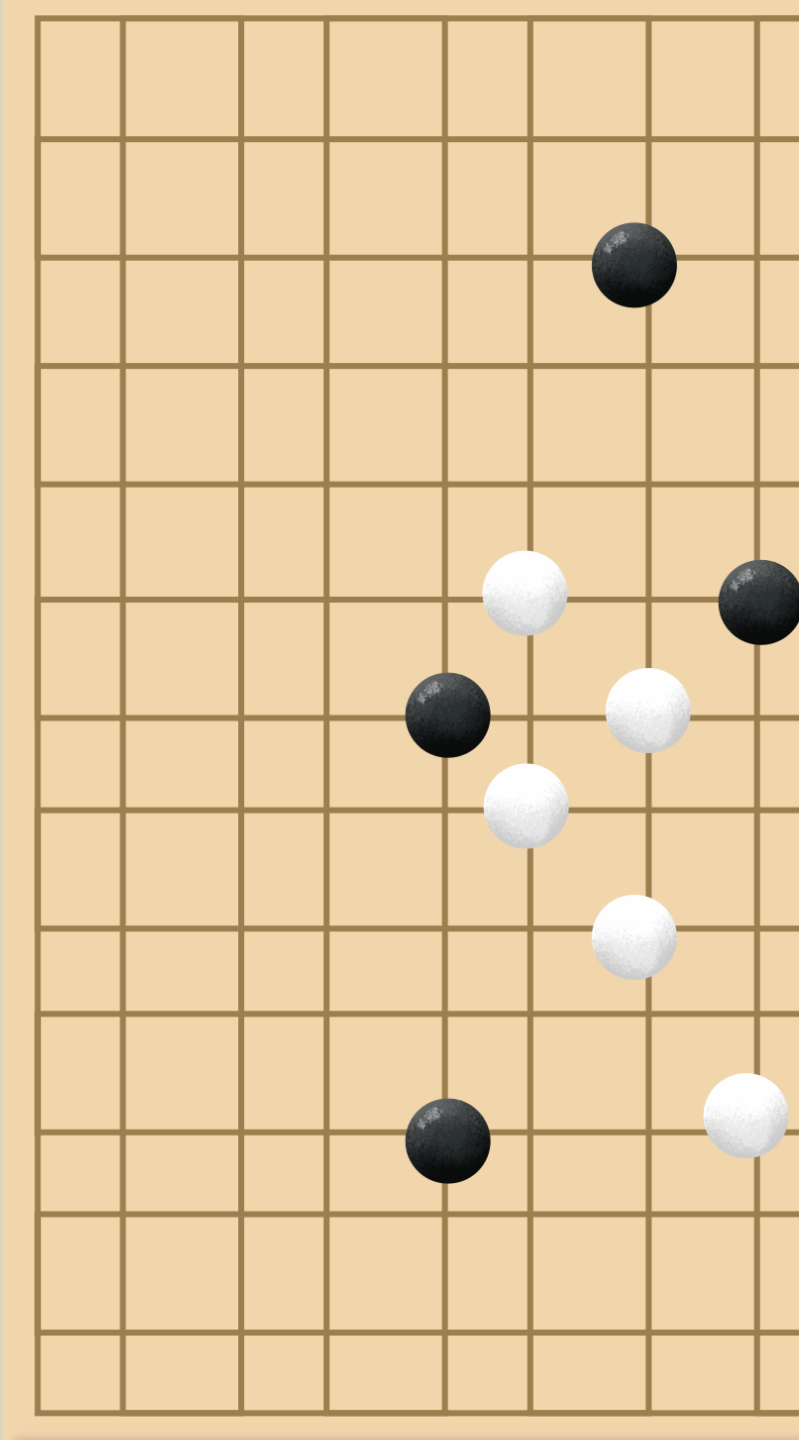
Chinese Board Game “Go”

Yiwei Mao



What is ‘Go’ ?

