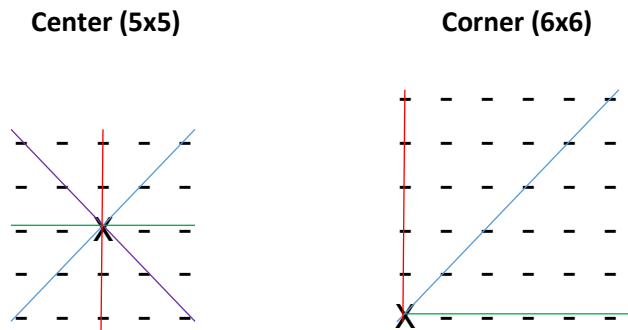


When discussing logic for a computer player (very loosely referred to as "AI" from here on), it is first vital to define what we mean by "unbeatable" and "perfect".

Unbeatable Strategy – Poisoning the Lines

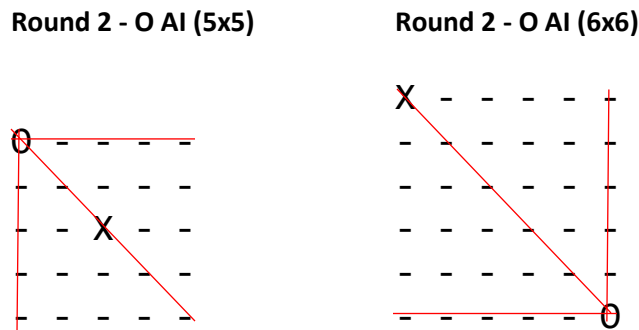
In plain terms, "unbeatable" simply means that the AI will never lose – at best it will win and at worst it will play to a draw. Developing the logic for an AI that cannot be beaten for NxN boards where N is greater than 3 is relatively straightforward if the ultimate goal is not winning, but simply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

In this situation, the AI can focus on "poisoning" all of the lines to ensure that a win is not possible. To accomplish this, the opening game should focus on moves that poison the maximum number winning lines - i.e. center (if the N in the NxN board is odd and has a true center) for "poisoning" 4 winning lines, or a corner for "poisoning" 3.



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.

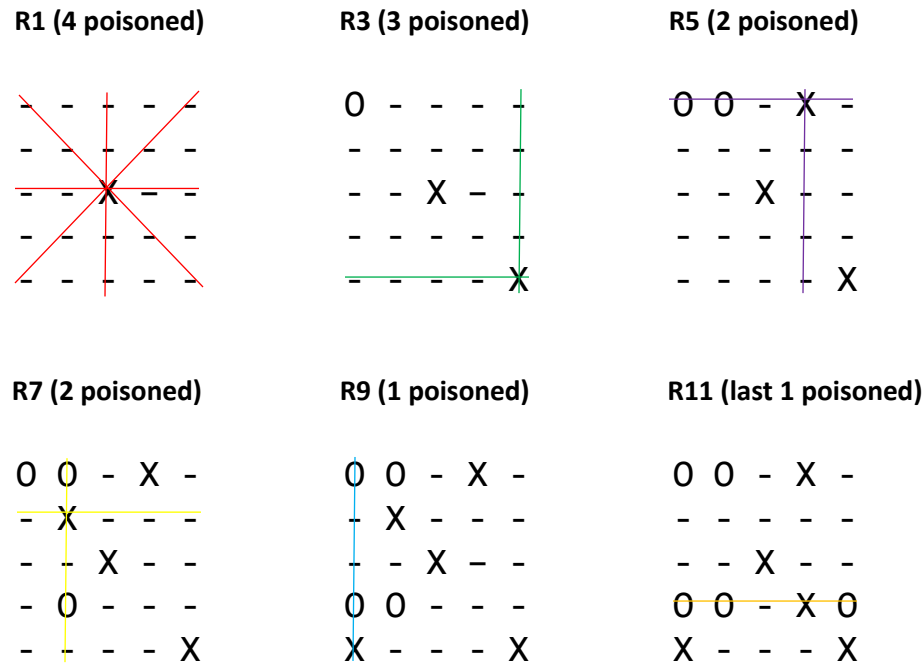
For example, if player X takes absolute center on an odd-based NxN board (5x5, for example), an unbeatable player O could take a corner to (1) "poison" a potential winning line for X and (2) "poison" two additional lines (that at the very least prevent player X from establishing a fork). Similarly, if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



Subsequently, "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.

