

MCTS Report

1 TicTacToe

1.1 Features of the Implementation for MCTS

1. The `wins` is viewed from the perspective of the last player of each node.
2. We add a field `parent` to `Node` for backpropagation.
3. Now `addChild` returns the added child node.
4. Backpropagation is faster than the original version since it only propagates the change to `wins` and `playouts` of each node.
5. We keep track of the structures generated during the stage of rollouts.
6. We use UCB1 to select the node for rollouts:

$$\frac{w}{n} + \sqrt{2} \cdot \sqrt{\frac{\ln N}{n}}$$

where w is `wins` of the current node, n is `playouts` of the current node, and N is `playouts` of the parent node. $\sqrt{2}$ is the exploration parameter, which can be chosen empirically.

1.2 Usage

1. The variable `human` is used to control who is first to move: if `human` is 1, then human is X; if `human` is 0, then human is O.
2. The variable `times` is used to control the number of iterations during each process of MCTS.

1.3 Examples

1.3.1 `human` is 1

```
TicTacToe{
. . .
. . .
. . .
}
enter your move (you are X
1 1
TicTacToe{
. . .
. X .
. . .
}
AI thinking ...
TicTacToe{
. . .
. X .
. . O
```

```

}
enter your move (you are X
0 0
TicTacToe{
X . .
. X .
. . 0
}
AI thinking ...
TicTacToe{
X . .
. X .
0 . 0
}
enter your move (you are X
2 1
TicTacToe{
X . .
. X .
0 X 0
}
AI thinking ...
TicTacToe{
X 0 .
. X .
0 X 0
}
enter your move (you are X
1 0
TicTacToe{
X 0 .
X X .
0 X 0
}
AI thinking ...
TicTacToe{
X 0 .
X X 0
0 X 0
}
enter your move (you are X
0 2
TicTacToe{
X 0 X
X X 0
0 X 0
}
draw

```

1.3.2 **human** is 0

```

TicTacToe{
. . .
. . .
. . .
}

```

```

AI thinking ...
TicTacToe{
. . .
. X .
. . .
}
enter your move (you are 0
2 2
TicTacToe{
. . .
. X .
. . 0
}
AI thinking ...
TicTacToe{
. . .
. X .
. X 0
}
enter your move (you are 0
0 1
TicTacToe{
. 0 .
. X .
. X 0
}
AI thinking ...
TicTacToe{
. 0 X
. X .
. X 0
}
enter your move (you are 0
2 0
TicTacToe{
. 0 X
. X .
0 X 0
}
AI thinking ...
TicTacToe{
. 0 X
. X X
0 X 0
}
enter your move (you are 0
1 0
TicTacToe{
. 0 X
0 X X
0 X 0
}
AI thinking ...
TicTacToe{
X 0 X
0 X X

```

```
0 X 0
}
draw
```

2 ConnectN

2.1 Introduction

Connect Four is a gravity-based Gomoku-like game. ConnectN is generalization of the classic Connect Four.

2.2 Features of the Implementation for ConnectN

1. The width and height of the board is configurable. The number of stones in a line for a player to win is also configurable.
2. We provide some facilities to help novices with learning ConnectN, such as taking-back and AI advice.
3. The strategy of MCTS implementation is almost the same as TicTacToe.
4. You can choose to play against a human player or an AI. Of course, with little modification, you can configure the game to be conducted by two human players or two AIs.
5. AI will evaluate the winning rate after the move, both for human and AI.
6. `moves` now will correctly compute the available moves when facing a terminal state. (In fact, there is none!)

2.3 Usage

1. **You may have to change the size of the heap space for JVM!**
2. The variable `human` is used to control who is first to move: if `human` is 0, then human is X; if `human` is 1, then human is O. X is the first player to move.
3. The variable `times` is used to control the number of iterations during each process of MCTS. (You can try different strategies for the number of iterations, such as reducing or increasing the number of iterations as the game goes.)
4. You enter the column for the move, beginning from zero. If the move is invalid, then it will prompt you to retry. -1 is for human players to take back the last move. -2 is for human players to get advice from AI (based on MCTS also).