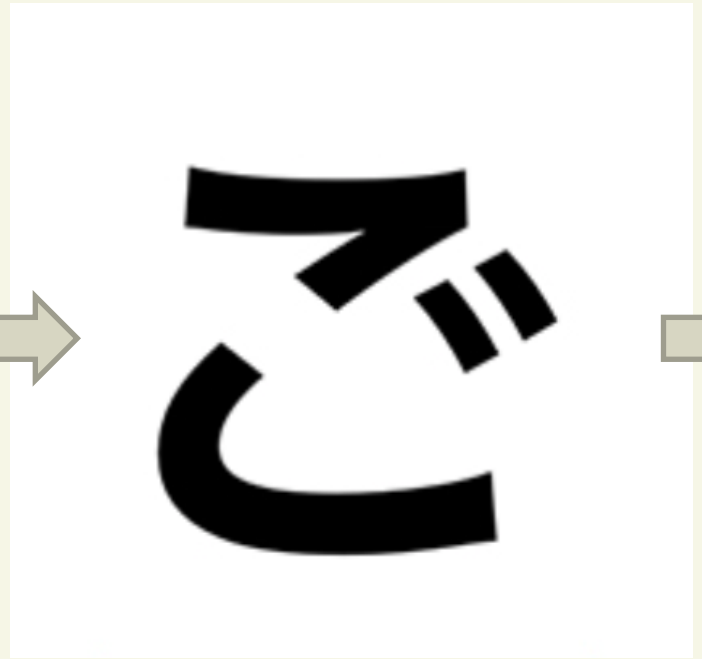
- Board game for two players, one player hold black pieces and the other hold white.
- Players places pieces on the **intersection** of the 19*19 Go board in turns
- The aim is to **capture more territory** than the opponent (further explained in later parts)

History of ‘Go’

- The game was invented in China more than 3000 years ago , and is first officially recorded in *Zuo Zhuan*（ancient historical chronicle）
- It is believed to be the oldest board game continuously played to the present day.
- The Chinese name of the game is “weiqi”, meaning: “the chess about “surrounding”(wei)。

History of ‘Go’