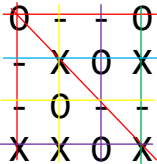
R4 (2 poisoned)	R6 (2 poisoned)	R8 (2 poisoned)	R10 (2 poisoned)	R12 (last 1 poisoned)
<pre>0 - - - - - - - - - - - X - - - - - - - - - - - X</pre>	<pre>0 - - - - - - - - - - - X - 0 - - - - - 0 - X - X</pre>	<pre>0 - X - - - - - - - - - X - 0 - - 0 - - 0 - X - X</pre>	<pre>0 - X - - - X - 0 - - - X - 0 - - 0 - - 0 - X - X</pre>	<pre>0 - X - - - X - 0 - - X X - 0 - - 0 - - 0 0 X - X</pre>

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

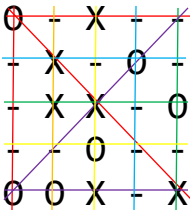


Taking this “poison” approach for an unbeatable AI produces similar results, regardless of board size. Essentially, the goal is to simply occupy every line to ensure that the opponent has no chance of winning.

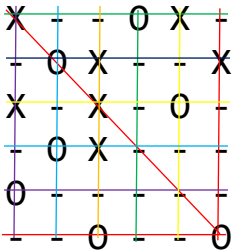
“Poison AI” Player O
4x4 (R10)
5 moves



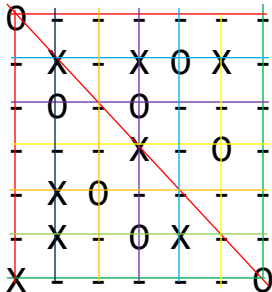
5x5 (R12)
6 moves



6x6 (R14)
7 moves



7x7 (R16)
8 moves



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.

Perfect Strategy – Quietly Building Forks

The “perfect” AI should not only be unbeatable, but should prioritize creating opportunities for wins. Rather than focusing on the most efficient way to sabotage the opponent (and force the game to a draw), a perfect AI should focus on creating lines that have the potential for creating forks.

Towards that end, when the AI 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 ultimate goal of creating a fork.

This is a slight detour from standard 3x3 tic tac toe “perfect player” logic, as the larger the board is the longer it will take to set up a fork and the greater the opportunity for an opponent to “poison” a line. However, certain aspects remain the same. For example, since center (on odd-numbered boards) and corners are strategically more important (as they include the potential for diagonal wins), these positions should be preferred when available.

The general rules of 3x3 tic tac toe can be observed for the AI, but as more moves are required to reach certain thresholds (i.e. create forks, require blocks), it is believed that the occurrence of ties will increase in proportion to the size of the board, as strategies will be more visible. Additionally, as was observed during the development of perfect AI logic for the standard 3x3 board, certain near-endgame board arrangements may need to be addressed through pattern matching in order to achieve a higher win-vs-tie ratio.

With those considerations in place, items to research include (1) determining the ideal board seeding strategy and (2) determining the ideal ratios for building/preventing forks.

In regards to the first point – if the AI simply takes positions on two lines with an aim on creating a fork, the strategy will be fairly obvious. As a result, a more effective strategy may be to seed the board with apparently random positions (once center and corners have been taken into account) to create a distraction from fork creation.

Along these lines, another idea would be - the larger the board, the more fork attempts the AI could/should take. Winning lines could be weighted, so that once a certain ratio threshold is met (for example once multiple lines are populated by 1/2 – 2/3), the AI would switch from a “seeding” strategy to a fork creation strategy.

While the viability of this approach ultimately remains to be seen, it is strongly believed that some sort of “subterfuge” will be required (particularly on larger boards), as the ease of poisoning lines would otherwise shut down any attempts at creating winning lines.