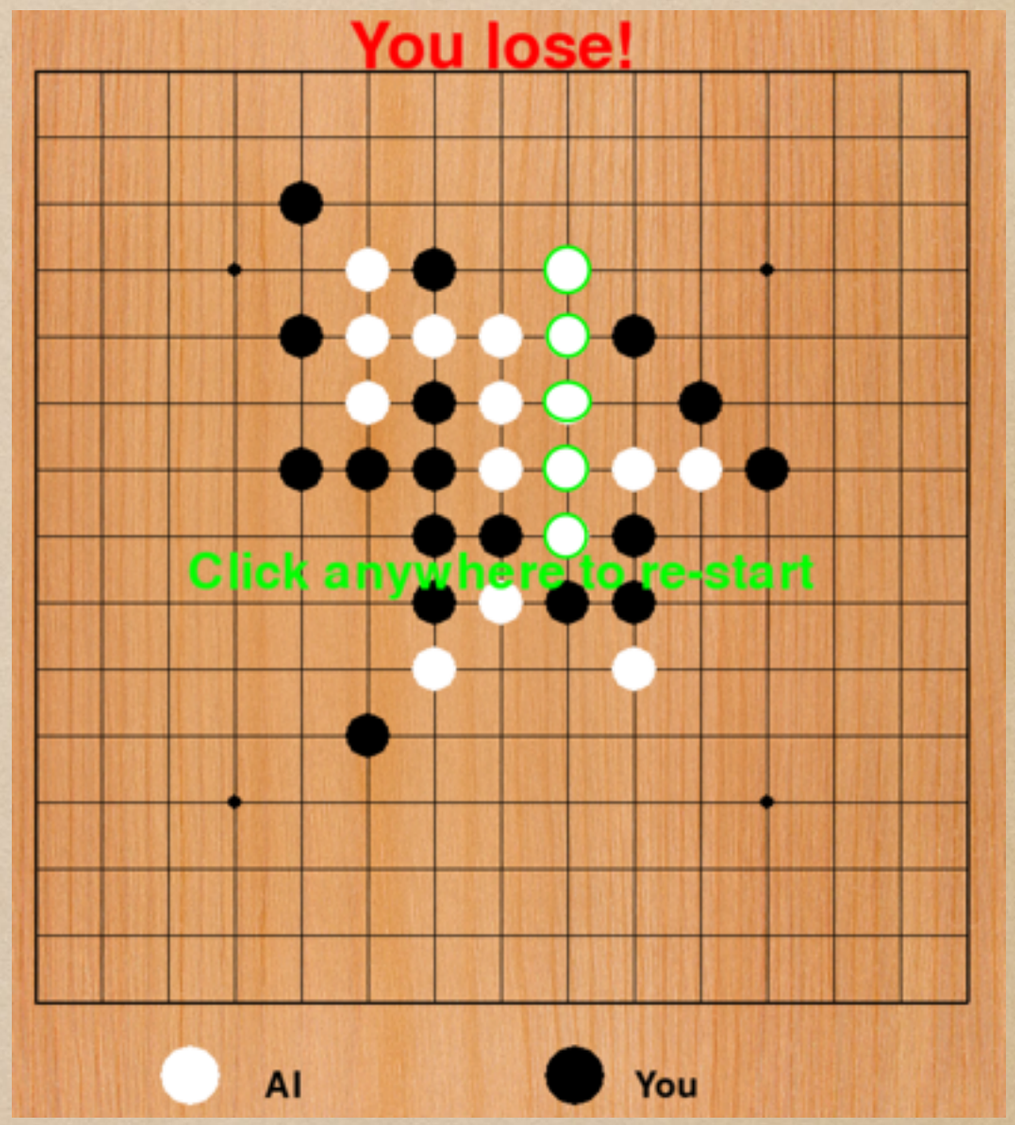
GOMOKU GAME

YUE GAO

GOMOKU RULES

- Gomoku, also called Five in a Row, is an abstract strategy board game. Two players, black and white, plays in turn on a 15x15 (or smaller) Go board.

- The first player who makes a line of exactly five stones wins.