囲棋

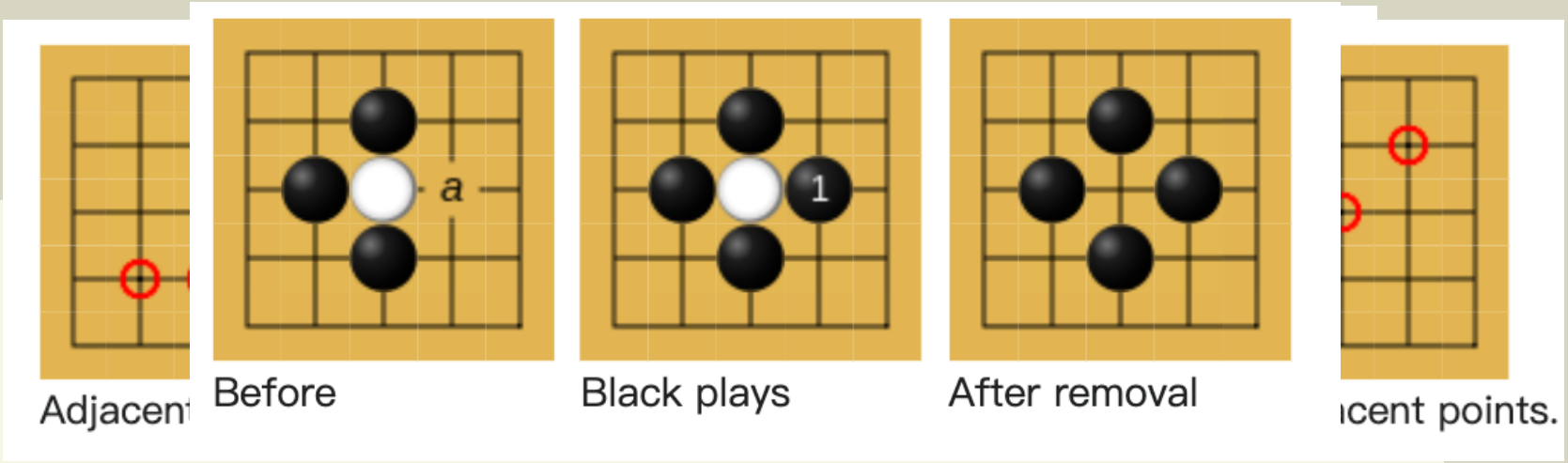


The game was introduced to Japan in the 7th century AD. Instead of the Chinese pronunciations, Japanese pronounce “棋(chess)” as ご (go)

Go

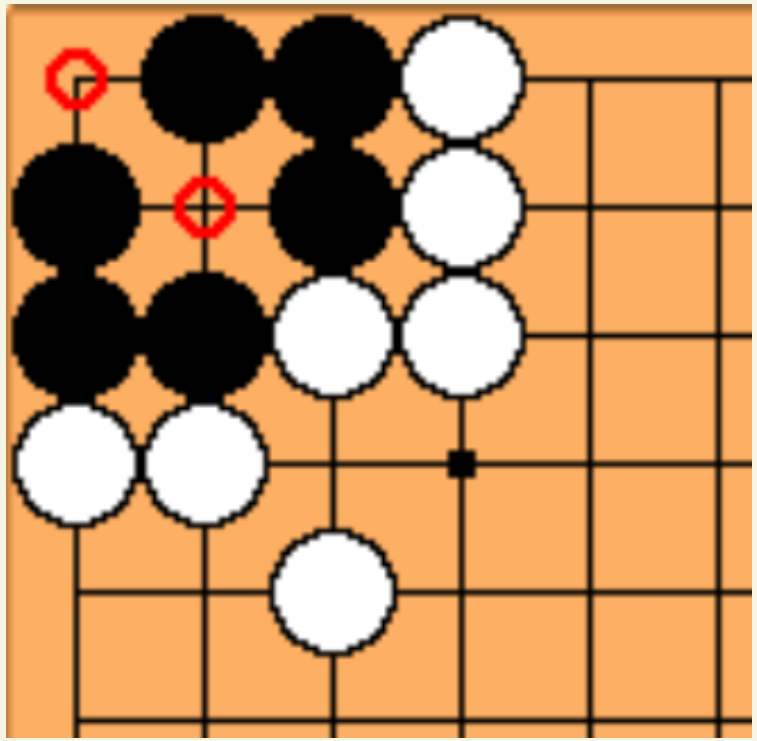
19th century, Oskar Korschelt, a German chemist, learned the game while he was working in Japan. Oskar transliterated the Japanese sound ご into “Go” to represent the game, and published works to

