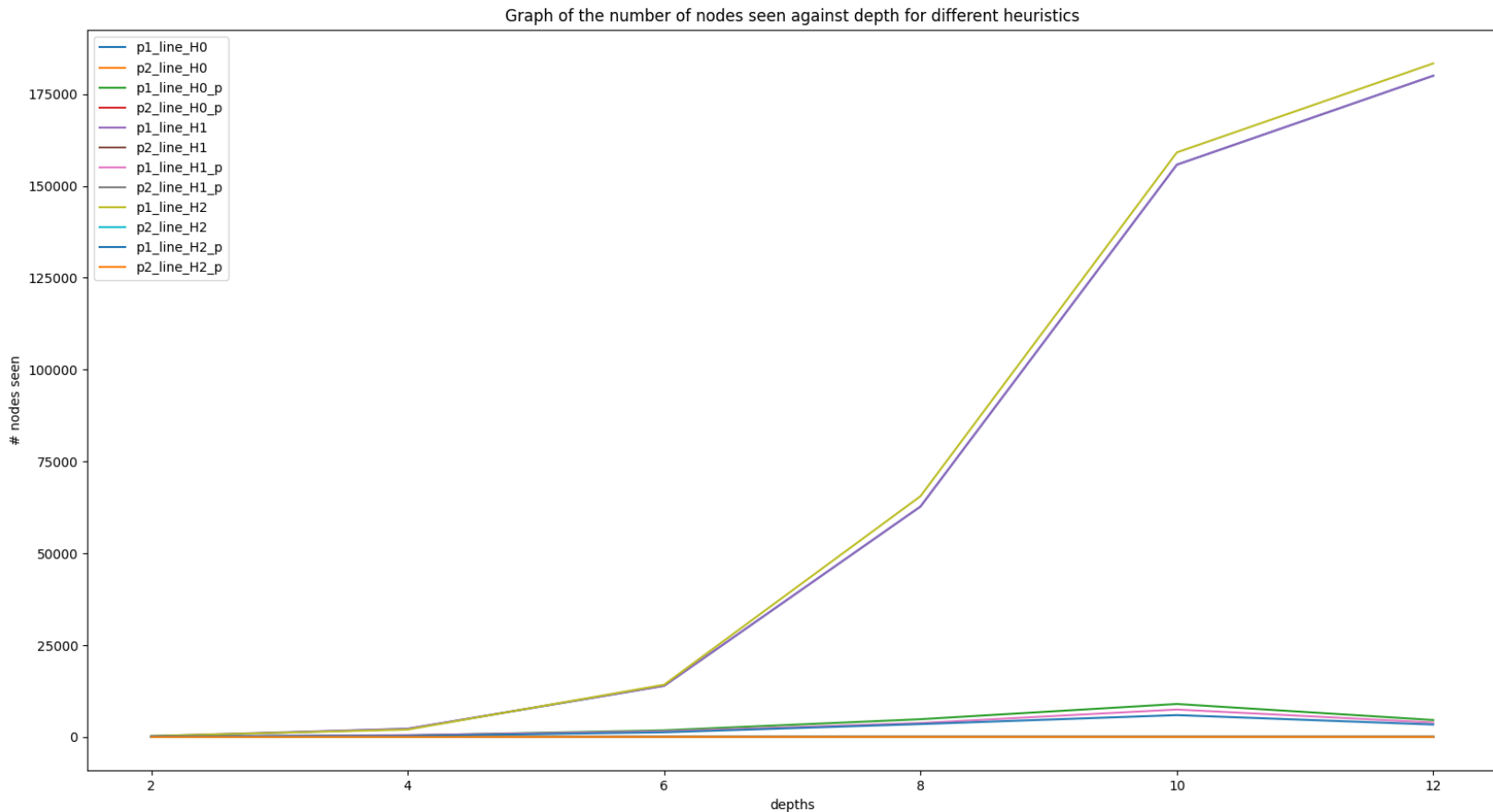


## 4x4 Othello Report

1. Search vs. depth: nodes expanded by each search method when you limit the depths to 2,4,6,8,10 and 12 steps from the starting position. Plot line or bar graphs with the number of nodes vs. depth for pruning on/off and the 3 heuristics.