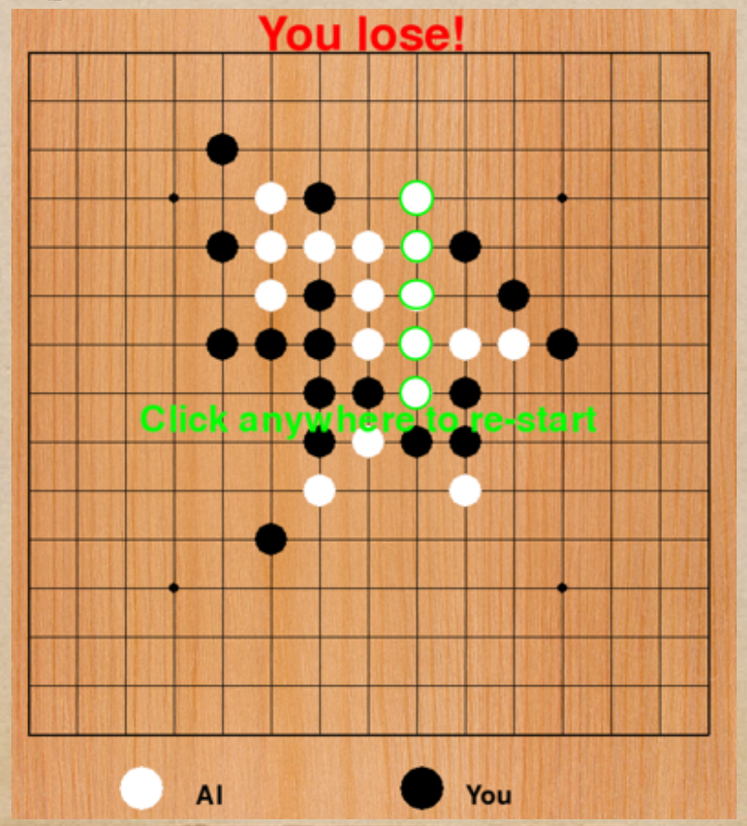


My Goals

- Visualizer

  —Player plays black & AI plays white

- Improve the performance (better winning rate, shorter thinking time) of AI



Methods to solve GOMOKU

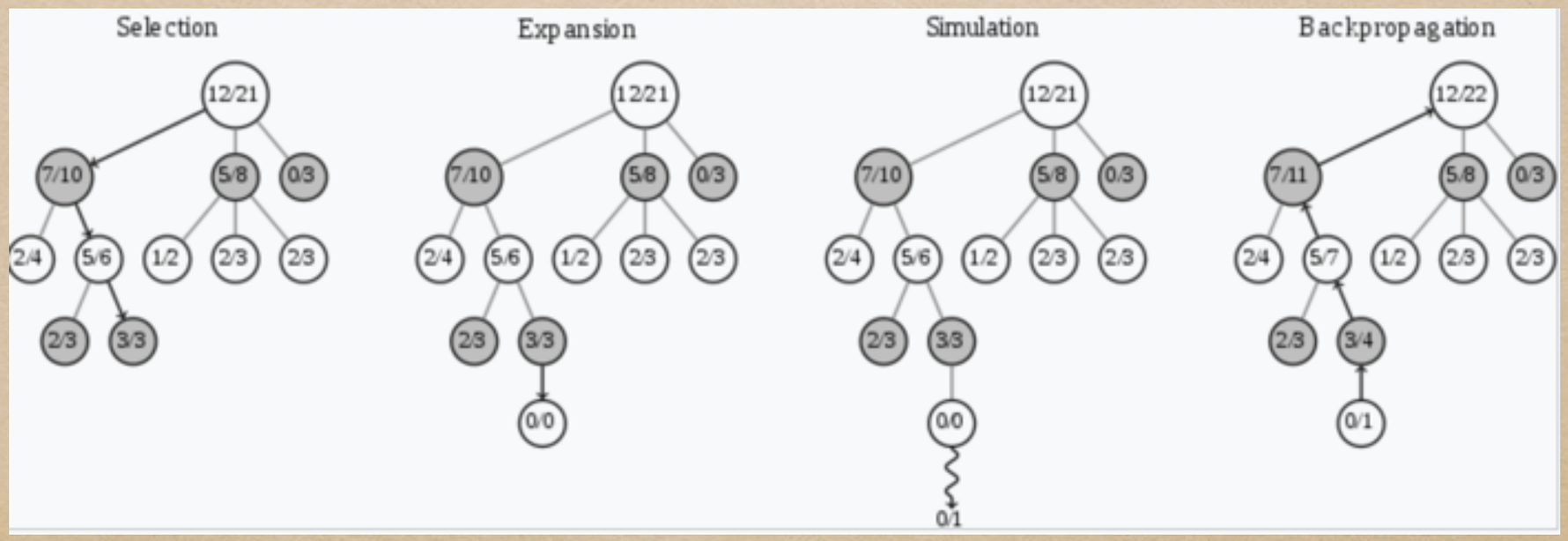
- Monte-Carlo Tree Search
- Value network algorithm.
  _Assigning value to each position, select the optimal one.

Monte-Carlo Tree Search

- Monte-Carlo Tree Search does not require any prior knowledge of the game strategies.

