MCTS
Ultimate Tic-Tac-Toe
Experiment 1

Analysis Report

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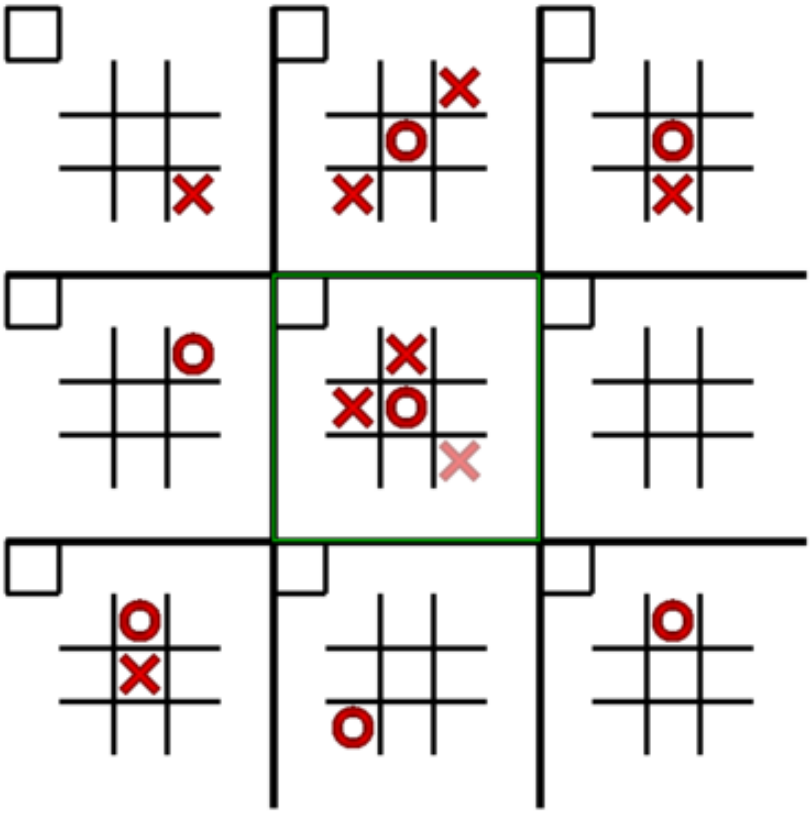
Introduction

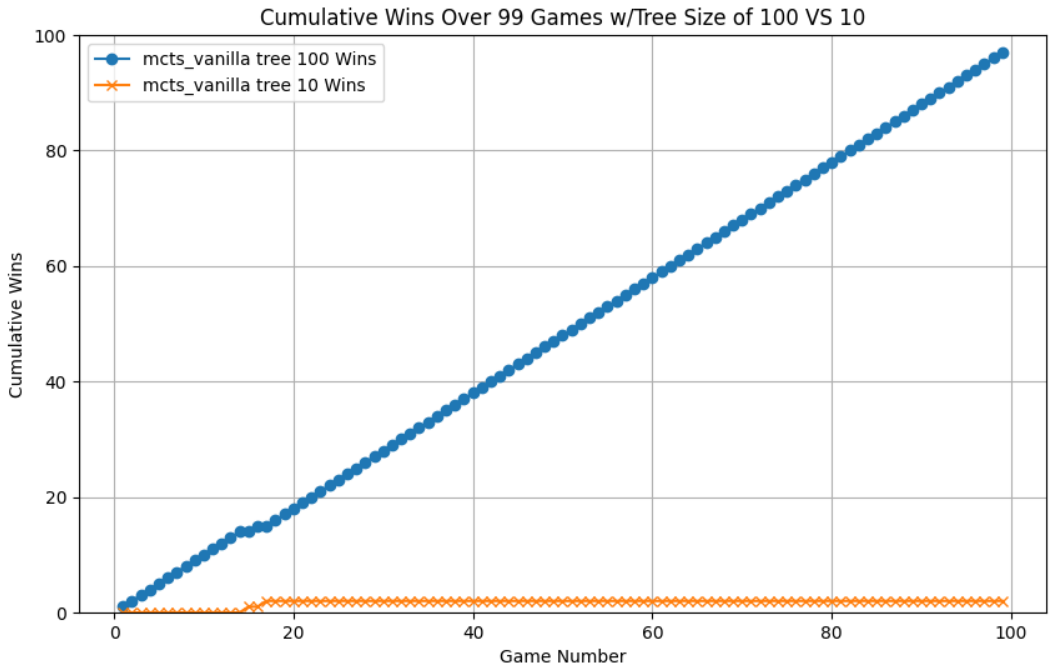
In the first experiment of the assignment, our task was to pit two versions of the vanilla MCTS, our implementation of the Monte Carlo Tree Search algorithm, against one another in a series of matches in Ultimate Tic-Tac-Toe. As part of the task, each set of 100 matches in the series compared a first version of MCTS vanilla set to be at a constant tree size of 100 nodes playing against a second version of vanilla of varying tree size for each set. In this analysis, we will be analyzing the trends in the data my partner and I observed as the tree size of player two changed.



