**CS4750-HW4 Report**

**Team member’s names:** Song Vu Nguyen, Caleb Fagan, Charlermpon Thongmotai

**References:**

**Description**: Implement the minimax algorithm in Python to play a two-player, four-in-a-row game, which is a variation of tic-tac-toe: two players, X and O, take turns marking the spaces in a 6×6 grid. Player 1 The player who succeeds in placing 4 of their marks consecutively in a horizontal, vertical, or diagonal row wins the game. The heuristic function that we used for our minimax algorithm is h(n) = 5\*[# of two-side-open-3-in-a-row for me]–10\*[# of two-side-open-3-in-a-row for opponent] + 3\*[# of one-side-open-3-in-a-row for me]–6\*[# of one-side-open-3-in-a-row for opponent] + [#of open-2-in-a-row for me] - [# of open-2-in-a-row for opponent] where:

“one-side-open-3-in-a-row”: there is a blank space at one end of a 3-in-a-row.

“two-side-open-3-in-a-row”: there are blank spaces at both ends of a 3-in-a-row.

“open-2-in-a-row”: there are blank spaces at one or both ends of a 2-in-a-row.

Player 1, with symbol X, running the minimax algorithm searching in the depth of 4 moves ahead. Player 2, with symbol O, running the minimax algorithm searching in the depth of 2 moves ahead. Player 1 moves first by placing X in the middle of the board. Each player then take turn placing their symbol on the board in the location that give them the highest heuristic value after running the minimax algorithm. The result of the game is listed below

**Result:**

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' 'X' '' '']

['' '' '' '' '' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 0.49805641174316406

Nodes generated this turn: 0

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' 'X' 'O' '']

['' '' '' '' '' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 240912.68682479858

Nodes generated this turn: 1297135

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' 'X' 'O' '']

['' '' '' '' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 233.88981819152832

Nodes generated this turn: 1156

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' 'X' 'O' '']

['' 'O' '' '' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 224017.31610298157

Nodes generated this turn: 2313040

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' 'X' 'O' '']

['' 'O' 'X' '' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 198.29082489013672

Nodes generated this turn: 2180

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 177163.33389282227

Nodes generated this turn: 3096131

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' '' 'X' '']

['' '' '' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 191.30802154541016

Nodes generated this turn: 3080

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' '' '' 'X' '']

['' '' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 160809.0329170227

Nodes generated this turn: 3688920

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' 'X' '' 'X' '']

['' '' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 198.93503189086914

Nodes generated this turn: 3864

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' '' 'X' '' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 133856.22000694275

Nodes generated this turn: 4128399

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' 'X' 'X' '' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 221.35186195373535

Nodes generated this turn: 4540

[['' '' '' '' '' '']

['' '' '' '' '' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 105883.45384597778

Nodes generated this turn: 4446424

[['' '' '' '' '' '']

['' '' 'X' '' '' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 179.77070808410645

Nodes generated this turn: 5116

[['' '' '' '' '' '']

['' 'O' 'X' '' '' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 82444.54717636108

Nodes generated this turn: 4670099

[['' '' '' '' '' '']

['' 'O' 'X' '' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 163.77806663513184

Nodes generated this turn: 5600

[['' '' '' '' '' '']

['' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' '' '' '' '' '']]

Time taken this turn (ms): 60274.473905563354

Nodes generated this turn: 4822160

[['' '' '' '' '' '']

['' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 468.066930770874

Nodes generated this turn: 6000

[['O' '' '' '' '' '']

['' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 40442.52395629883

Nodes generated this turn: 4921359

[['O' 'X' '' '' '' '']

['' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 119.89665031433105

Nodes generated this turn: 6324

[['O' 'X' 'O' '' '' '']

['' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 25461.83180809021

Nodes generated this turn: 4982848

[['O' 'X' 'O' 'X' '' '']

['' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 105.67498207092285

Nodes generated this turn: 6580

[['O' 'X' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 15493.657112121582

Nodes generated this turn: 5018563

[['O' 'X' 'O' 'X' 'O' 'X']

['' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 82.80587196350098

Nodes generated this turn: 6776

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' '']

['' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 9038.114786148071

Nodes generated this turn: 5037608

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' '']

['X' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 62.95299530029297

Nodes generated this turn: 6920

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' '']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 4057.1048259735107

Nodes generated this turn: 5046639

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 44.52919960021973

Nodes generated this turn: 7020

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' '']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 1638.4668350219727

Nodes generated this turn: 5050248

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' 'X']

['' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 29.161930084228516

Nodes generated this turn: 7084

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' '']

['X' '' '' '' '' '']]

Time taken this turn (ms): 497.4842071533203

Nodes generated this turn: 5051347

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'X']

['X' '' '' '' '' '']]

Time taken this turn (ms): 20.233154296875

Nodes generated this turn: 7120

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'X']

['X' 'O' '' '' '' '']]

Time taken this turn (ms): 71.75302505493164

Nodes generated this turn: 5051552

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'X']

['X' 'O' 'X' '' '' '']]

Time taken this turn (ms): 8.064985275268555

Nodes generated this turn: 7136

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'X']

['X' 'O' 'X' 'O' '' '']]

Time taken this turn (ms): 0.5640983581542969

Nodes generated this turn: 5051567

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'X']

['X' 'O' 'X' 'O' 'X' '']]

Time taken this turn (ms): 1.3659000396728516

Nodes generated this turn: 7140

[['O' 'X' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'O']

['X' 'X' 'X' 'O' 'X' 'X']

['O' 'O' 'O' 'X' 'O' 'X']

['O' 'O' 'X' 'O' 'X' 'X']

['X' 'O' 'X' 'O' 'X' 'O']]

Time taken this turn (ms): 0.20694732666015625

Nodes generated this turn: 5051568