- Steps :

Selection → Expansion → Simulation → Backpropagation



Performance of MCTS

- On 15x15 board : Set simulation time as 90 seconds, the AI never wins me.
- On 8x8 board (Other's code) : Set simulation time as 90 seconds, most of the time it's end up with a tie game.

```
   0 1 2 3 4 5 6 7
0  _ _ _ X O _ _ _
1  _ _ O X O _ _ X
2  _ O X O X _ _ _
3  O O X O O O X _
4  X X O X O X _ _
5  _ _ X O X O _ O
6  _ _ X O X O O X
7  _ O _ X O _ X X
```

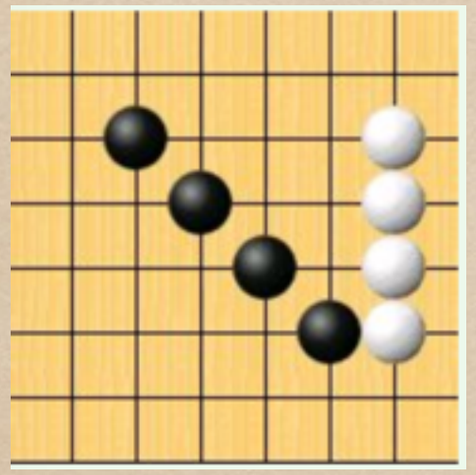
Neither x or o will have the opportunity to form a 5-in-row

Performance of MCTS

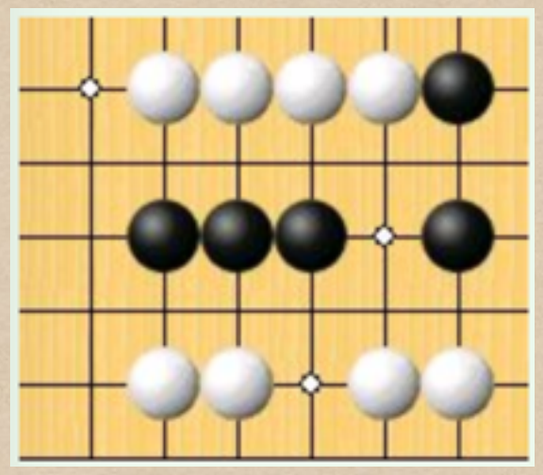
- MCTS works well on small board, but in larger game board, it's performance is not good enough.
- The simulation time is too long, it will ruin your playing experience.
- So perhaps an algorithm that combines playing tricks would be better…

Common tricks in Gomoku

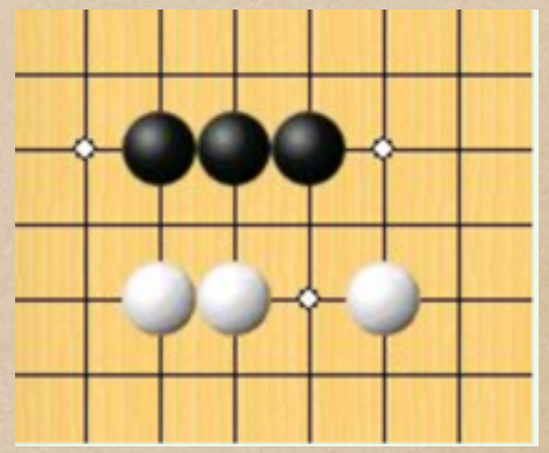
An important factor in assessing the position is how significant figures are built rivals. Here are several positions that can lead to advantages.