(Example image of a standard Ultimate Tic-Tac-Toe game featuring 9 tic-tac-toe games)

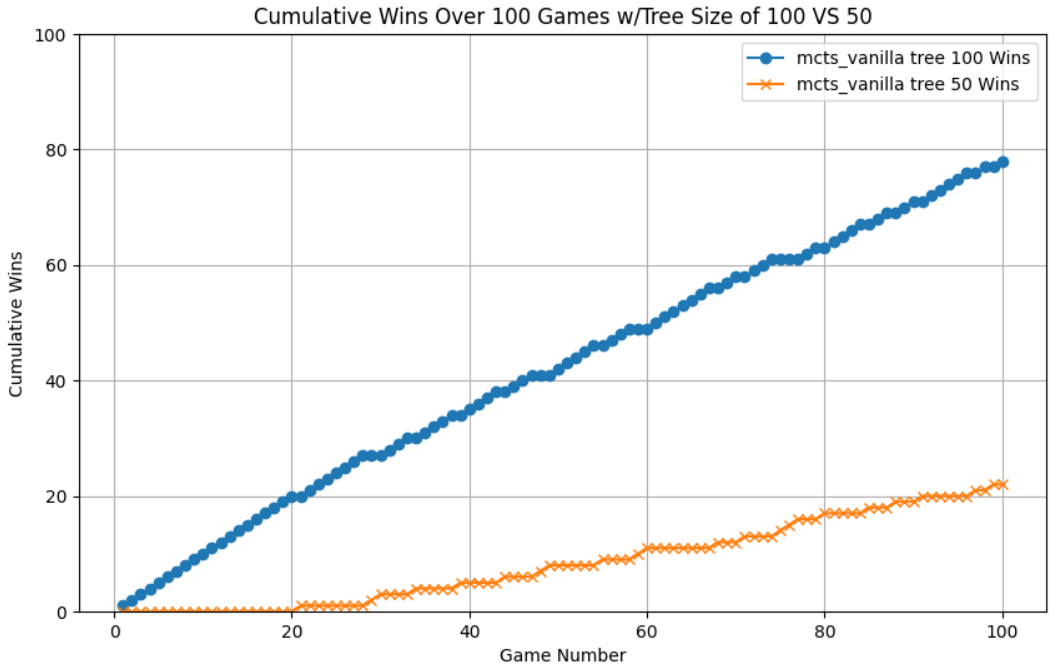
Experiment Results + Analysis

We begin with a tiny tree size of only 10 nodes for the second player's tree size, pitted against player one stuck at 100 nodes. As demonstrated by the below graph, we observe a complete dominance from player one, only losing in a few outlier cases to player two between the 10th & 20th matches. (The y-axis measures the current accumulated number of wins for the players, and the x-axis tracks the current match in the series of 100 games.) Additionally, we can also see player two remains at a constant of 0 cumulative victories for about the first 16 matches.



(Figure 1a. BLUE: Player 1 tree size - 100 nodes, ORANGE: Player 2 tree size - 10 nodes)

As we gradually increase the tree size of player two moving from a tree size of 10 nodes to 50, we see player two continues to lose out but at a significantly smaller scale, performing 1000% better than it did in the first round and multiplying its number of victories over player one by a factor of 11.