2.4 Examples

2.4.1 `human` is 0

```
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | | | | | |
```

```

6 | | | | | | | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Please enter your move (you are X

```

4
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | | | | | |
6 | | | | |X| | | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Estimated winning rate for human after move is 0.5895

AI thinking ... (AI is O
The chosen move is 2
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | | | | | |
6 | | |O| |X| | | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.46226415094339623

Please enter your move (you are X

```

4
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | |X| | | | |
6 | | |O| |X| | | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Estimated winning rate for human after move is 0.6600387972841901

AI thinking ... (AI is O
The chosen move is 4
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | |O| | | | |
5 | | | | |X| | | | |
6 | | |O| |X| | | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.4086161879895561

Please enter your move (you are X

```
2
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | |0| | | | |
5 | | |X| |X| | | | |
6 | | |0| |X| | | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8
```

Estimated winning rate for human after move is 0.574784276126558

AI thinking ... (AI is O
The chosen move is 5
The resulting position is

```
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | |0| | | | |
5 | | |X| |X| | | | |
6 | | |0| |X|0| | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8
```

Estimated winning rate after move for AI is 0.47424242424242424

Please enter your move (you are X

```
5
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | |0| | | | |
5 | | |X| |X|X| | | |
6 | | |0| |X|0| | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8
```

Estimated winning rate for human after move is 0.6603498542274052

AI thinking ... (AI is O
The chosen move is 4
The resulting position is

```
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | |0| | | | |
4 | | | | |0| | | | |
5 | | |X| |X|X| | | |
6 | | |0| |X|0| | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8
```

Estimated winning rate after move for AI is 0.39054054054054055

Please enter your move (you are X

```
4
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X| | | | |
3 | | | | |O| | | | |
4 | | | | |O| | | | |
5 | | |X| |X|X| | | |
6 | | |O| |X|O| | | |
```

+--+--+--+--+--+--+

0 1 2 3 4 5 6 7 8

Estimated winning rate for human after move is 0.678709055876686

AI thinking ... (AI is O

The chosen move is 2

The resulting position is

```
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X| | | | |
3 | | | | |O| | | | |
4 | | |O| |O| | | | |
5 | | |X| |X|X| | | |
6 | | |O| |X|O| | | |
```

+--+--+--+--+--+--+

0 1 2 3 4 5 6 7 8

Estimated winning rate after move for AI is 0.34655172413793106

Please enter your move (you are X

```
2
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X| | | | |
3 | | |X| |O| | | | |
4 | | |O| |O| | | | |
5 | | |X| |X|X| | | |
6 | | |O| |X|O| | | |
```

+--+--+--+--+--+--+

0 1 2 3 4 5 6 7 8

Estimated winning rate for human after move is 0.6445198836081474

AI thinking ... (AI is O

The chosen move is 3

The resulting position is

```
0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X| | | | |
3 | | |X| |O| | | | |
4 | | |O| |O| | | | |
5 | | |X| |X|X| | | |
6 | | |O|O|X|O| | | |
```

+--+--+--+--+--+--+

0 1 2 3 4 5 6 7 8

Estimated winning rate after move for AI is 0.3775167785234899

Please enter your move (you are X

3

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X| | | | |
3 | | |X| |O| | | | |
4 | | |O| |O| | | | |
5 | | |X|X|X|X| | | |
6 | | |O|O|X|O| | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Estimated winning rate for human after move is 0.8435374149659864

AI thinking ... (AI is O
The chosen move is 5
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X| | | | |
3 | | |X| |O| | | | |
4 | | |O| |O|O| | | |
5 | | |X|X|X|X| | | |
6 | | |O|O|X|O| | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.227735368956743

Please enter your move (you are X
3

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X| | | | |
3 | | |X| |O| | | | |
4 | | |O|X|O|O| | | |
5 | | |X|X|X|X| | | |
6 | | |O|O|X|O| | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Estimated winning rate for human after move is 0.8191489361702128

AI thinking ... (AI is O
The chosen move is 5
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X| | | | |
3 | | |X| |O|O| | | |
4 | | |O|X|O|O| | | |
5 | | |X|X|X|X| | | |
6 | | |O|O|X|O| | | |
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.21069182389937108

Please enter your move (you are X
5

