**Logic for Unbeatable and Perfect AI on an NxN Board**

When discussing logic for a computer player (very loosely referred to as "AI" from here on), it is first vital to define what we mean by “unbeatable” and “perfect”.

In plain terms, “unbeatable” simply means that the AI will never lose – at best it will win and at worst it will play to a draw. Developing the logic for an AI that cannot be beaten for NxN boards where N is greater than 3 is relatively straightforward if the ultimate goal is not to win, but simply to prevent the other player from winning.

In this situation, the AI can either begin the game by taking a position which occupies 3+ multiple winning lines - i.e. center (if the N in the NxN board is odd and has a true center) for populating 4 winning lines, or a corner for populating 3 winning lines.

**Center (5x5) Corner (6x6)**

- - - - - -

- - - - - - - - - - -

- - - - - - - - - - -

- - X - - - - - - - -

- - - - - - - - - - -

- - - - - X - - - - -

With subsequent moves (or when AI is the second player), move selection can simply seek to occupy as many winning lines as possible where the player last moved, after wins, blocks and forking opportunities/blocks have been checked.

For example, if player X takes absolute center on an odd-based NxN board (5x5, for example), an unbeatable player O could take a corner to (1) “poison” a potential winning line for X and (2) “poison” two additional lines (that at the very least prevent player X from establishing a fork). Similarly, if player X takes a corner on an even-based NxN board (6x6, for example), an unbeatable player O could again take corner to similar effect.

**Round 2 - O AI (5x5) Round 2 - O AI (6x6)**

X - - - - -

O - - - - - - - - - -

- - - - - - - - - - -

- - X - - - - - - - -

- - - - - - - - - - -

- - - - - - - - - - O

Subsequent, “poison the lines” moves can end up reducing the game to a tie in (at most) N+1 moves by the unbeatable player, depending on whether the opponent prioritizes moves with multiple potential winning lines. For example, to illustrate let’s continue from the 5x5 game where player 2 (O) is the unbeatable player – after 6 moves, all lines are poisoned.

**R4 (2 poisoned) R6 (2 poisoned) R8 (2 poisoned) R10 (2 poisoned) R12 (last 1 poisoned)**

O - - - - O - - - - O - X - - O - X - - O - X - -

- - - - - - - - - - - - - - - - X - O - - X - O -

- - X - O - - X - O - - X – O - - X - O - X X - O

- - - - - - - - - - - - O - - - - O - - - - O - -

- - - - X O - X - X O - X - X O - X - X O O X - X

Similarly, if we play through the 5x5 game where player 1 (X) is the unbeatable player, again after 6 moves all lines are poisoned.

**R1 (4 poisoned) R3 (3 poisoned) R5 (2 poisoned)**

- - - - - O - - - - O O - X -

- - - - - - - - - - - - - - -

- - X – - - - X – - - - X - -

- - - - - - - - - - - - - - -

- - - - - - - - - X - - - - X

**R7 (2 poisoned) R9 (1 poisoned) R11 (last 1 poisoned)**

O O - X - O O - X - O O - X -

- X - - - - X - - - - - - - -

- - X - - - - X – - - - X - -

- O - - - O O - - - O O - X O

- - - - X X - - - X X - - - X

Taking this “poison” approach for an unbeatable AI produces similar results, regardless of board size. Essentially, the goal is to simply occupy every line to ensure that the opponent has no chance of winning.

**“Poison AI” Player O**

**4x4 (R10) 5x5 (R12) 6x6 (R14) 7x7 (R16)**

**5 moves 6 moves 7 moves 8 moves**

O - - O O - X - - X - - O X - - - - - - - -

- X O X - X - O - - O X - - X - - - - - - -

- O - - - X X - O X - X - O - - - - - - - -

X X O X - - O - - - O X - - - - - - - - - -

O O X - X O - - - - - - - - - - - -

- - O - - O - - - - - - -

- - - - - - -

|  |  |
| --- | --- |
| Move 1 | Move 5 |
| Move 2 | Move 6 |
| Move 3 | Move 7 |
| Move 4 | Move 8 |

That being said, while this “poison the line” strategy will prevent the opponent from winning, it will not produce wins in and of itself.

A perfect player should focus on creating lines that have the potential for creating forks. Towards that end, when a perfect player does not have an opportunity to (1) win, (2) block the opponent from winning, (3) create a fork, or (4) block the opponent from creating a fork, the focus should be on populating at least two lines with the goal of creating a fork.

Since corners and center are strategically more important (as they include the potential for diagonal wins), these should be weighted higher when available (note that even-by-even boards will not have an absolute center).

The general rules of 3x3 tic tac toe can be observed for the perfect player, but

more moves are required to reach certain thresholds (i.e. create forks, force blocks) and, as a result, it is believed that the occurence of ties will increase with the size of the board as strategies will be more visible.

X - O - O

- - - - -

X - O - - > Playing through the typical "perfect X versus perfect O" on 5x5

- - - - -

X - O - X

For blocking forks, a perfect player would \*at least\* evaluate opponent lines that are at least (board size - 2) and do not include any player marks.

For example, on a 3x3 board, if the oppoent has 1 common potential mark (board size - 2) in multiple lines that do not contain the player's piece, the potential for a fork exists.

X - - X - X

- O - > - O -

- - X O - X

Occupied lines for 0 = [0, 1, 2], [0, 3, 6]

Occupied lines for 8 = [2, 5, 8], [6, 7, 8]

Two potential forks at 2 and 6.

Similarly, on a 4x4 board, if an opponent has 2 common potential marks (again, board size - 2) in multiple lines that do not contain the player's piece, the potential for a fork exists.

X X - - X X - X

O - - - > O - - -

O - - X O O - X

O - - X O - - X