# Ultimate Tic-Tac-Toe

By: Justin Na (jn377)

Overview:

- Implementing heuristic approach, in the form of a min-max algorithm, to analyze how AI performs against people and against itself
- Mainly focusing on AI vs AI, as I've lost almost every game against the AI
- Will differentiate starting position and AIs' depths to observe how this affects the AIs' performance and win results
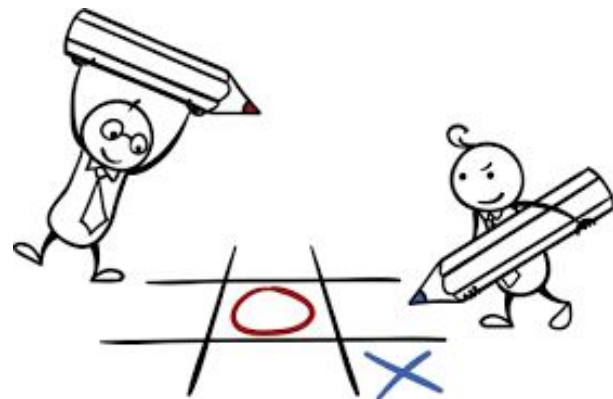
Hypothesis:

- Starting Grid/Box Position will not affect win/lose results
- The greater the depth of the AI compared to its counterpart, the more games it will win
- If both AIs have the same depth, the AI to move first will win more
- The greater overall depth of the 2 AIs combined, the longer it will take for a winner to emerge
- Someone will beat the AI with a depth greater than 2

Related Works

- Chess AI
    - Keep dictionary of rules and board states
    - Position evaluation - assign points to different pieces
    - Create search tree a min-max algo can search through to find best move
    - Implement alpha-beta pruning to make search process faster
- AlphaGo
    - AI designed for Go, most complex board game
    - Combined advance tree search and neural networks to create
   - Played against amatuers and itself multiple times to become smarter at the game

Method

- AI implements a min-max algorithm to determine the best move to make for a given board state.
- Each possible outcome is given a score, and the min-max algorithm chooses the best score. It then plays the moves corresponding to that score
- Having 2 AIs play against each other and observing the results
- Chaging the depth of each AI and starting position for variance
- Measuring win/loss results, time, and human performance

Results: Same Depth

- First mover advantage has little influence over who wins when same depths
- Bot X does not win more as depth increases
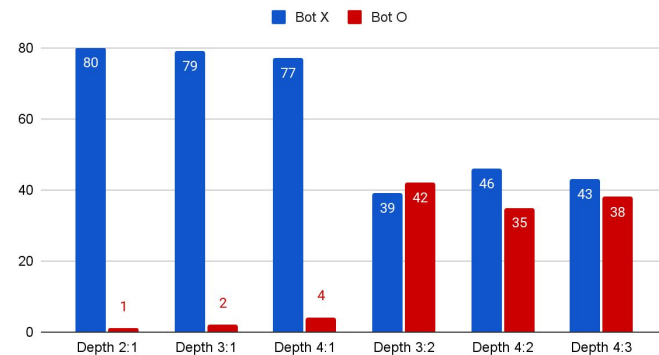- Bot O wins more at depth 4, but Bot X wins more at depth 5
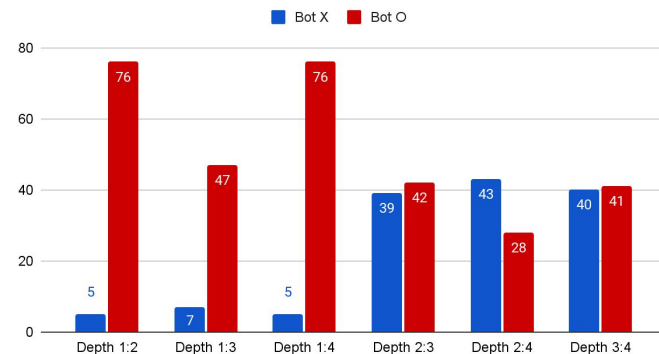

Same Depth Win Results
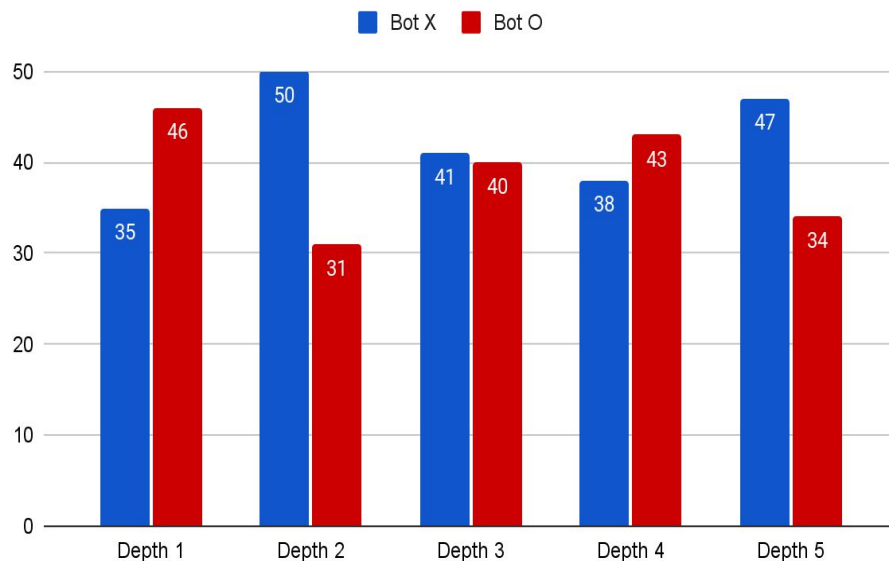
Results: Different Depth

