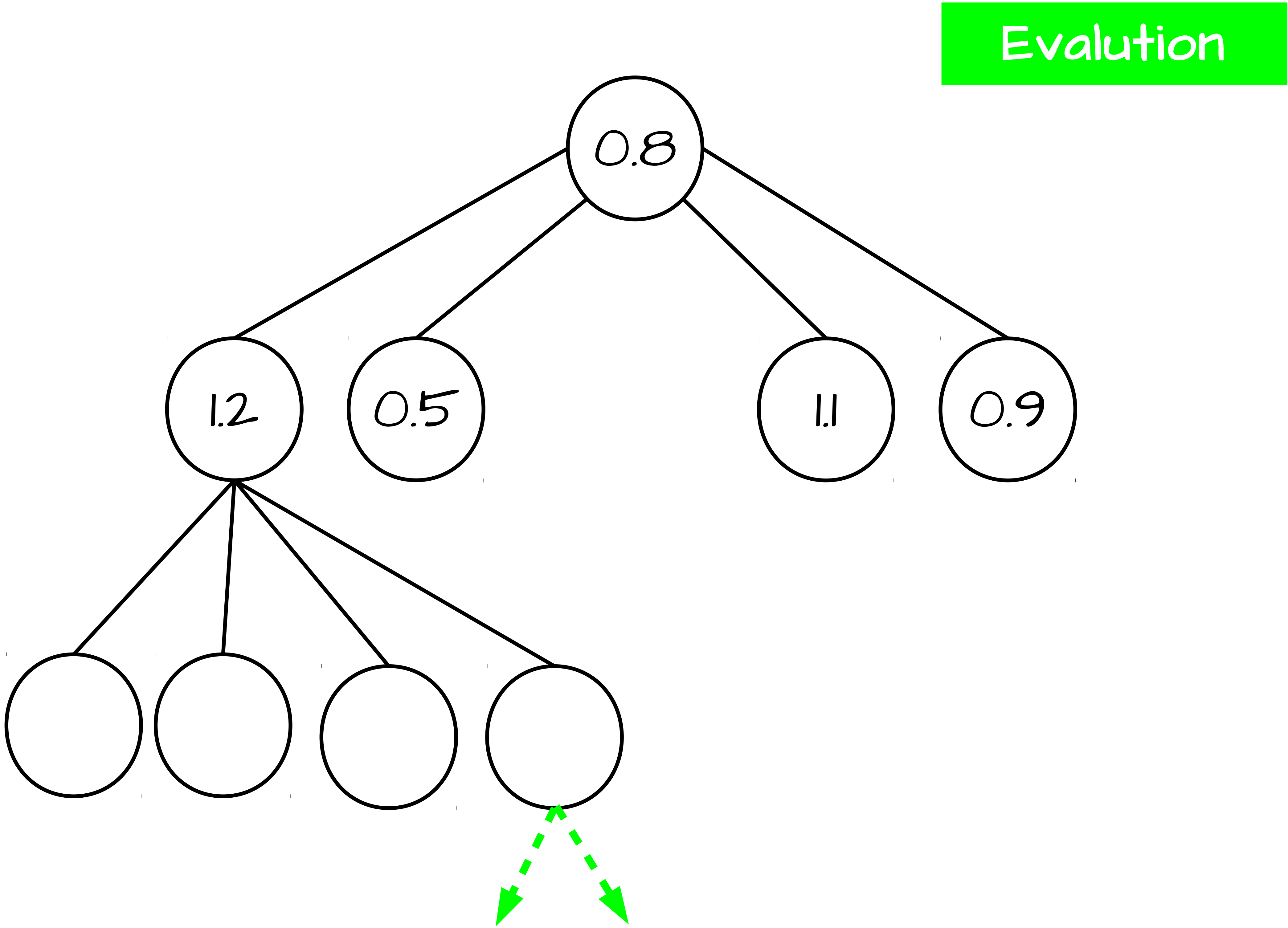


Prior Probability

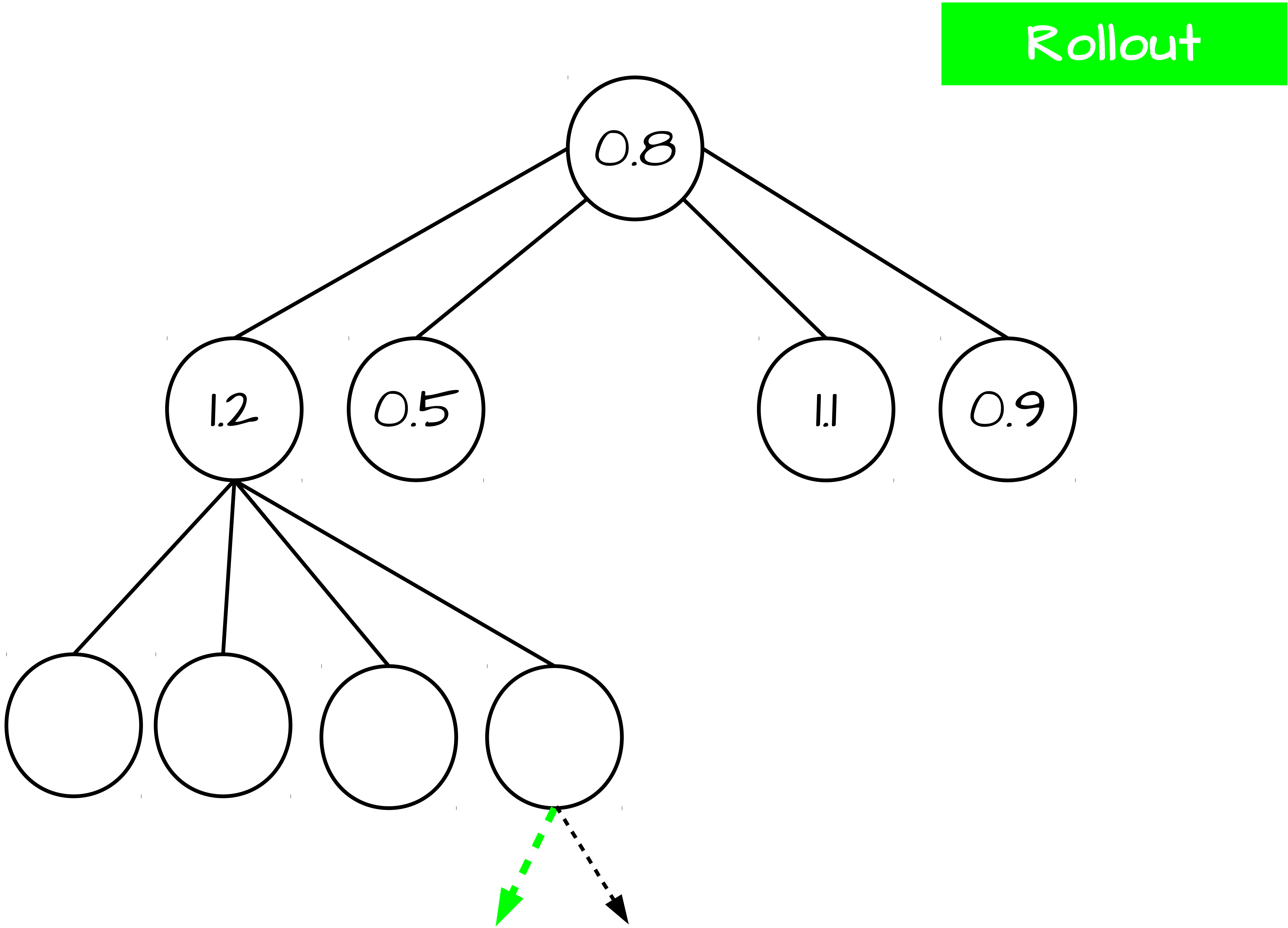


Evalution

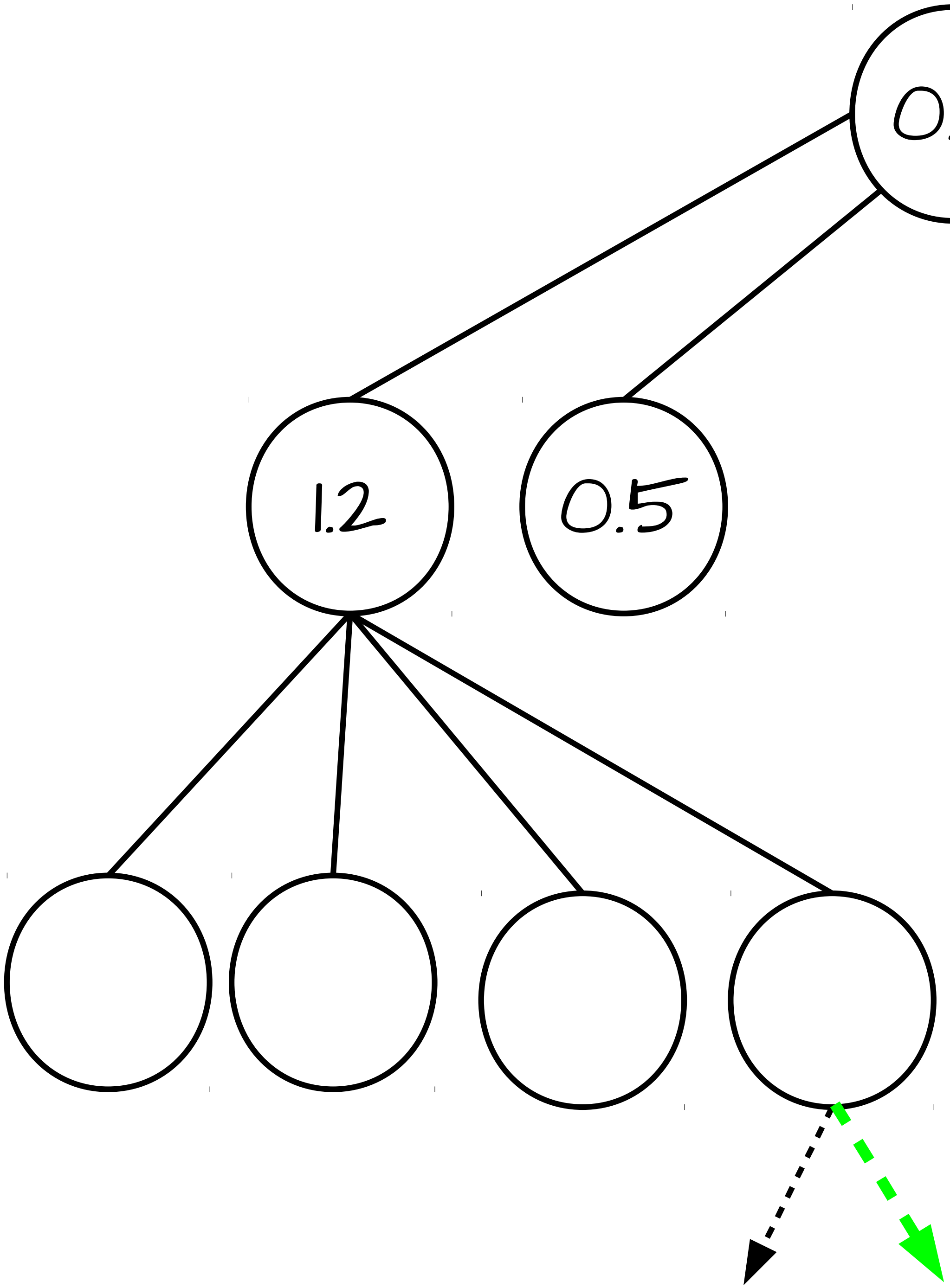




