**Gomoku Algorithm**

1. **The game is not only the game**

Our team members are young, energetic and also huge game fans. When we play the different games, the questions come to our mind. What drive us making decision of the move? What is the best move according to this situation? How can I always win during the games? So we choose game as our study topic, even we are newbies in this huge topic.

* 1. **Game theory & AI**

Game theory is the scientific approach to study game, naturally we research the Game theory first, and find the wide usage in the real world.

|  |  |  |
| --- | --- | --- |
| related to warfare | Pursuit and evasion | dogfights, missiles, troops |
| Strategic resource deployment | troops, weapons |
| related to economics | Auctions | FCC Spectrum, Google keywords |
| Buying/Selling | resource procurement, stock market, dynamic pricing |
| related to networks | Network formation | social, corporate, P2P |
| Graphical games | dependency of player actions is described by network between players |
| games | Perfect information | chess, checkers, gomoku |
| Limited information | poker, football, video games |

Table 1 Game theory related in real world [1]

Almost every big move including the game theory. AI (Artificial Intelligence) is the method to teach computer make a wise decision based on the specific condition, to some extends, thinking like human. Let’s picture it. Given some conditions, we should research all the reachable strategies, value each of them, and select the best one to implement and repeat the same process on every decision. As to computer, it also need three steps to fulfill every move, find strategy set, value them, select the big/min score; it also use the same steps to predicate opposite’s move. We can make it think more steps forward to make computer thinking smartly which come to game tree.

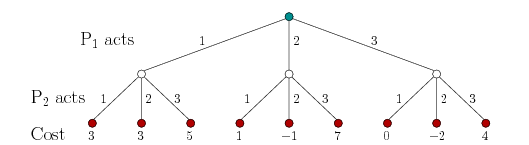


Table 2 Game Tree [2]

All theoretical knowledge need practice. We choose to implement the “Gomoku” as our project because it’s a fun game and using some specific AI algorithms which we can learn a lot and these algorithms can widely be used in the advanced situation. Also there is seldom JAVA version Gomoku, most of them are implement with C.

* 1. **What is Gomoku**

Gomoku is a chess game. Two players can take turn place one stone, black and white respectively, until K consecutive stones in a row, let’s say k black stones is in a row, in that case the black wins. It also be called k-in-row. The game board is the mxn grid, within each empty intersection, player can place the stone. [1]

We follow these steps to implementation Gomoku Algorithm：

1. Research the patter of Gomoku, and give each patten a score, the higher score, the higher possible to win.
2. Define the data structure.
3. Design searching algorithm which aims to go through the whole board.
4. Design the value algorithm which using different algorithm, for example game-tree to make the wise decision as human.
5. Trying to using α-β pruning Algorithm to speedy up the decision.
6. **The Patten of the Gomoku**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Pattern | Definition | Expression  （1 black，2 white，0 blank） | Picture[2] | Value |
| Overline | At least five of the same color in an unbroken row, either horizontally, vertically or diagonally. | 11111 | http://imgsrc.baidu.com/forum/w%3D580/sign=ca8f95c4d439b6004dce0fbfd9503526/9230fdfaaf51f3de6bce2f4395eef01f3a2979bb.jpg | 100 |
| Straight four | Four stones of the same color in an unbroken row (horizontally, vertically or diagonally) with both ends open. A straight four ensures a win. | 011110 | http://imgsrc.baidu.com/forum/w%3D580/sign=544199e43b87e9504217f3642038531b/fcf8b48f8c5494ee125e993e2cf5e0fe99257ebb.jpg | 80 |
| Four | Four stones of one color in a row, which in one move can become a five. One end open and another end intercept. Or miss a stone in the middle of one line. | 011112  0101110  0110110 | http://imgsrc.baidu.com/forum/w%3D580/sign=d36b654b113853438ccf8729a313b01f/ff393a292df5e0fe7f641f265d6034a85edf72bb.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=a21079a34bed2e73fce98624b701a16d/0560f21fbe096b63624ec8770d338744ebf8ac6c.jpg  http://imgsrc.baidu.com/forum/w%3D580/sign=334be987f703738dde4a0c2a831bb073/406c20a4462309f71a183b35730e0cf3d7cad64c.jpg | 70 |
| Straight three | Three stones of the same color in an unbroken row, or with one-intersection gap between the stones that can become a straight four on the next move | 01110  010110 | http://imgsrc.baidu.com/forum/w%3D580/sign=59503004b17eca80120539efa1239712/b3175c6034a85edf66f0680448540923dd5475bb.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=1bf30a164d086e066aa83f4332087b5a/db0c2834349b033bf8df6afd14ce36d3d539bd6c.jpg | 60 |
| Three | Three stones of the same color which only can become a four on the next move. | 001112  010112  011012  10011  10101  2011102 | http://imgsrc.baidu.com/forum/w%3D580/sign=27e3afe330adcbef01347e0e9caf2e0e/bcf89c82d158ccbf9bc0231d18d8bc3eb13541bb.jpg  http://imgsrc.baidu.com/forum/w%3D580/sign=d09c00db7dd98d1076d40c39113fb807/b318b13533fa828b585f0bc4fc1f4134970a5abb.jpg  http://imgsrc.baidu.com/forum/w%3D580/sign=e942cd111c950a7b75354ecc3ad1625c/3bbd033b5bb5c9eab08495c4d439b6003af3b34c.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=1e03059c86d6277fe912323018381f63/03158744ebf81a4cc80d7deed62a6059252da684.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=81c4d19c4610b912bfc1f6f6f3fcfcb5/bc3febc4b74543a9cef36ceb1f178a82b80114d6.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=63acab3343a7d933bfa8e47b9d4bd194/b7bfa9014c086e06718aae6c03087bf40ad1cb99.jpg | 50 |
| Straight Two | Two stones of the same color which can become a straight three on the next move | 00110  01010  010010 | http://imgsrc.baidu.com/forum/w%3D580/sign=032da31f29381f309e198da199014c67/5e29d9f9d72a6059b82f703d2934349b033bba84.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=afd63152d788d43ff0a991fa4d1fd2aa/85a4b9014a90f60320580a603812b31bb151edd7.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=a20cd7e783025aafd3327ec3cbedab8d/74d20ad162d9f2d32433b5c8a8ec8a136327cc99.jpg | 40 |
| Two | Two stones of the same color which only can become a Three on the next move. | 000112  001012  010012  10001  2010102  2011002 | http://imgsrc.baidu.com/forum/w%3D580/sign=e80aca111c950a7b75354ecc3ad1625c/3bbd033b5bb5c9eab1cc92c4d439b6003af3b384.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=bb97ae6c03087bf47dec57e1c2d3575e/5493c9ea15ce36d3733b12173bf33a87e950b184.jpg  http://imgsrc.baidu.com/forum/w%3D580/sign=f0bb7ed350da81cb4ee683c56267d0a4/893e367adab44aed73a628c3b21c8701a08bfbd7.jpghttp://imgsrc.baidu.com/forum/w%3D580/sign=580e15ea5366d0167e199e20a72ad498/21558bd4b31c8701c05e24c1267f9e2f0608ffd7.jpg  （TBD） | 30 |
| Dead four | Four stones of the same color in two blocked-end row | 211112 | （Omission） | 0 |
| Dead three | Three stones of the same color in two blocked-end row | 21112 | （Omission） | 0 |
| Dead two | Two stones of the same color in two blocked-end row | 2112 | （Omission） | 0 |