- When AI with less depth is 1, AI with greater depth wins almost all games
- Opposite for other ratios
- Results somewhat even
- The AI with less depth wins more for one ratio in each simulation


Bot X Greater Depth Win Results


Bot O Greater Depth Win Results

Results: Time

- When depth is the same, time to find winner increases as depth increases
- When depth is different, do not have same correlation
- Possibly due to min-max algorithm running more/calculating more win possibilites the greater the difference of depth b/w the AIs


Time to Find Winner For 81 Games (Min)
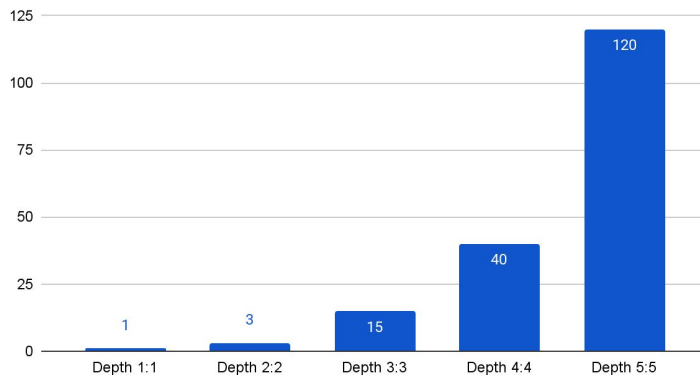
Time to Find Winner for 81 Games (Min)
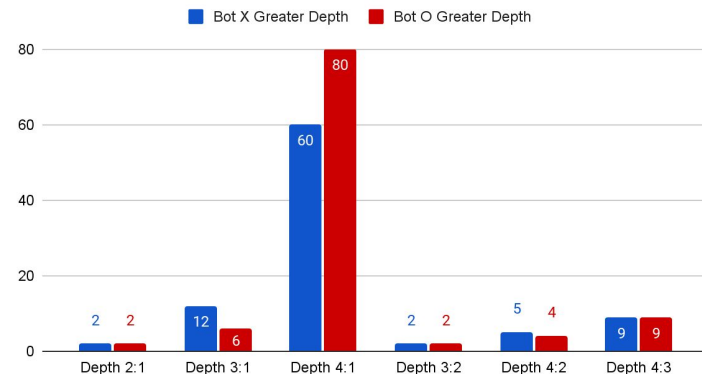
Results: Starting Position

- Ran each variation of depth 81 times, one for each possible tile
- Starting position affects the outcome if depth is the same
- Win rates when start in center box increases as depth increases
- Will need to do more simulations with greater depth to have a concrete conclusion if a correlation exists or not

Center Box Starting Position Wins

Bot X ■ Bot Y ■

	Bot X	Bot Y
Depth 1	3	6
Depth 2	4	5
Depth 3	4	5
Depth 4	4	5
Depth 5	7	2
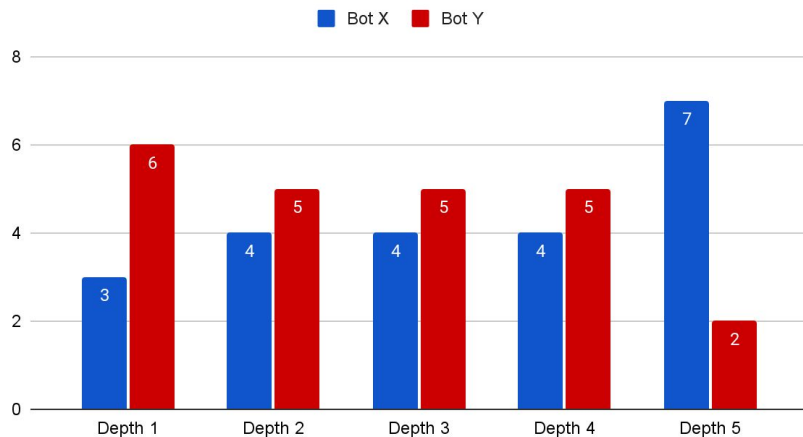
Results: Human Performance

- Won against AI with depth 1 most times as long as thoughtful about moves and made no careless mistakes
- AI will always perform the same moves if player performs the same moves each game
- Different depths change the moves AI performs
- Can cheat against AI to win
- Obeserve moves 1 AI plays against another AI
- Take note of the moves and perform the same moves against the AI to win

Conclusion

- Results went against most expectations
- Almost all prediction were proven wrong by results
- Future Direction: Can change AI to factor in ties
- Currently, if AI recognizes it is impossible to win, forfeits
- If AI continues to play best move, even though it will lose, could lead to interesting results if we run the same simulations

Thank You