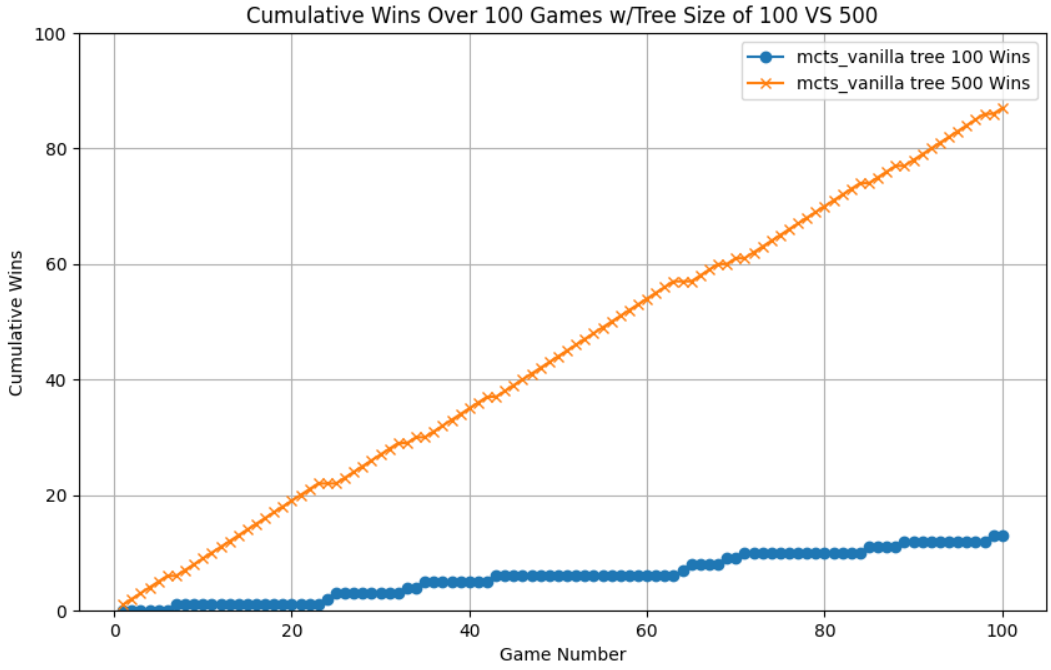


(Figure 1b. BLUE: Player 1 tree size - 100 nodes, ORANGE: Player 2 tree size - 50 nodes)

Similar to what we saw in the Figure 1a. when we increase the tree size to 50 nodes the graph of player two remains at a constant value of 0 accumulated wins, this time for the first 20 games. The lower tree size player, in these two instances player two, likely had 0 wins for the first 10-20 games because the larger tree size player is more likely to identify optimal opening moves leading to this seen 'cold start effect', which can have a critical effect on the flow of the game long-term. Early advantages in Ultimate Tic-Tac-Toe will also compound on itself, effectively 'snowballing' as the suboptimal opening leads to drastically less effective moves later in the games.

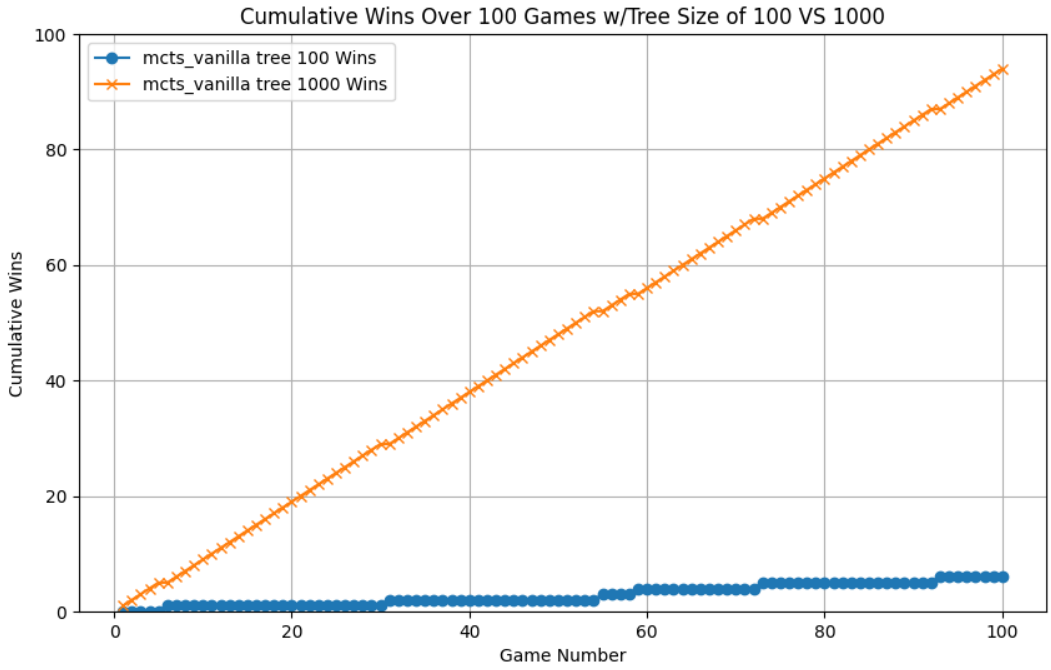
These results also align with the known behavior of MCTS, which is that the model using more nodes will result in higher performance because it results in deeper exploration, exploring the game tree more thoroughly, and better long-term strategical planning.

As we observe the resulting graph from increasing the tree size of player two to 500, where both players are now working with fairly decent size trees, we see the graphs now both become fairly linear without as noticeable spikes in the data. The slope of player one's graph, the now smaller tree player, is less smooth and consistent than that of the 500 node tree used for player two.



(Figure 1c. BLUE: Player 1 tree size - 100 nodes, ORANGE: Player 2 tree size - 500 nodes)

To see a more extreme demonstration of this correlation between tree size and the graph data, we elected to raise player two up to 1000 nodes for the final graph, shown below. We also can observe that when both players' trees reach a sizable number of nodes, that the cold start effect observed from the smaller tree graphs is no longer observable, despite the factor separating the two players' tree sizes being 1:10 for both the first and final graphs.



(Figure 1b. BLUE: Player 1 tree size - 100 nodes, ORANGE: Player 2 tree size - 1000 nodes)

Conclusion

To summarize the findings of our experiment & our analysis, we concluded that changing the red size when pitting two versions of the MCTS bot against each other resulted in 2 key characteristics:

- 'Cold Start' effect, primarily seen on relatively small tree sizes
- Deeper exploration & expansion of game tree with larger tree sizes