2. Heuristic quality: Play alpha-beta search with pruning with the 3 heuristics against each other from both sides (X and O) at depths of 2, 4, 6, and 8 (i.e., H1(X) vs H2(O), H2(X) vs. H1(O), H1(X) vs H3(O), H3(X) vs. H1(O), H2(X) vs H3(O) and H3(X) vs. H2(O). Report the win-loss results.

Win-loss results:

```
H_0_d2 v H_0_d2: winner: H_0_d2
H_0_d2 v H_0_d4: winner: H_0_d4
H_0_d2 v H_0_d6: winner: H_0_d6
H_0_d2 v H_0_d8: winner: H_0_d8
H_0_d4 v H_0_d2: winner: H_0_d4
H_0_d4 v H_0_d4: winner: H_0_d4
```

H\_0\_d4 v H\_0\_d6: winner: H\_0\_d6  
H\_0\_d4 v H\_0\_d8: winner: H\_0\_d8  
H\_0\_d6 v H\_0\_d2: winner: H\_0\_d6  
H\_0\_d6 v H\_0\_d4: winner: H\_0\_d4  
H\_0\_d6 v H\_0\_d6: winner: H\_0\_d6  
H\_0\_d6 v H\_0\_d8: winner: H\_0\_d8  
H\_0\_d8 v H\_0\_d2: winner: H\_0\_d2  
H\_0\_d8 v H\_0\_d4: winner: H\_0\_d4  
H\_0\_d8 v H\_0\_d6: winner: H\_0\_d6  
H\_0\_d8 v H\_0\_d8: winner: H\_0\_d8  
H\_0\_d2 v H\_1\_d2: winner: H\_1\_d2  
H\_0\_d2 v H\_1\_d4: winner: H\_1\_d4  
H\_0\_d2 v H\_1\_d6: winner: H\_1\_d6  
H\_0\_d2 v H\_1\_d8: winner: H\_1\_d8  
H\_0\_d4 v H\_1\_d2: winner: TIE!!!  
H\_0\_d4 v H\_1\_d4: winner: H\_1\_d4  
H\_0\_d4 v H\_1\_d6: winner: H\_1\_d6  
H\_0\_d4 v H\_1\_d8: winner: H\_1\_d8  
H\_0\_d6 v H\_1\_d2: winner: H\_0\_d6  
H\_0\_d6 v H\_1\_d4: winner: H\_1\_d4  
H\_0\_d6 v H\_1\_d6: winner: H\_1\_d6  
H\_0\_d6 v H\_1\_d8: winner: H\_1\_d8  
H\_0\_d8 v H\_1\_d2: winner: H\_0\_d8  
H\_0\_d8 v H\_1\_d4: winner: H\_1\_d4  
H\_0\_d8 v H\_1\_d6: winner: H\_1\_d6  
H\_0\_d8 v H\_1\_d8: winner: H\_1\_d8  
H\_0\_d2 v H\_2\_d2: winner: H\_2\_d2  
H\_0\_d2 v H\_2\_d4: winner: H\_2\_d4  
H\_0\_d2 v H\_2\_d6: winner: H\_2\_d6  
H\_0\_d2 v H\_2\_d8: winner: H\_2\_d8  
H\_0\_d4 v H\_2\_d2: winner: H\_2\_d2  
H\_0\_d4 v H\_2\_d4: winner: H\_2\_d4  
H\_0\_d4 v H\_2\_d6: winner: H\_2\_d6  
H\_0\_d4 v H\_2\_d8: winner: H\_2\_d8