Rules



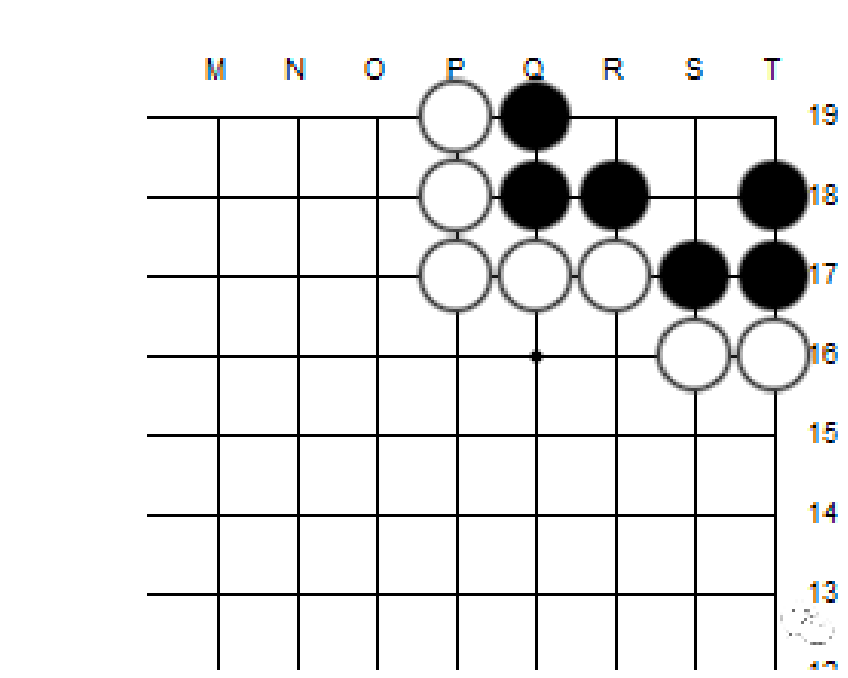
- Two players one holding black and the other holding white, take turns to place pieces on the intersection of an 19*19 Go board.
- If a piece or group of pieces on the board is completely surrounded on all adjacent sides, then those pieces are “captured” and removed from the board
- When every point is either surrounded or occupied by black or white, the game ends.

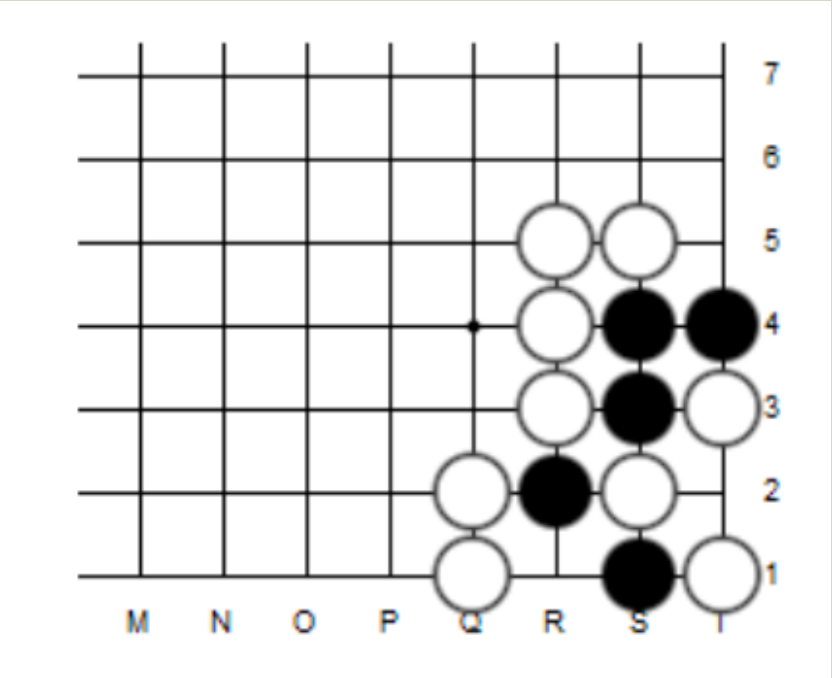
Special Pattern:



The black pieces surrounded by the white cannot be captured.
They are considered to be “alive” because they have two “**eyes**” (marked by red circles).
White cannot place a stone in both locations in the same turn, therefore there is no way for white to completely surround the black pieces.
If such patterns are created, these black pieces will be preserved

Challenge: Black's turn, how to be alive in 1 step? (Hint: Create the two eyes)