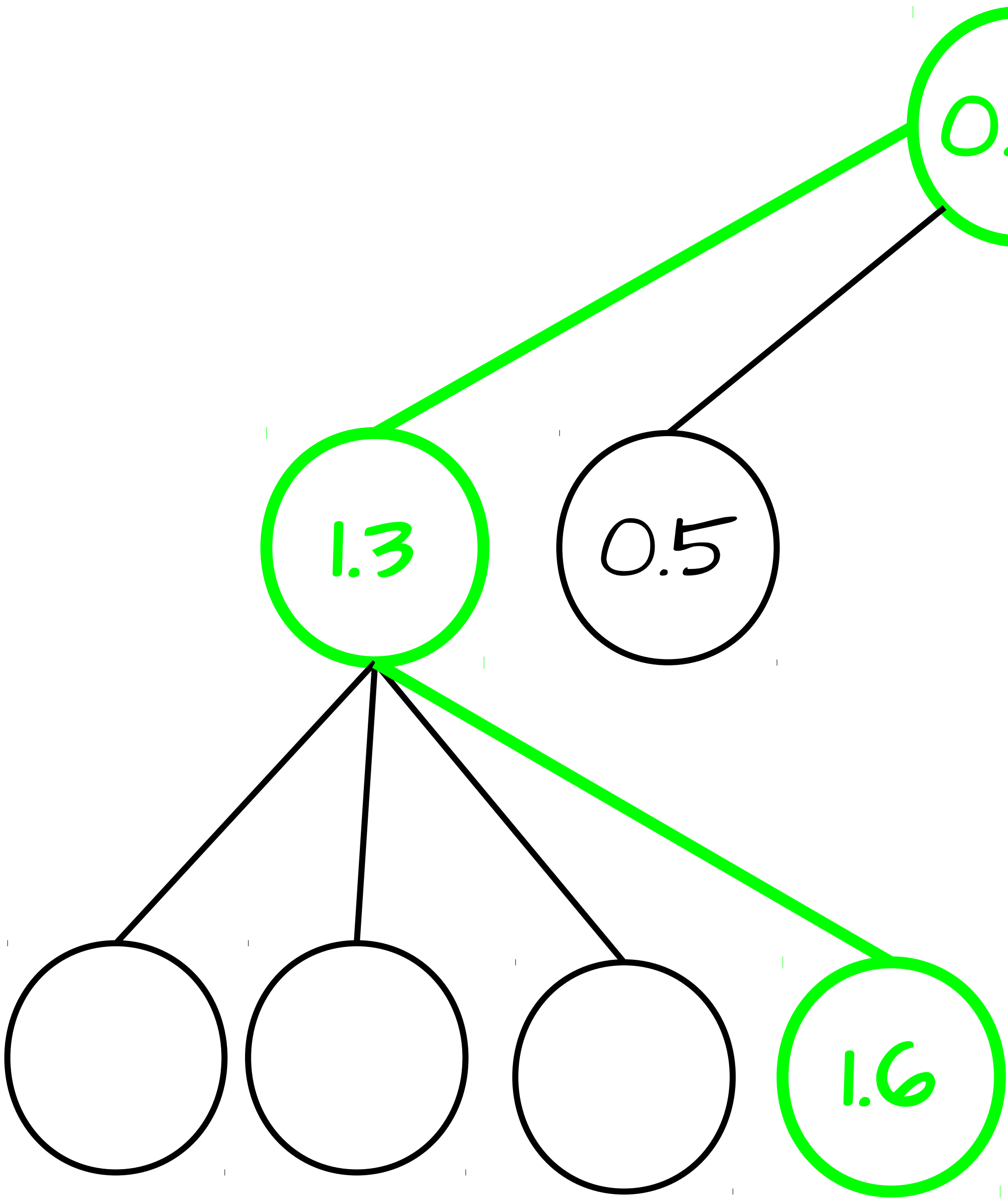
Evalution
0.8
1.2
0.5
1.1
0.9


Rollout
0.8
1.2
0.5
1.1
0.9