```

0 | | | | | | | | |
1 | | | | | | | | |

```



```

2 | | | | |X|X| | | |
3 | | |X| |O|O| | | |
4 | | |O|X|O|O| | | |
5 | | |X|X|X|X| | | |
6 | | |O|O|X|O| | | |

```

+--+--+--+--+--+--+

0 1 2 3 4 5 6 7 8

Estimated winning rate for human after move is 0.8626320845341018

AI thinking ... (AI is O

The chosen move is 6

The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X|X| | | |
3 | | |X| |O|O| | | |
4 | | |O|X|O|O| | | |
5 | | |X|X|X|X| | | |
6 | | |O|O|X|O|O| | |

```

+--+--+--+--+--+--+

0 1 2 3 4 5 6 7 8

Estimated winning rate after move for AI is 0.17446043165467626

Please enter your move (you are X

6

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |X|X| | | |
3 | | |X| |O|O| | | |
4 | | |O|X|O|O| | | |
5 | | |X|X|X|X|X| | |
6 | | |O|O|X|O|O| | |

```

+--+--+--+--+--+--+

0 1 2 3 4 5 6 7 8

X wins

2.4.2 A game between two AIs

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | | | | | |
6 | | | | | | | | |

```

+--+--+--+--+--+--+

0 1 2 3 4 5 6 7 8

AI thinking ... (AI is X

The chosen move is 4

The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |

```

```

5 | | | | | | | | |
6 | | | | |X| | | |
+-+--+--+--+--+--+
 0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.5964467005076142

AI thinking ... (AI is O
The chosen move is 2
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | | | | | |
6 | | |O| |X| | | |
+-+--+--+--+--+--+
 0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.5024509803921569

AI thinking ... (AI is X
The chosen move is 4
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | |X| | | |
6 | | |O| |X| | | |
+-+--+--+--+--+--+
 0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.6498054474708171

AI thinking ... (AI is O
The chosen move is 6
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | |X| | | |
6 | | |O| |X| |O| |
+-+--+--+--+--+--+
 0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.388888888888889

AI thinking ... (AI is X
The chosen move is 1
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |

```

```

5 | | | | |X| | | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.7019704433497537

AI thinking ... (AI is 0
The chosen move is 6
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | | | | | |
5 | | | | |X| |0| | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.4541284403669725

AI thinking ... (AI is X
The chosen move is 4
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | |X| | | | |
5 | | | | |X| |0| | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.6781609195402298

AI thinking ... (AI is 0
The chosen move is 6
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | | | |
4 | | | | |X| |0| | |
5 | | | | |X| |0| | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.3952380952380952

AI thinking ... (AI is X
The chosen move is 6
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | | | |X| | |
4 | | | | |X| |0| | |

```

```

5 | | | | |X| |0| | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.6890243902439024

AI thinking ... (AI is 0
The chosen move is 4
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | |0| |X| | |
4 | | | | |X| |0| | |
5 | | | | |X| |0| | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.43167701863354035

AI thinking ... (AI is X
The chosen move is 1
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | |0| |X| | |
4 | | | | |X| |0| | |
5 | |X| | |X| |0| | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.6513157894736842

AI thinking ... (AI is 0
The chosen move is 1
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | |0| |X| | |
4 | |0| | |X| |0| | |
5 | |X| | |X| |0| | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.4228855721393035

AI thinking ... (AI is X
The chosen move is 2
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | | | | | |
3 | | | | |0| |X| | |
4 | |0| | |X| |0| | |

```

```

5 | |X|X| |X| |0| | |
6 | |X|0| |X| |0| | |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.6584158415841584