Let’s see some mathematics

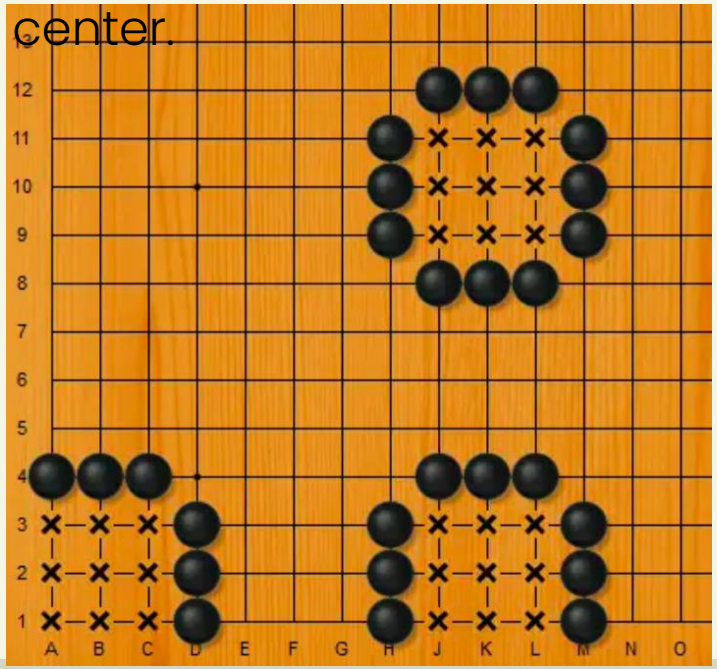
Regardless of the complicated rule...or even the opponent
What should beginners do? What are player aiming to do in Go in the first place?
Circling maximum space

Circling area in Go can be seen as: Simple Conditional extreme value problem: The perimeter C of an rectangle is a fixed value(formed by the pieces). Find the maximum value of the area S of the rectangle (the area surrounded).

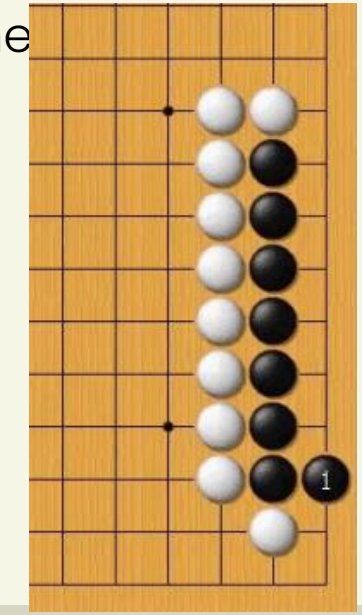
This can explain most basic proverbs in ‘Go’ for beginners

- “**多子**围空方胜扁”
- Multiple pieces circling, square exceed flat.

- “**金角**银边草肚皮”
- Golden edge, silver sides, grass center.



- “**七子沿**边活也输”
- Severn pieces aligning on edge, even alive the

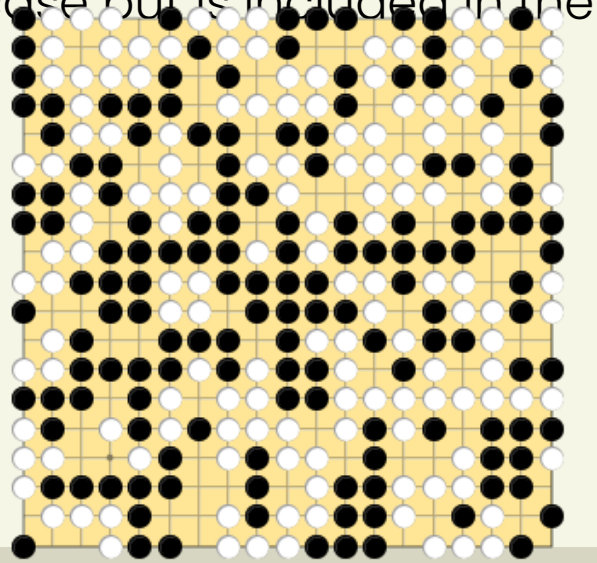


Probability in Go

End Pattern

Considering only the end pattern but not the process to get there:
On the final board, one spot is either:
Occupied by white(Physically)
Occupied by black
Unoccupied by both
...
There are total 361 spots:
This gives a: 3^ 361 total results.