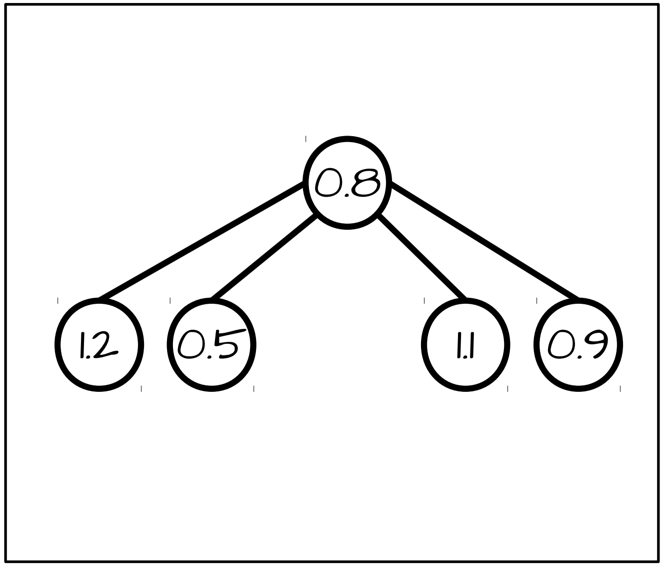
Value Network



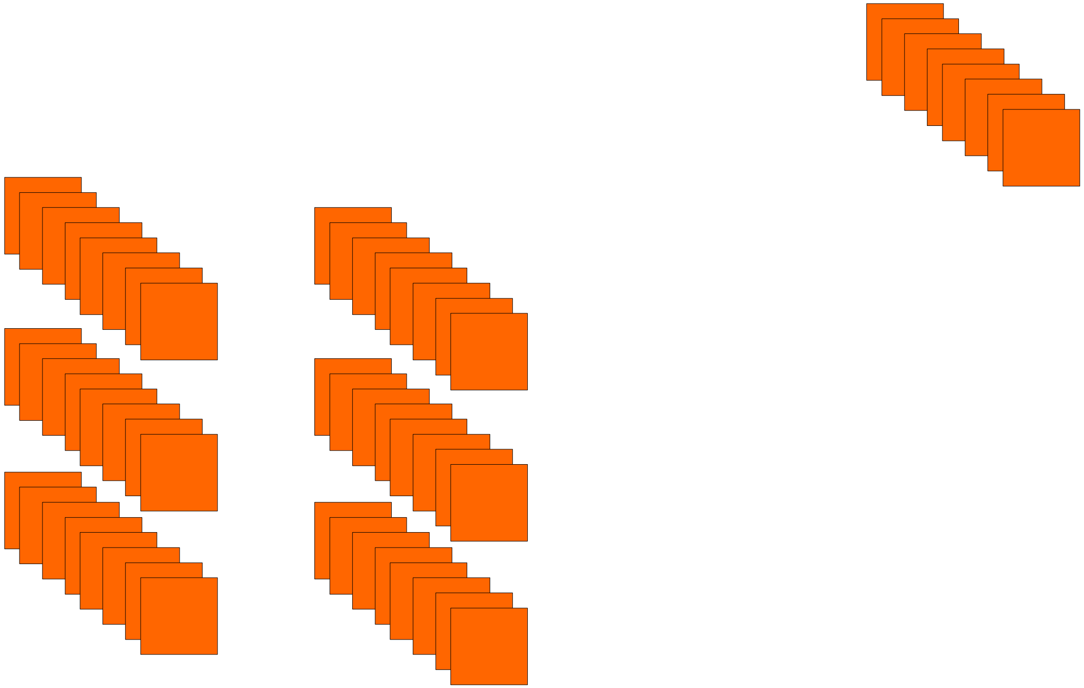
Backup

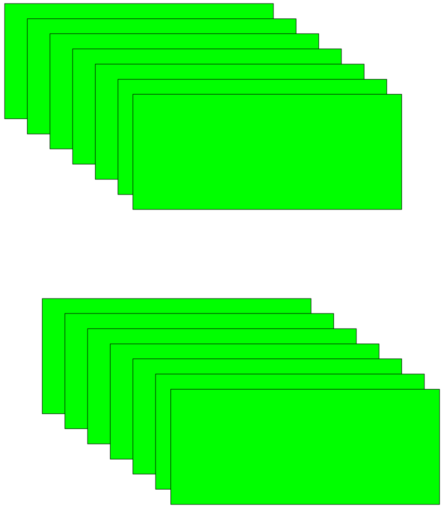


1202 CPUs



176 GPUS





Tensor

3 Strengths of AlphaGo

Human Instinct	Policy Network
Reading Capability	Search
Positional Judgement	Value Network