AI thinking ... (AI is 0
The chosen move is 4
The resulting position is

```

0 | | | | | | | | |
1 | | | | | | | | |
2 | | | | |0| | | |
3 | | | | |0| |X| |
4 | |0| | |X| |0| |
5 | |X|X| |X| |0| |
6 | |X|0| |X| |0| |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.36163522012578614

AI thinking ... (AI is X
The chosen move is 4
The resulting position is

```

0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |0| | | |
3 | | | | |0| |X| |
4 | |0| | |X| |0| |
5 | |X|X| |X| |0| |
6 | |X|0| |X| |0| |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.6867088607594937

AI thinking ... (AI is 0
The chosen move is 2
The resulting position is

```

0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |0| | | |
3 | | | | |0| |X| |
4 | |0|0| |X| |0| |
5 | |X|X| |X| |0| |
6 | |X|0| |X| |0| |
+-+--+--+--+--+--+
0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.38484848484848483

AI thinking ... (AI is X
The chosen move is 6
The resulting position is

```

0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |0| |X| |
3 | | | | |0| |X| |
4 | |0|0| |X| |0| |

```

```

5 | |X|X| |X| |0| | |
6 | |X|0| |X| |0| | |
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.6560509554140127

```

```

AI thinking ... (AI is 0
The chosen move is 7
The resulting position is
0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |0| |X| | |
3 | | | | |0| |X| | |
4 | |0|0| |X| |0| | |
5 | |X|X| |X| |0| | |
6 | |X|0| |X| |0|0| |
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.4119170984455959

```

```

AI thinking ... (AI is X
The chosen move is 2
The resulting position is
0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |0| |X| | |
3 | | |X| |0| |X| | |
4 | |0|0| |X| |0| | |
5 | |X|X| |X| |0| | |
6 | |X|0| |X| |0|0| |
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.7244897959183674

```

```

AI thinking ... (AI is 0
The chosen move is 5
The resulting position is
0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |0| |X| | |
3 | | |X| |0| |X| | |
4 | |0|0| |X| |0| | |
5 | |X|X| |X| |0| | |
6 | |X|0| |X|0|0|0| |
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.3333333333333333

```

```

AI thinking ... (AI is X
The chosen move is 5
The resulting position is
0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |0| |X| | |
3 | | |X| |0| |X| | |
4 | |0|0| |X| |0| | |

```

```

5 | |X|X| |X|X|O| | |
6 | |X|O| |X|O|O|O| |
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.7255434782608695

```

```

AI thinking ... (AI is O
The chosen move is 7
The resulting position is
0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |O| |X| |
3 | | |X| |O| |X| |
4 | |O|O| |X| |O| |
5 | |X|X| |X|X|O|O| |
6 | |X|O| |X|O|O|O| |
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.37012987012987014

```

```

AI thinking ... (AI is X
The chosen move is 8
The resulting position is
0 | | | | | | | | |
1 | | | | |X| | | |
2 | | | | |O| |X| |
3 | | |X| |O| |X| |
4 | |O|O| |X| |O| |
5 | |X|X| |X|X|O|O| |
6 | |X|O| |X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.7170212765957447

```

```

AI thinking ... (AI is O
The chosen move is 6
The resulting position is
0 | | | | | | | | |
1 | | | | |X| |O| |
2 | | | | |O| |X| |
3 | | |X| |O| |X| |
4 | |O|O| |X| |O| |
5 | |X|X| |X|X|O|O| |
6 | |X|O| |X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.300561797752809

```

```

AI thinking ... (AI is X
The chosen move is 7
The resulting position is
0 | | | | | | | | |
1 | | | | |X| |O| |
2 | | | | |O| |X| |
3 | | |X| |O| |X| |
4 | |O|O| |X| |O|X| |

```

```

5 | |X|X| |X|X|O|O| |
6 | |X|O| |X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.7907608695652174

```

```

AI thinking ... (AI is O
The chosen move is 8
The resulting position is
0 | | | | | | | | |
1 | | | | |X| |O| | |
2 | | | | |O| |X| | |
3 | | |X| |O| |X| | |
4 | |O|O| |X| |O|X| |
5 | |X|X| |X|X|O|O|O|
6 | |X|O| |X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.2457627118644068

```