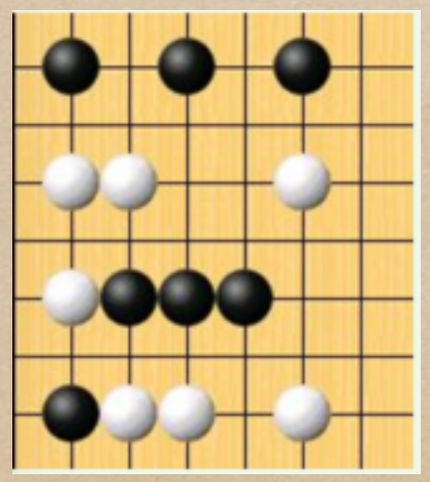
Live Four



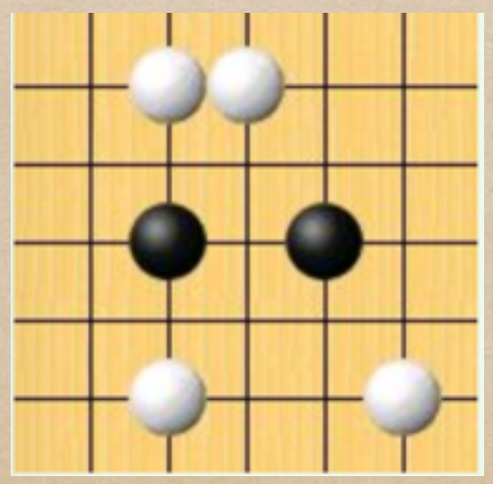
Die Four



Live Three



Die Three



Live two

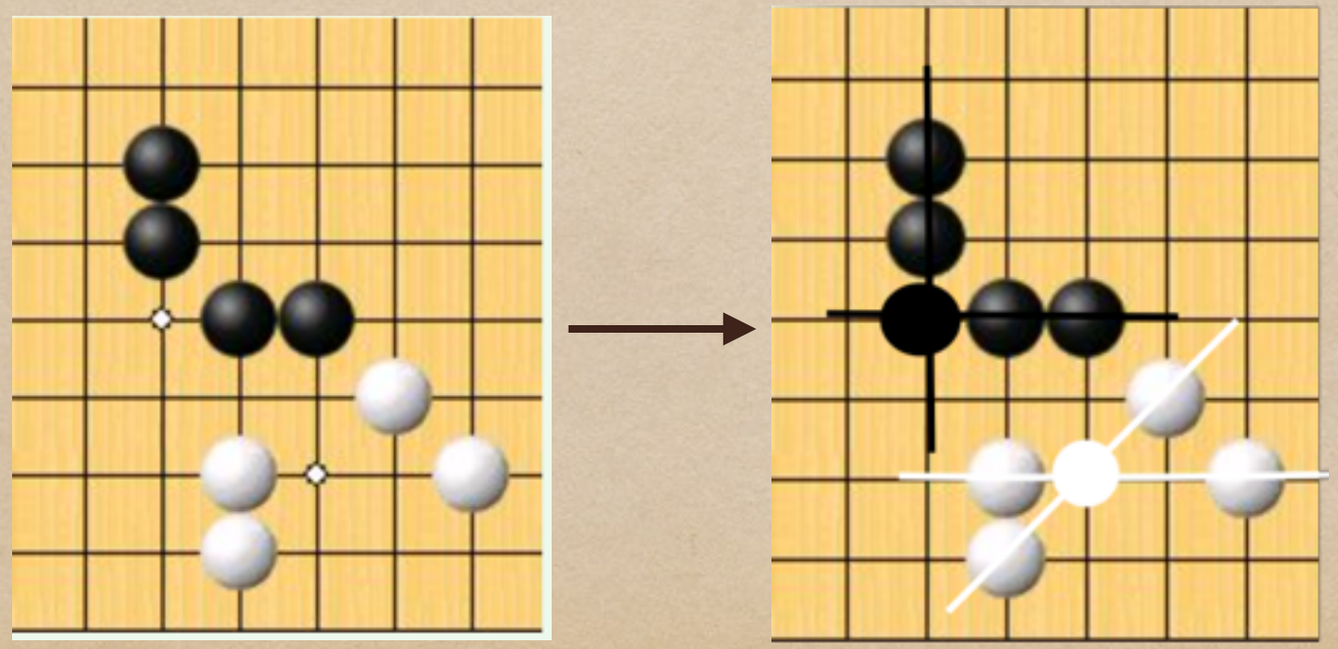
Value Network Algorithm

- The word 'network' does not mean neural network, it's simply a value matrix.
- A 15x15 matrix is used to store the value of each position, the matrix will be updated after each move. Each time AI will play on an empty position with the highest value.
- AI should also pay attention to the opponent's move, when the opponent forms a live three or die four, AI must block it immediately.

Value Assigning Rules

- value = horizontal value + vertical value + slash value + backslash value

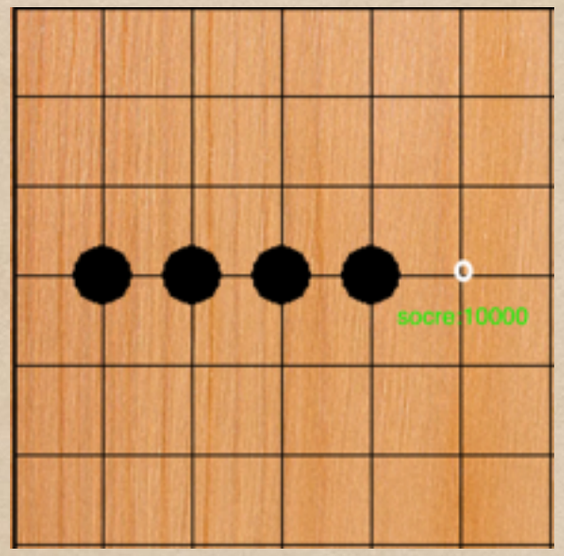
  —Since we prefer the moves that can lead to a double/triple/quadruple live three/die four/…

