

COMP 472 AI Mini-Project 2

AI Tech:

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Due November 15th, 2021

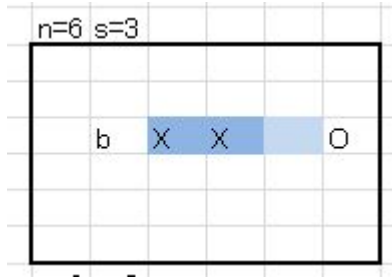
Description of Heuristics

Two heuristics, e1 and e2, were implemented to estimate how favorable each state of the game tree is for the white box player compared to the black box player.

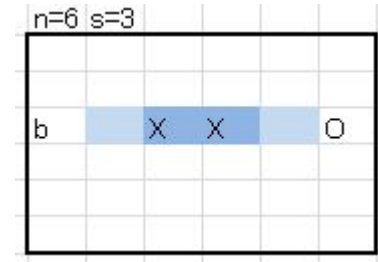
Heuristic e1

- e1 is the simple and fast heuristic.
- It is calculated by summing up the total possible wins (horizontal, vertical, diagonal, and anti-diagonal) of both players and then subtracting the total possible wins of white box player by that of the black box player for each state.

Heuristic e2: Evaluating the Attack

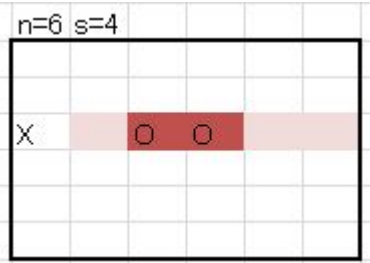


- Find the blue (light and dark) counts of each section.
- Consider only those with minimum length.
- Count the dark blue cells of the section.
- Points given depend on the progress to win.

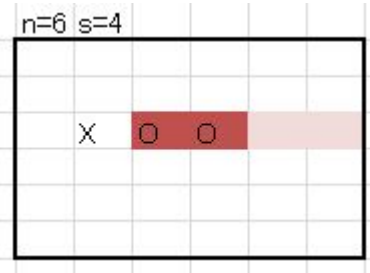


- Sections that are longer than the minimum have a better chance to win.
- Points from longer sections will be weighted higher.
- This makes it so the heuristic is incentivised to block the opponent by shortening their sections with the highest progress.

Incentivizing Defence

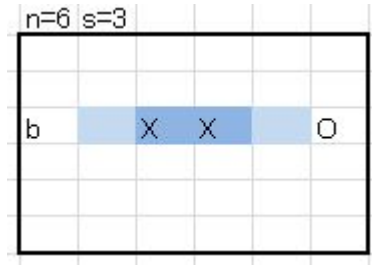
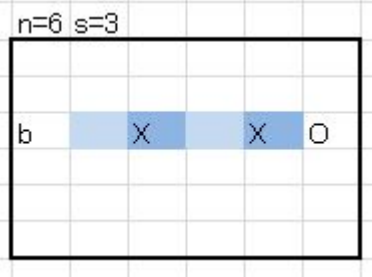


-The X shortens the highlighted section for O, but there's a better way to block.
(Here, O can force a win-in-two)



-The X shortens the highlighted section better.
(Here, O cannot force a win-in-two)
X will prefer this one, since O's section length gets reduced more.

Weakness



- Since the evaluated progress of a section does not make a distinction on the specific position of the pieces inside the section,
 - ... It can lead to an inferior position being ranked the same as a higher one
 - (X could've guaranteed a win instead.)

Internally

	n=6						
b	b	b	b	b	b	b	b
b							b
b							b
b		b	X		X	O	b
b							b
b							b
b							b
b	b	b	b	b	b	b	b

- Flatten the board into 1D, to fit np.split's format.
- Split on cells that are the opposing player's or a bloc.
(np.split will keep the separator in the split as the first element, so just ignore the first element.)
- However, when the board gets flattened, there's no longer a distinction between different rows/column/diagonals.
- So surround the board with blocs. That way, when it splits on those blocs, it also splits on rows/column/diagonals.
- This bloc surround is done on a copy of the board. The actual board is unaffected.