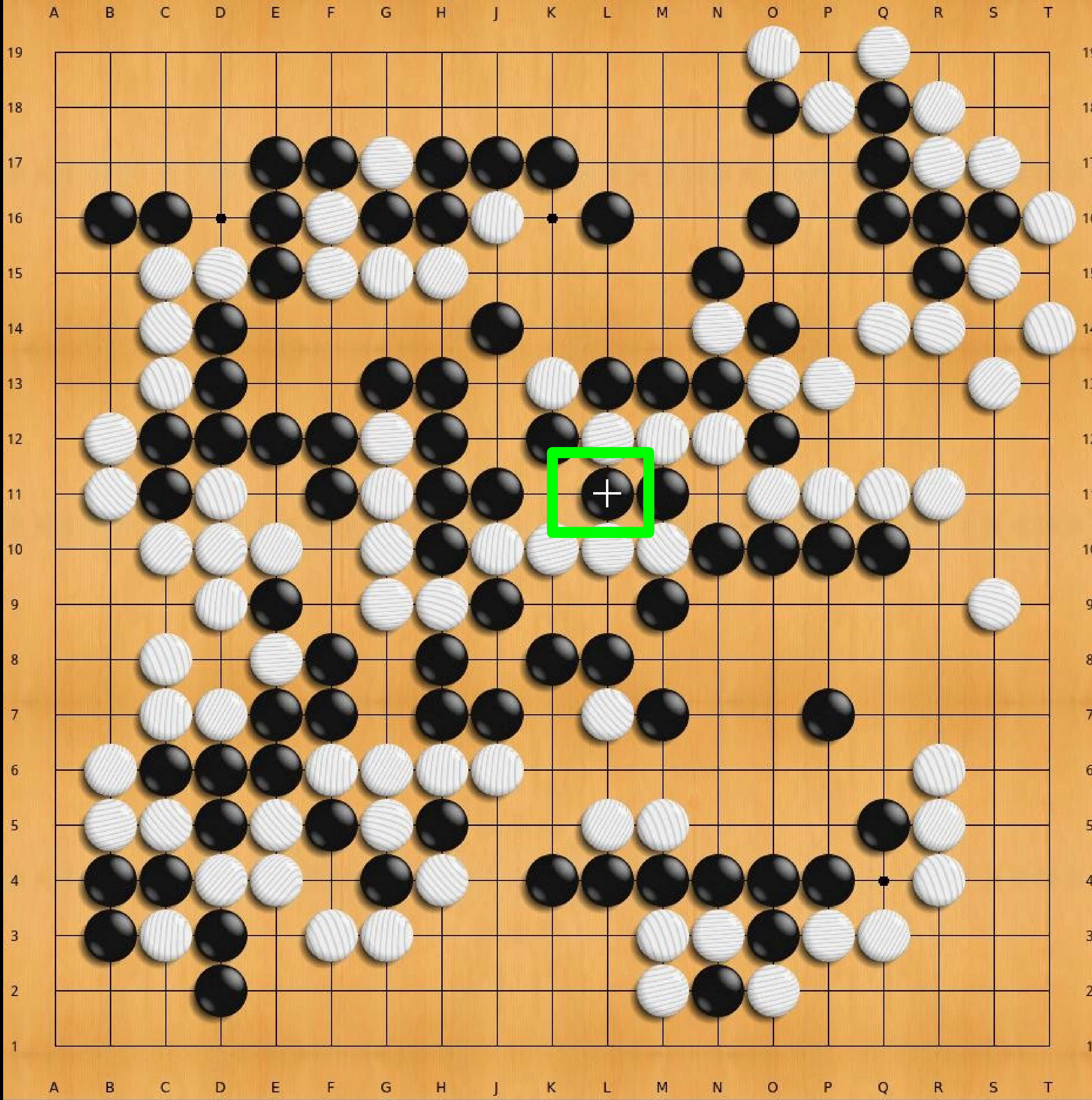
Most Important Strength

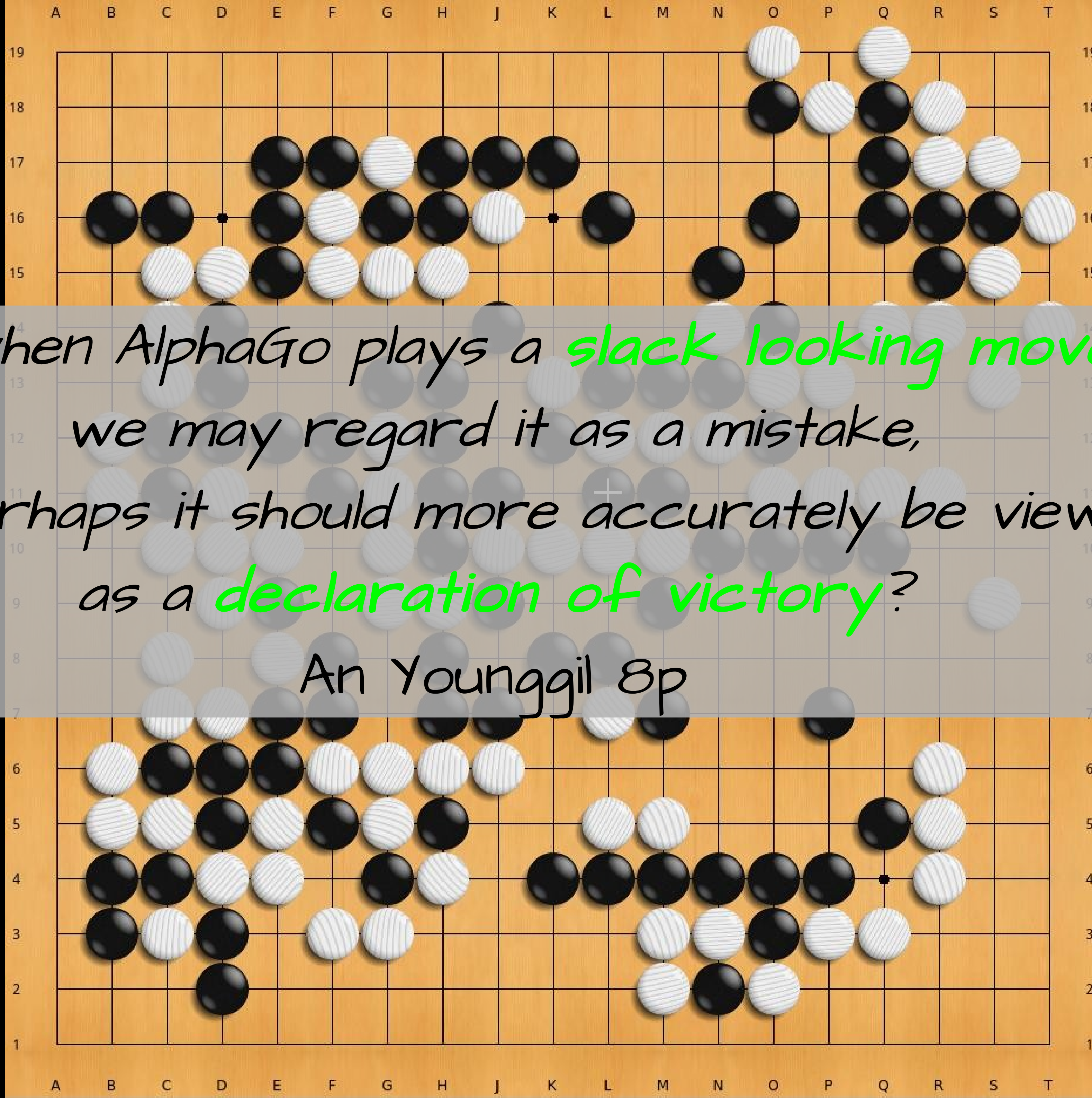
Human Instinct	Policy Network
Reading Capability	Search
Positional Judgement	Value Network