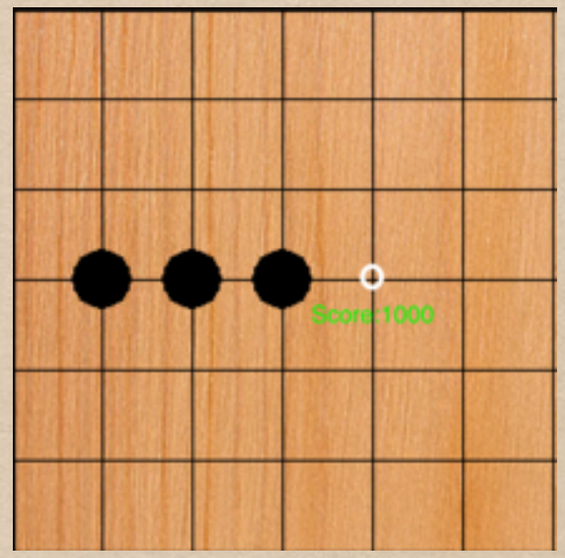


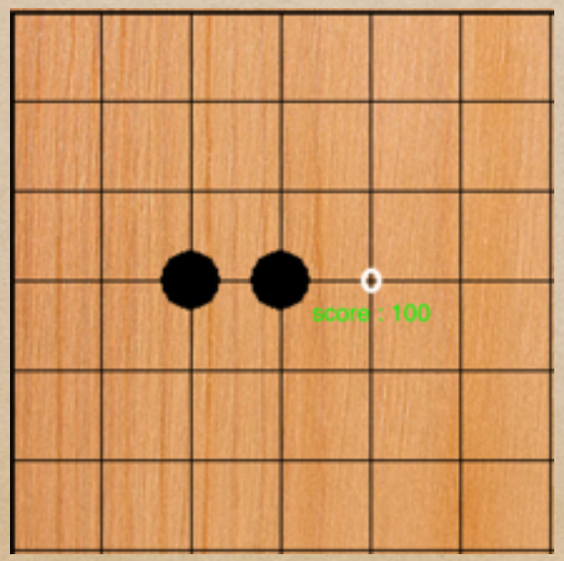
Form live three in two different directions

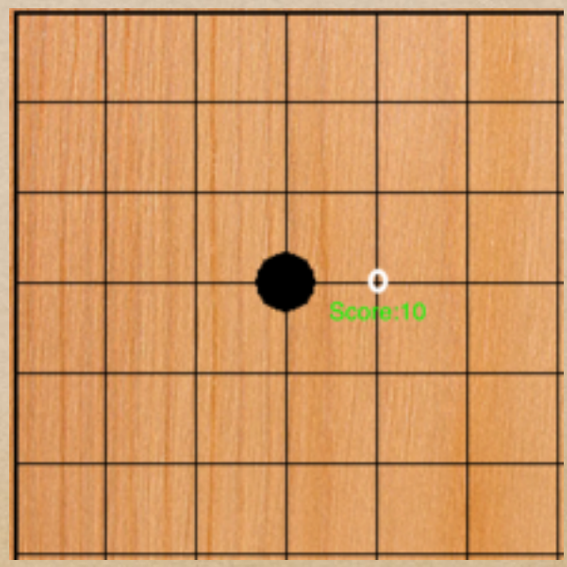
Value Assigning Rules

- Take horizontal direction as an example :