However, there are some illegal moves:
The pieces captured will not be presented on the board in any case but is included in the results.

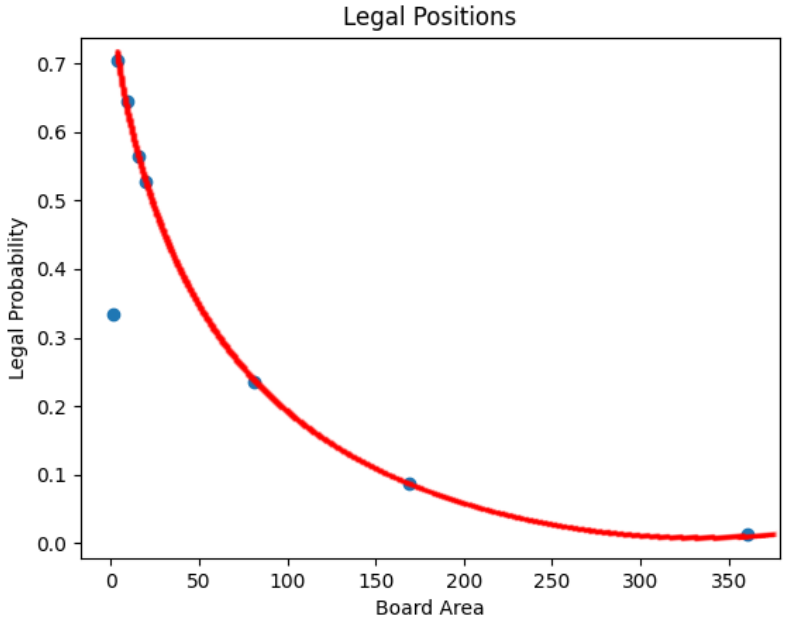


End Pattern

Mathematicians John Tromp and Gunnar Farnebäck proposed an estimation in 2016: They noticed:

1. As the size of the board increases, the percentage of legal pattern decreases.
2. Using computer simulations, they approximated that the percentage of legal positions on a 19 x 19 Go board was close to $2.081 \times 3.361 \sim 2.089 \times 10^{170}$

Probability	Illegal positions	Legal positions	Board Size
0.333333	2	1	1x1
0.703704	24	57	2x2
0.643957	7008	12675	3x3
0.564925	18728556	24318165	4x4
0.527724	1646725708	1840058693	4x5
0.235	approximation	approximation	9x9
0.087	approximation	approximation	13x13
0.012	approximation	approximation	19x19



Possible games

The number of possible games, in which each step given account.
Most simple idea: In the first move, there are 361 intersections to begin with....
In the second...
... **361**!
This gives a: ( ) total results.

There are still illegal moves, and Go games rarely lasts for 361 moves.

Possible games

However, currently, the more precise calculation about the possible games is generally vague, and we can only rely on the best result possibly get.

Computer Scientist Victor Allis uses the statistical fact that typical games of Go will last an average of 150 moves with an average of 250 choices per move, resulting in a value close to 10^{360} (250^{150} = **4.9 x 10^{359}**) possible games

Chess: Approaching Infinity?

- End Pattern: ~2.089×10^{170}
- Possible Games:~ 4.9×10^{359}

- There are approximately 10^{50} atoms on earth
- The Universe has $1.38*10^{10}$ year of history
- Assume there is a computer that generate a possible game in one nano second(10^{-9} second) and starts from the origination of the universe, until now, it only generates less than 0.0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000001% of possible games in 'Go'.
- If an atom can store a possible game, it takes atoms on 10^{100} earths to store all

What can we see in ‘Go’?