```

AI thinking ... (AI is X
The chosen move is 5
The resulting position is
0 | | | | | | | | |
1 | | | | |X| |O| | |
2 | | | | |O| |X| | |
3 | | |X| |O| |X| | |
4 | |O|O| |X|X|O|X| |
5 | |X|X| |X|X|O|O|O|
6 | |X|O| |X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.8486238532110092

```

```

AI thinking ... (AI is O
The chosen move is 5
The resulting position is
0 | | | | | | | | |
1 | | | | |X| |O| | |
2 | | | | |O| |X| | |
3 | | |X| |O|O|X| | |
4 | |O|O| |X|X|O|X| |
5 | |X|X| |X|X|O|O|O|
6 | |X|O| |X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.22588832487309646

```

```

AI thinking ... (AI is X
The chosen move is 6
The resulting position is
0 | | | | | | |X| | |
1 | | | | |X| |O| | |
2 | | | | |O| |X| | |
3 | | |X| |O|O|X| | |
4 | |O|O| |X|X|O|X| |

```



```

5 | |X|X| |X|X|O|O|O|
6 | |X|O| |X|O|O|O|X|
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.8304093567251462

```

```

AI thinking ... (AI is O
The chosen move is 5
The resulting position is
0 | | | | | | |X| | |
1 | | | | |X| |O| | |
2 | | | | |O|O|X| | |
3 | | |X| |O|O|X| | |
4 | |O|O| |X|X|O|X| |
5 | |X|X| |X|X|O|O|O|
6 | |X|O| |X|O|O|O|X|
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.2345360824742268

```

```

AI thinking ... (AI is X
The chosen move is 5
The resulting position is
0 | | | | | | |X| | |
1 | | | | |X|X|O| | |
2 | | | | |O|O|X| | |
3 | | |X| |O|O|X| | |
4 | |O|O| |X|X|O|X| |
5 | |X|X| |X|X|O|O|O|
6 | |X|O| |X|O|O|O|X|
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.8459821428571429

```

```

AI thinking ... (AI is O
The chosen move is 7
The resulting position is
0 | | | | | | |X| | |
1 | | | | |X|X|O| | |
2 | | | | |O|O|X| | |
3 | | |X| |O|O|X|O| |
4 | |O|O| |X|X|O|X| |
5 | |X|X| |X|X|O|O|O|
6 | |X|O| |X|O|O|O|X|
+-+--+--+--+--+--+
  0 1 2 3 4 5 6 7 8
Estimated winning rate after move for AI is 0.23697916666666666

```

```

AI thinking ... (AI is X
The chosen move is 7
The resulting position is
0 | | | | | | |X| | |
1 | | | | |X|X|O| | |
2 | | | | |O|O|X|X| |
3 | | |X| |O|O|X|O| |
4 | |O|O| |X|X|O|X| |

```

```

5 | |X|X| |X|X|O|O|O|
6 | |X|O| |X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.8665413533834586

AI thinking ... (AI is O
The chosen move is 3
The resulting position is

```

0 | | | | | | |X| | |
1 | | | | |X|X|O| | |
2 | | | | |O|O|X|X| |
3 | | |X| |O|O|X|O| |
4 | |O|O| |X|X|O|X| |
5 | |X|X| |X|X|O|O|O|
6 | |X|O|O|X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 0.24812967581047382

AI thinking ... (AI is X
The chosen move is 3
The resulting position is

```

0 | | | | | | |X| | |
1 | | | | |X|X|O| | |
2 | | | | |O|O|X|X| |
3 | | |X| |O|O|X|O| |
4 | |O|O| |X|X|O|X| |
5 | |X|X|X|X|X|O|O|O|
6 | |X|O|O|X|O|O|O|X|
  +-+--+--+--+--+--+
    0 1 2 3 4 5 6 7 8

```

Estimated winning rate after move for AI is 1.0

X wins