1. **The Data structure of the Gomoku**

We use a 2-D array to store the board, let’s say board[m][n] represents mxn board. Each element of the array represents the intersection of the board. The value should be 1(black), 2(white), 0(blank).

As we all know there are four direction to one stone on the board which is horizon, vertical, right-diagonal, and left-diagonal. We check these four directions to see whether there are five stones of the same color which means win or consider whether it is a better move. It’s safely draw the conclusion that we should set two 3-D array, let’s say xStone[m][n][4], yStone[m][n][4], to store the value of the two players decision’s value. After every move, we’ll check these 3-D array to find the best move.

1. **The Searching Algorithm of the Gomoku**

**4.1**  minimax algorithm

It’s naturally find a way to analysis the game pattern. First we scan the whole board from the left-up corner to right, when we meet a blank spot, we search four direction based on the blank spot and record the value of the pattern. If we encounter the other players’ stone, another blank spot, and boundary, we stop search. Using these method to fill in the 3-D array: xStone[m][n][4], yStone[m][n][4],

Since we’ve already refined the value for different pattern, the most likely win pattern get the highest value. In that case, the computer will easily choose the max value for its next move.

1. **The value Algorithm of the Gomoku**
2. **The Speed-up Algorithm of the Gomoku**

The minimax algorithm can figure out the best move problem, however this approach just consider the right moment situation, it doesn’t have any predicates, if the opposite place a stone, it need compute all the possible move which will cause long time computation to constructor the game tree. So, we think about to omit some unimportant branch to speed up the game tree.

The algorithm need to predicated N step situation, and score them, pick the highest one as its move, the lowest for the other one’s move.

Reference

[1] [*https://www.cs.cmu.edu/~ggordon/780-fall07/fall06/lectures/Game\_theory\_I.pdf*](https://www.cs.cmu.edu/~ggordon/780-fall07/fall06/lectures/Game_theory_I.pdf)

[2] When Machine Learning Meets AI and Game Theory Anurag Agrawal, Deepak Jaiswal

[3]http://planning.cs.uiuc.edu/node519.html

[4] A New Family of k-in-a-row Games from I-Chen Wu and Dei-Yen Huang

[5] [*http://tieba.baidu.com/p/2443877229*](http://tieba.baidu.com/p/2443877229)

[6] [*https://www.ocf.berkeley.edu/~yosenl/extras/alphabeta/alphabeta.html*](https://www.ocf.berkeley.edu/~yosenl/extras/alphabeta/alphabeta.html)

[7] <https://www.cs.cornell.edu/courses/cs312/2002sp/lectures/rec21.htm>