01 | Game Theory

Change one’s own decision-making based on the acts of others

02 | Market Economy

A progress to compete for limited total resource

03 | Optimal Decision Making

Placing the pieces further away from each other may results in:

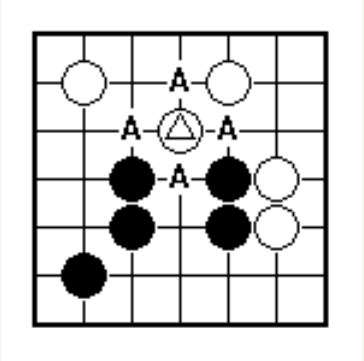
1. Potential to surround more area
2. Risk of being separated or removed from board

Further Explorations

- 3 Dimensional ‘GO’

How will the strategy be modified/ probability be expanded?

- Making the pieces ‘Fluid’



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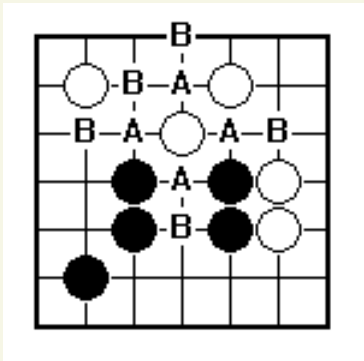

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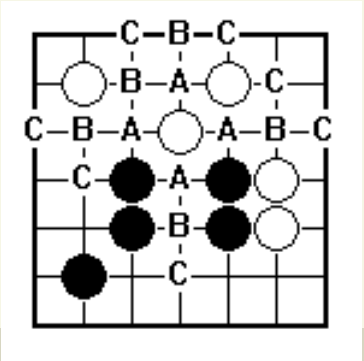

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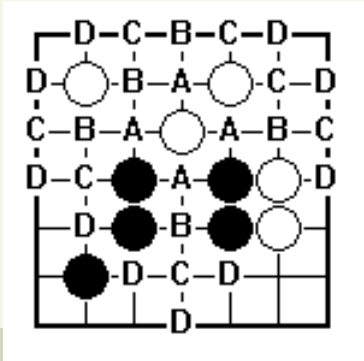

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In computer science called 'flooding'. Imagine that black pieces can flood out black water, and white pieces white water. The water can run anywhere between empty points, but is blocked by occupied points.

Further Explorations

- AI ‘Go’

Simulate the few steps ahead as branches, cut the ‘bad moves’ (to increase capacity) and analyze expert games for ‘good moves’. After enough data, play against itself and continuously train for maximum points.(Good patterns& winning: higher points.)

Thank you!

Questions?

Reference

British Go Association. (2020, May 05). A Brief History of Go.https://www.britgo.org/intro/history

Lei, L. (n.d.). Go and Mathematics. American Go Foundation.https://agfgo.org/downloads/Go%20and%20Mathematics.pdf

Tromp, J., & Farnebäck, G. (2007). Combinatorics of Go. In Lecture Notes in Computer Science (Vol. 4630). https://link.springer.com/chapter/10.1007/978-3-540-75538-8_8

Lichtenstein, D., & Sipser, M. (1980). GO Is Polynomial-Space Hard. Journal of the ACM, 27(2), 393–401. https://doi.org/10.1145/322186.322201

nrich.maths.org. (2011). Behind the Rules of Go. https://nrich.maths.org/1433

Related Links

A interesting attempt for an 3-Dimensional Chess:

A fictional type of chess created in manga *Hunter x Hunter*. Played on a 9*9 board, with rule similar to Japanese Shogi, while pieces can be paced piled on each other up to 3 layers.

Specific rules:

https://www.youtube.com/watch?v=W6WqxeC_S-s

Go & Turing Machine:

In the game of Go, the question of whether a ladder—a method of capturing stones-works, is shown to be PSPACE-complete.

https://www.researchgate.net/publication/225160127_Ladders_Are_PSPACE-Complete