More Natural

Lee Sedol match

Style



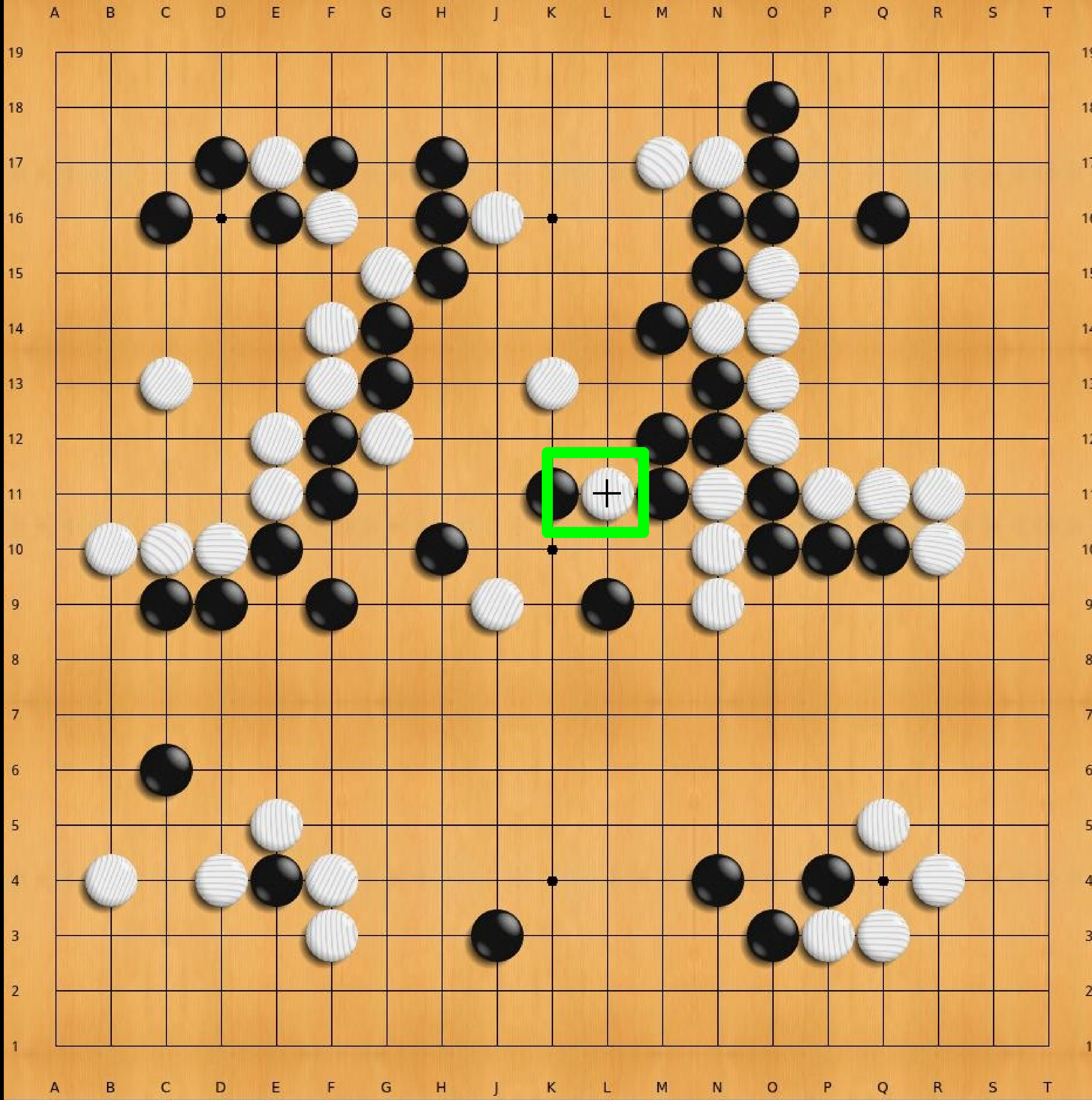


So when AlphaGo plays a slack looking move,
we may regard it as a mistake,
but perhaps it should more accurately be viewed
as a declaration of victory?

An Younggil 8p

Game 2

Game 4


A B C D E F G H J K L M N O P Q R S T
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Game 4

Game 4

What can we learn?

Making X faster

vs

Doing less of X

Benchmark everything

Solving problems the human way

vs

Solving problems the computer way

Don't **blindly dismiss** approaches as infeasible

One Approach

vs

Combination of Approaches

Joy of Creation

```
white's turn to move!'
Make a move in the form XY, e.g. A19, D7 as the labels indicate!
> F8
    A B C D E F G H J
  9 . . . . . . . . .  9
  8 . X . . . O X . .  8
  7 . O O . . . O . .  7
  6 . . . . O . . . .  6
  5 . O O X . . . O .  5
  4 . X X . . . . . .  4
  3 . . X . . X . . .  3
  2 . . . . . . . X .  2
  1 . . . . . . . . .  1
    A B C D E F G H J
white played at F8
black's turn to move!'
Rubykon is thinking...
D2 => 0.4881516587677725
C8 => 0.4827586206896552
F4 => 0.4827586206896552
F5 => 0.47761194029850745
G4 => 0.47474747474747475
E8 => 0.4744897959183674
G6 => 0.47150259067357514
D6 => 0.46875
D4 => 0.4627659574468085
F7 => 0.46236559139784944
    A B C D E F G H J
  9 . . . . . . . . .  9
  8 . X . . . O X . .  8
  7 . O O . . . O . .  7
  6 . . . . O . . . .  6
  5 . O O X . . . O .  5
  4 . X X . . . . . .  4
  3 . . X . . X . . .  3
  2 . . . X . . . X .  2
  1 . . . . . . . . .  1
    A B C D E F G H J
black played at D2
white's turn to move!'
Make a move in the form XY, e.g. A19, D7 as the labels indicate!