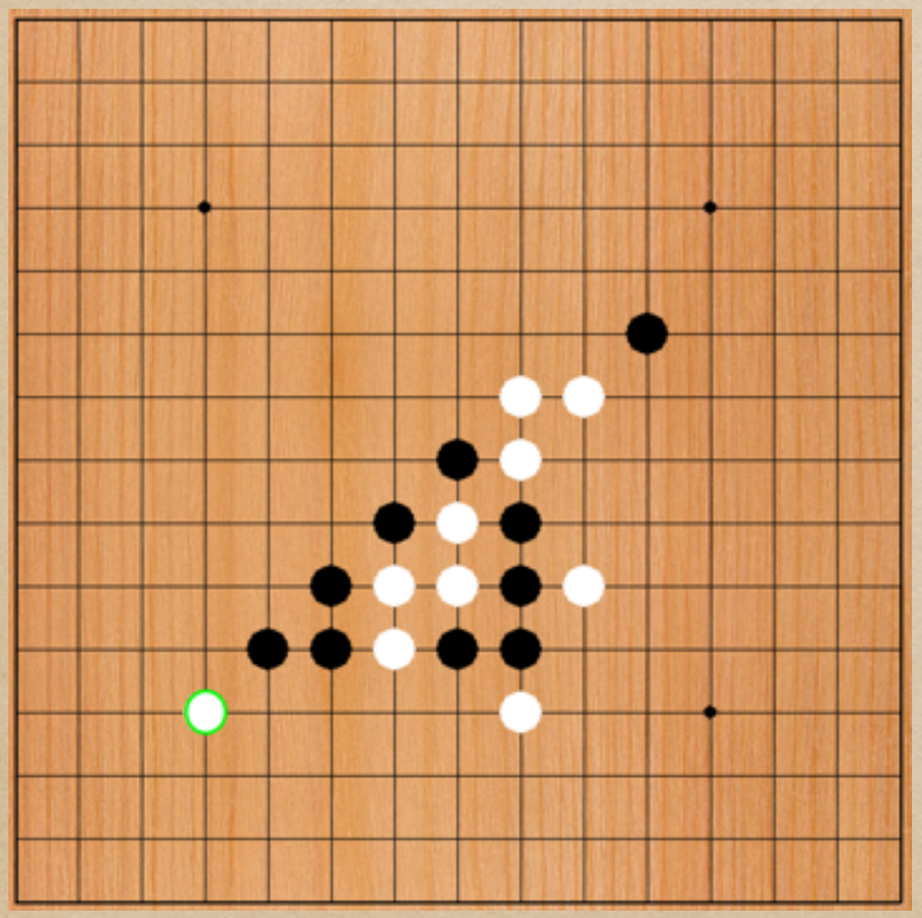




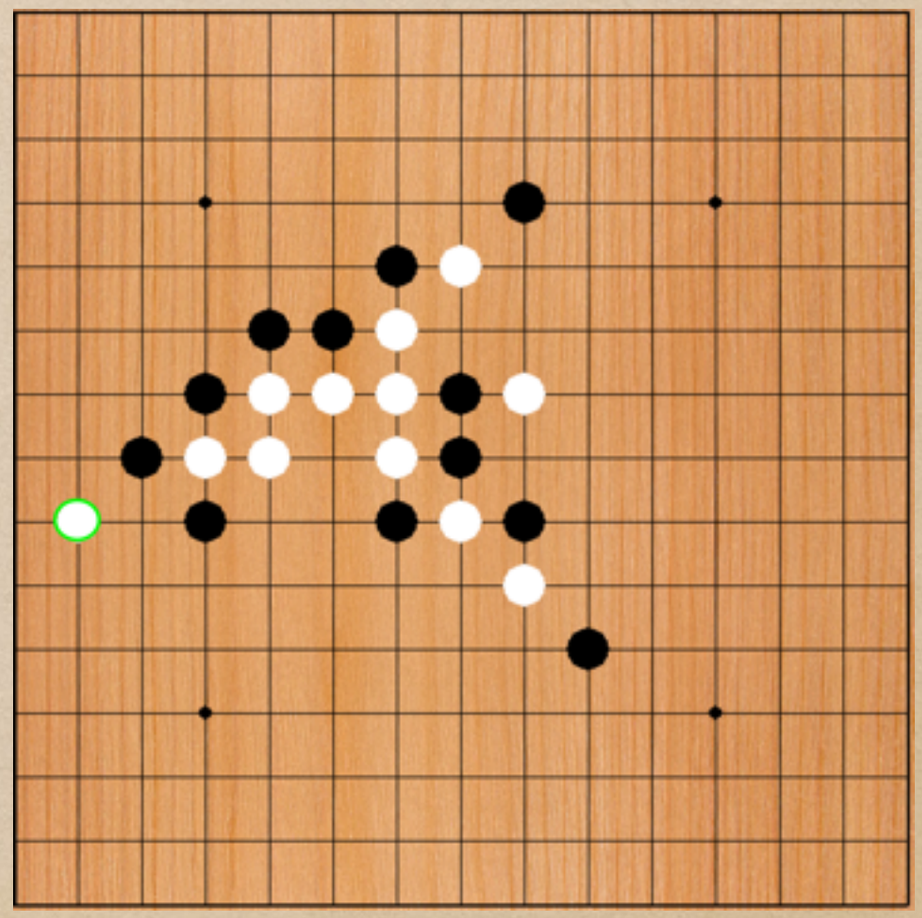


An example of selecting movement

- Block opponent's die four

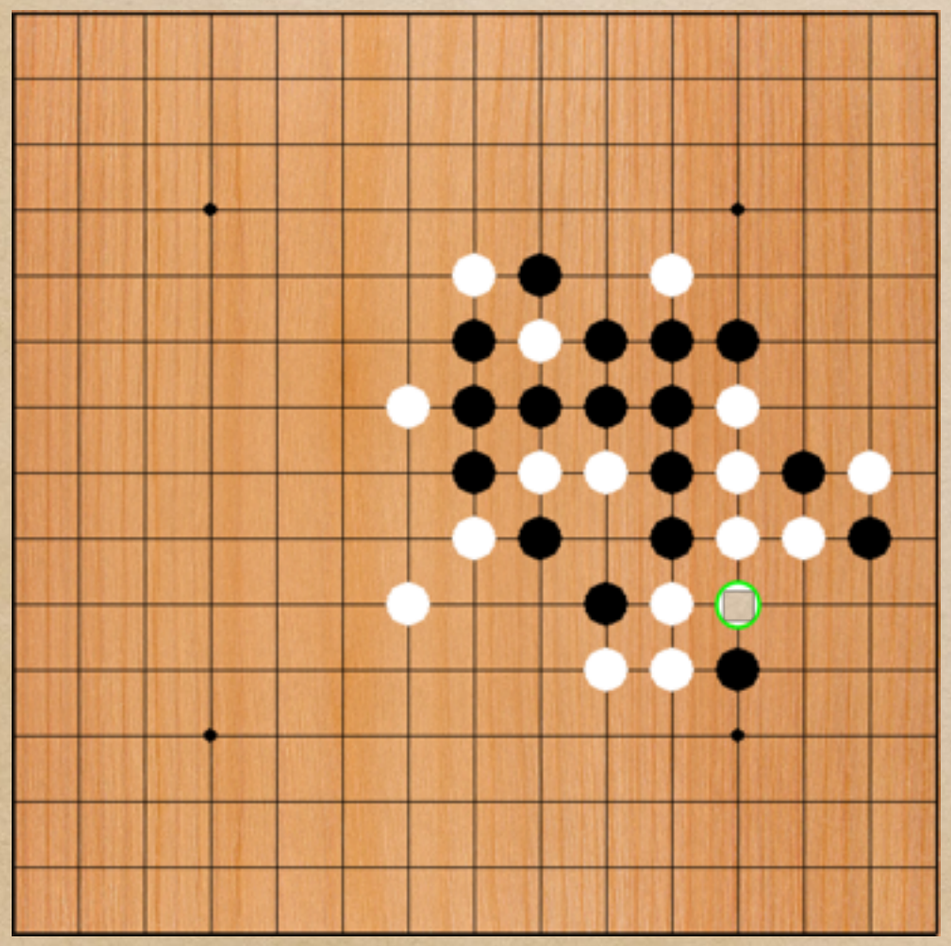


- Block opponent's live three



An example of selecting movement

AI selects to play on the green-circled position since it's opponent do not have live three or die four, and this position has the highest value



```
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
[0, 0, 0, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 0]
[0, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 0]
[0, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 0]
[0, 4, 4, 4, 4, 4, 4, 4, 4, 13, 13, 103, 4, 4, 4]
[0, 4, 4, 4, 13, 4, 22, -1, 22, 13, -1, 13, 4, 4, 4]
[0, 4, 4, 4, 4, -1, -2, -2, -2, -1, 13, 13, 4, 4, 4]
[0, 4, 4, 4, 13, -2, -1, -2, -1, -2, 103, 13, 103, 4, 4, 4]
[0, 4, 4, 4, 4, 13, -2, -2, -1, 4, -2, -1, 1003, 4, 4, 4]
[0, 4, 4, 4, 4, -1, -2, -2, -2, -1, -1, 22, 4, 4, 4]
[0, 4, 4, 4, 4, 13, -2, -1, -1, -1, -1, -2, 4, 4, 4, 4]
[0, 4, 4, 4, 4, 4, 4, 4, -2, -1, 13, 4, 4, 4, 4, 4]
[0, 4, 4, 4, 4, 4, 4, 4, 1003, -2, 13, 4, 4, 4, 4, 4]
[0, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4]
```