H\_0\_d6 v H\_2\_d2: winner: H\_2\_d2  
H\_0\_d6 v H\_2\_d4: winner: H\_2\_d4  
H\_0\_d6 v H\_2\_d6: winner: H\_2\_d6  
H\_0\_d6 v H\_2\_d8: winner: H\_2\_d8  
H\_0\_d8 v H\_2\_d2: winner: H\_2\_d2  
H\_0\_d8 v H\_2\_d4: winner: H\_2\_d4  
H\_0\_d8 v H\_2\_d6: winner: H\_2\_d6  
H\_0\_d8 v H\_2\_d8: winner: H\_2\_d8  
H\_1\_d2 v H\_0\_d2: winner: H\_0\_d2  
H\_1\_d2 v H\_0\_d4: winner: H\_0\_d4  
H\_1\_d2 v H\_0\_d6: winner: H\_0\_d6  
H\_1\_d2 v H\_0\_d8: winner: H\_0\_d8  
H\_1\_d4 v H\_0\_d2: winner: H\_0\_d2  
H\_1\_d4 v H\_0\_d4: winner: H\_0\_d4  
H\_1\_d4 v H\_0\_d6: winner: H\_0\_d6  
H\_1\_d4 v H\_0\_d8: winner: H\_0\_d8  
H\_1\_d6 v H\_0\_d2: winner: H\_1\_d6  
H\_1\_d6 v H\_0\_d4: winner: H\_0\_d4  
H\_1\_d6 v H\_0\_d6: winner: H\_0\_d6  
H\_1\_d6 v H\_0\_d8: winner: H\_0\_d8  
H\_1\_d8 v H\_0\_d2: winner: H\_0\_d2  
H\_1\_d8 v H\_0\_d4: winner: H\_0\_d4  
H\_1\_d8 v H\_0\_d6: winner: H\_0\_d6  
H\_1\_d8 v H\_0\_d8: winner: H\_0\_d8  
H\_1\_d2 v H\_1\_d2: winner: H\_1\_d2  
H\_1\_d2 v H\_1\_d4: winner: H\_1\_d4  
H\_1\_d2 v H\_1\_d6: winner: H\_1\_d6  
H\_1\_d2 v H\_1\_d8: winner: H\_1\_d8  
H\_1\_d4 v H\_1\_d2: winner: H\_1\_d4  
H\_1\_d4 v H\_1\_d4: winner: H\_1\_d4  
H\_1\_d4 v H\_1\_d6: winner: H\_1\_d6  
H\_1\_d4 v H\_1\_d8: winner: H\_1\_d8  
H\_1\_d6 v H\_1\_d2: winner: H\_1\_d6  
H\_1\_d6 v H\_1\_d4: winner: H\_1\_d4

H\_1\_d6 v H\_1\_d6: winner: H\_1\_d6  
H\_1\_d6 v H\_1\_d8: winner: H\_1\_d8  
H\_1\_d8 v H\_1\_d2: winner: H\_1\_d8  
H\_1\_d8 v H\_1\_d4: winner: H\_1\_d4  
H\_1\_d8 v H\_1\_d6: winner: H\_1\_d6  
H\_1\_d8 v H\_1\_d8: winner: H\_1\_d8  
H\_1\_d2 v H\_2\_d2: winner: H\_2\_d2  
H\_1\_d2 v H\_2\_d4: winner: H\_2\_d4  
H\_1\_d2 v H\_2\_d6: winner: H\_2\_d6  
H\_1\_d2 v H\_2\_d8: winner: H\_2\_d8  
H\_1\_d4 v H\_2\_d2: winner: H\_2\_d2  
H\_1\_d4 v H\_2\_d4: winner: H\_2\_d4  
H\_1\_d4 v H\_2\_d6: winner: H\_2\_d6  
H\_1\_d4 v H\_2\_d8: winner: H\_2\_d8  
H\_1\_d6 v H\_2\_d2: winner: H\_2\_d2  
H\_1\_d6 v H\_2\_d4: winner: H\_2\_d4  
H\_1\_d6 v H\_2\_d6: winner: H\_2\_d6  
H\_1\_d6 v H\_2\_d8: winner: H\_2\_d8  
H\_1\_d8 v H\_2\_d2: winner: H\_2\_d2  
H\_1\_d8 v H\_2\_d4: winner: H\_2\_d4  
H\_1\_d8 v H\_2\_d6: winner: H\_2\_d6  
H\_1\_d8 v H\_2\_d8: winner: H\_2\_d8  
H\_2\_d2 v H\_0\_d2: winner: H\_0\_d2  
H\_2\_d2 v H\_0\_d4: winner: H\_0\_d4  
H\_2\_d2 v H\_0\_d6: winner: H\_0\_d6  
H\_2\_d2 v H\_0\_d8: winner: H\_0\_d8  
H\_2\_d4 v H\_0\_d2: winner: H\_0\_d2  
H\_2\_d4 v H\_0\_d4: winner: H\_0\_d4  
H\_2\_d4 v H\_0\_d6: winner: H\_0\_d6  
H\_2\_d4 v H\_0\_d8: winner: H\_0\_d8  
H\_2\_d6 v H\_0\_d2: winner: H\_0\_d2  
H\_2\_d6 v H\_0\_d4: winner: H\_0\_d4  
H\_2\_d6 v H\_0\_d6: winner: H\_0\_d6  
H\_2\_d6 v H\_0\_d8: winner: H\_0\_d8