> F5
    A B C D E F G H J
  9 . . . . . . . . .  9
  8 . X . . . O X . .  8
  7 . O O . . . O . .  7
  6 . . . . O . . . .  6
  5 . O O X . O . O .  5
  4 . X X . . . . . .  4
  3 . . X . . X . . .  3
  2 . . . X . . . X .  2
  1 . . . . . . . . .  1
    A B C D E F G H J
white played at F5
black's turn to move!'
Rubykon is thinking...
```

PragTob/Rubykon

pasky / michi

Watch ▾ 18

Minimalistic Go MCTS Engine

117 commits | 2 branches | 0 releases | 5 contributors

Branch: master ▾ michi / + Fork this project and create a new file

pasky Merge pull request #5 from traveller42/master ... Latest commit 2f22d84 18 days

.gitignore	Keep only repository specific entries in repository .gitignore	a month
README.md	Update links to michi-c and michi-c2	a month
michi.py	Test for Pass in the GTP code was too strict	18 days

pasky/michi

Michi --- Minimalistic Go MCTS Engine

Michi aims to be a minimalistic but full-fledged Computer Go program based on state-of-art methods (Monte Carlo Tree Search) and written in Python. Our goal is to make it easier for new people to enter the domain of Computer Go, peek under the hood of a "real" playing engine and be able to learn by

What did AlphaGo do to beat the strongest human Go player?

Tobias Pfeiffer

@PragTob

pragtob.info

bitcrowd

Sources

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- Silver, D. et al., 2016. Mastering the game of Go with deep neural networks and tree search. Nature, 529(7587), p.484-489.
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- https://www.youtube.com/watch?v=LX8Knl0g0LE&index=9&list=WL

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