Value matrix before the green-circled movement

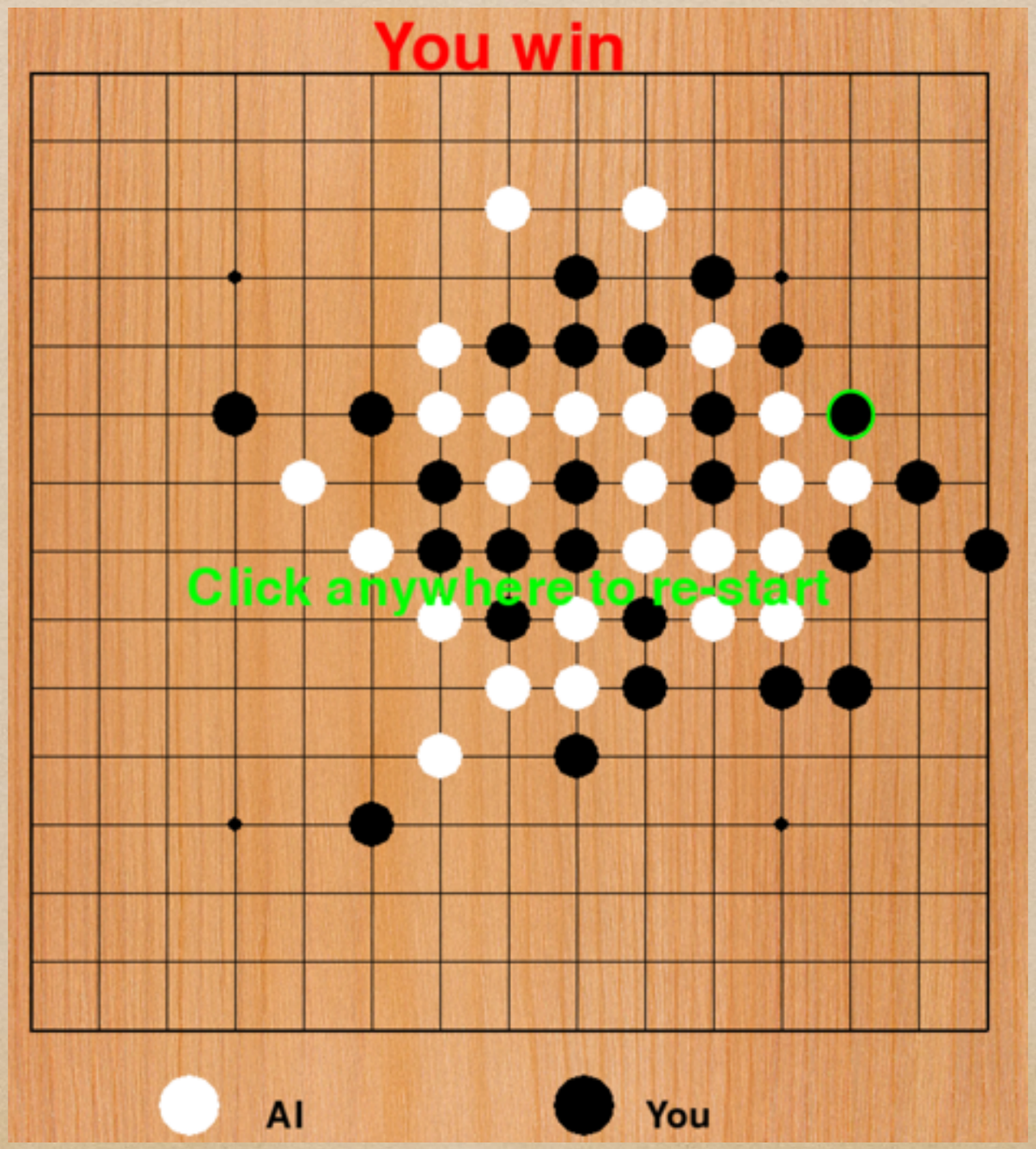
Performance of value network AI

- Thinking Time of this AI is negligible.

- Test against me :
  —AI beats me with probability > 70%
  —I'm familiar with this game, but I don't think I'm an excellent player.

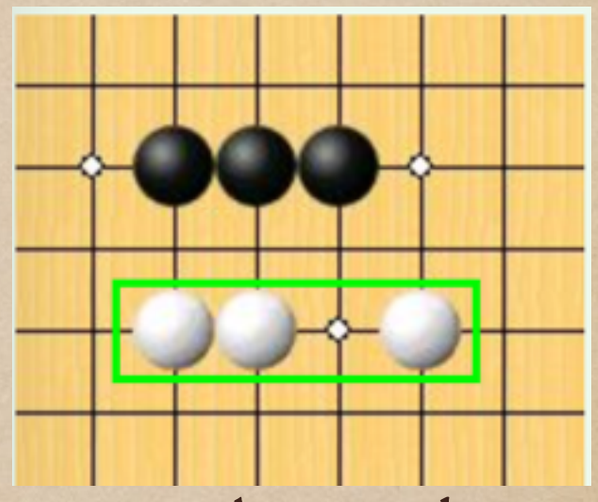
- Test against a stronger player :
  —At first the winning rate is about 50%
  —Then he found the disadvantage of AI, and his winning rate improved.

A player-winning case

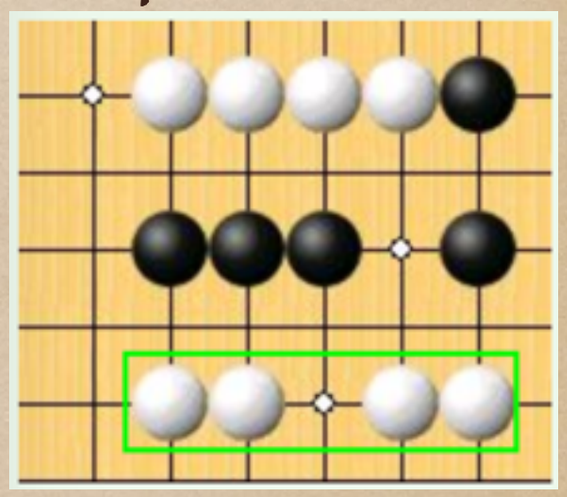


Disadvantages

In my program, the AI will block its opponent's connected live three /die four, but it cannot block its opponent's jump three and jump die four .



Jump live Three



Jump Die Four

Further Improvements

There's a trade-off between focusing on selecting positions with high value and blocking the opponent's moves.

—If the player is strong, AI should block jump live three and jump die four.

—If the player is not that good, perhaps AI can focus more on selecting valuable positions.

So it would be better if player can set different modes

—Easy mode & Hard mode