H\_2\_d8 v H\_0\_d2: winner: H\_0\_d2  
H\_2\_d8 v H\_0\_d4: winner: H\_0\_d4  
H\_2\_d8 v H\_0\_d6: winner: H\_0\_d6  
H\_2\_d8 v H\_0\_d8: winner: H\_0\_d8  
H\_2\_d2 v H\_1\_d2: winner: H\_2\_d2  
H\_2\_d2 v H\_1\_d4: winner: H\_1\_d4  
H\_2\_d2 v H\_1\_d6: winner: H\_1\_d6  
H\_2\_d2 v H\_1\_d8: winner: H\_1\_d8  
H\_2\_d4 v H\_1\_d2: winner: H\_2\_d4  
H\_2\_d4 v H\_1\_d4: winner: H\_1\_d4  
H\_2\_d4 v H\_1\_d6: winner: H\_1\_d6  
H\_2\_d4 v H\_1\_d8: winner: H\_1\_d8  
H\_2\_d6 v H\_1\_d2: winner: H\_2\_d6  
H\_2\_d6 v H\_1\_d4: winner: H\_1\_d4  
H\_2\_d6 v H\_1\_d6: winner: H\_1\_d6  
H\_2\_d6 v H\_1\_d8: winner: H\_1\_d8  
H\_2\_d8 v H\_1\_d2: winner: H\_2\_d8  
H\_2\_d8 v H\_1\_d4: winner: H\_1\_d4  
H\_2\_d8 v H\_1\_d6: winner: H\_1\_d6  
H\_2\_d8 v H\_1\_d8: winner: H\_1\_d8  
H\_2\_d2 v H\_2\_d2: winner: H\_2\_d2  
H\_2\_d2 v H\_2\_d4: winner: H\_2\_d4  
H\_2\_d2 v H\_2\_d6: winner: H\_2\_d6  
H\_2\_d2 v H\_2\_d8: winner: H\_2\_d8  
H\_2\_d4 v H\_2\_d2: winner: H\_2\_d2  
H\_2\_d4 v H\_2\_d4: winner: H\_2\_d4  
H\_2\_d4 v H\_2\_d6: winner: H\_2\_d6  
H\_2\_d4 v H\_2\_d8: winner: H\_2\_d8  
H\_2\_d6 v H\_2\_d2: winner: H\_2\_d2  
H\_2\_d6 v H\_2\_d4: winner: H\_2\_d4  
H\_2\_d6 v H\_2\_d6: winner: H\_2\_d6  
H\_2\_d6 v H\_2\_d8: winner: H\_2\_d8  
H\_2\_d8 v H\_2\_d2: winner: H\_2\_d2  
H\_2\_d8 v H\_2\_d4: winner: H\_2\_d4

H\_2\_d8 v H\_2\_d6: winner: H\_2\_d6

H\_2\_d8 v H\_2\_d8: winner: H\_2\_d8

3. Write a brief report about how the different heuristics performed against each other in terms of winning rates and amount of search.

Looking at the results, the second player is favored to win most of the time, with the slight chance even with a difference in depth, they would still win. We observe that heuristic 1 is better than heuristic 0 in most cases except for when h0 is at a depth of +2 as compared to h1, this is because we observe that the first player is able to win in these circumstances.

As for the amount of search, we see that at a higher depth, there are more nodes visited which makes sense because a higher depth requires more traversal to get to depth 0. However, when we look at the pruned values, there is a drop off at depth 10 to 12 for player 1, this is ironic because we would assume that a higher depth would visit more nodes even for pruned because the lower depth and a higher depth would visit the same path, but my guess is that at a lower depth, shows a lower alpha and higher beta which allows us to prune more frequently, thus showing lesser visited nodes. As seen that the number of nodes increases greatly for the non-prune players, we do observe that player 1 will always have more nodes visited as compared to player 2, this is because player 1 goes first and the board is more open to changes as compared to player 2 where the board will first be introduced to a terminal state.