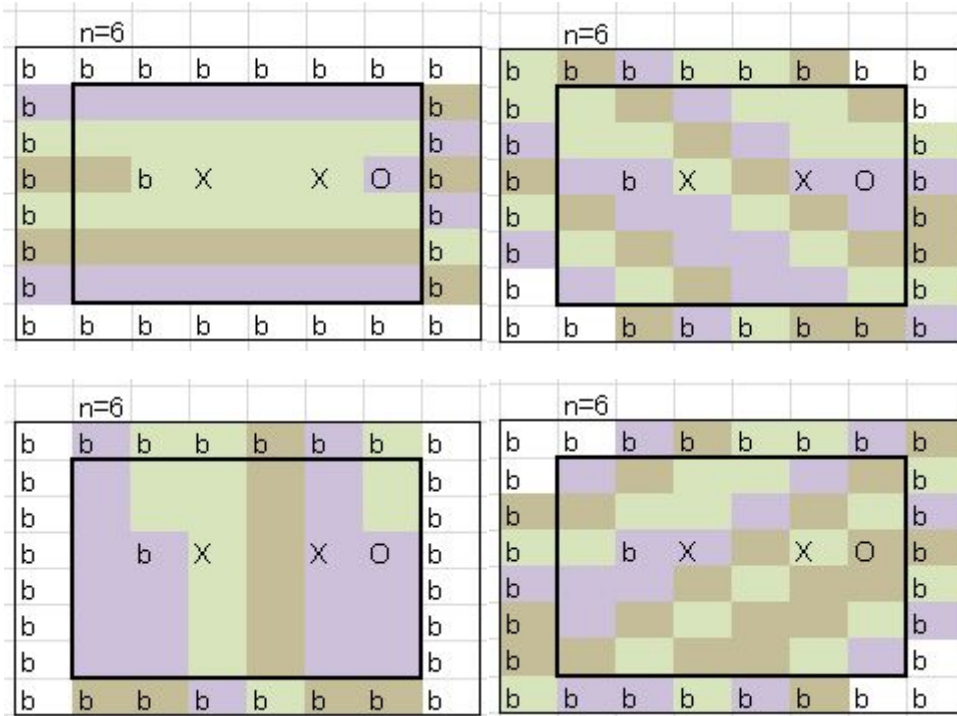
Internally

n=6							
b	b	b	b	b	b	b	b
b							b
b							b
b							b
b							b
b							b
b							b
b							b
b	b	b	b	b	b	b	b

For each split:

- Compare the length of the split to the minimum length.
 - The weight of the split has exponential growth.
 - Evaluate the player's progress to win (num of pieces) of the split. This value has exponential growth.
 - Compute the product of these two.
- (Only the best lines matter, and many equally good lines give more points than a single one.)
- Gather the sum of all splits' product.
 - The heuristic is the difference of this sum between the two players.

Internally



-Highlighted alternating horizontal, vertical, diagonals splits for X (3-colors)
(colors are visual only, the heuristic only cares about the split, not the 3-parity.)

Result - Scoreboard for GameTrace-4435

4. Game wins:

Player e1 wins, ratio: 1, 10.00%

Player e2 wins, ratio: 8, 80.00%

5. Average gametrace (Note: Incl. 'Total's reported below have been averaged.):

Summary of the game heuristics e1:

i Average evaluation time: 3.632007298072179

ii Total states visited: 9228.6

iii Average AD: 5.485647370384195

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 2.0, depth 2: 13.1, depth 3: 42.7, depth 4: 239.0, depth 5: 722.6, depth 6: 8209.2}

v Average ARD: 3.7452557319223985

vi Total number of moves: 3.8

Summary of the game heuristics e2:

i Average evaluation time: 3.3836770375569665

ii Total states visited: 4723.9

iii Average AD: 5.211742226631278

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 2.9, depth 2: 7.1, depth 3: 52.8, depth 4: 124.4, depth 5: 500.9, depth 6: 4035.8}

v Average ARD: 3.919943053980851

vi Total number of moves: 4.2

Result - Scoreboard for GameTrace-4431

4. Game wins:

Player e1 wins, ratio: 0, 0.00%

Player e2 wins, ratio: 10, 100.00%

5. Average gametrace (Note: Incl. 'Total's reported below have been averaged.):

Summary of the game heuristics e1:

i Average evaluation time: 0.690401383638382

ii Total states visited: 1267.8

iii Average AD: 5.558685486197111

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 1.9, depth 2: 4.1, depth 3: 14.0, depth 4: 34.2, depth 5: 109.4, depth 6: 1104.2}

v Average ARD: 4.009313714059258

vi Total number of moves: 3.5

Summary of the game heuristics e2:

i Average evaluation time: 0.6838797811667124

ii Total states visited: 773.2

iii Average AD: 5.2444473059551875

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 1.5, depth 2: 4.7, depth 3: 20.2, depth 4: 45.6, depth 5: 108.9, depth 6: 592.3}

v Average ARD: 4.304658210965713

vi Total number of moves: 4.0

Result - Scoreboard for GameTrace-5441

4. Game wins:

Player e1 wins, ratio: 1, 10.00%

Player e2 wins, ratio: 7, 70.00%

5. Average gametrace (Note: Incl. 'Total's reported below have been averaged.):

Summary of the game heuristics e1:

i Average evaluation time: 0.4784667989805147

ii Total states visited: 1244.2

iii Average AD: 3.9628751098984205

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 2.4, depth 2: 196.4, depth 3: 1.1, depth 4: 4.9, depth 5: 1.4, depth 6: 1038.0}

v Average ARD: 2.970252338129043

vi Total number of moves: 7.1

Summary of the game heuristics e2:

i Average evaluation time: 0.5047091232405767

ii Total states visited: 1124.3

iii Average AD: 3.7393991335828316

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 1.2, depth 2: 266.5, depth 3: 2.5, depth 4: 14.0, depth 5: 6.2, depth 6: 833.9}

v Average ARD: 3.3008430803176836

vi Total number of moves: 7.3

Result - Scoreboard for GameTrace-5445

5. Average gametrace (Note: Incl. 'Total's reported below have been averaged.):

Summary of the game heuristics e1:

i Average evaluation time:

3.928496065593901

ii Total states visited: 13566.6

iii Average AD: 5.88208360385773

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 2.4, depth 2: 6.8, depth 3: 16.3, depth 4: 69.4, depth 5: 209.2, depth 6: 13262.5}

v Average ARD: 4.797254526633806

vi Total number of moves: 7.2

4. Game wins:

Player e1 wins, ratio: 0, 0.00%

Player e2 wins, ratio: 10, 100.00%

Summary of the game heuristics e2:

i Average evaluation time: 4.096809932986895

ii Total states visited: 8339.7

iii Average AD: 5.765217214160724

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 2.2, depth 2: 4.3, depth 3: 33.1, depth 4: 58.2, depth 5: 342.6, depth 6: 7899.3}

v Average ARD: 4.884954651328098

vi Total number of moves: 7.7

Result - Scoreboard for GameTrace-8655

5. Average gametrace (Note: Incl. 'Total's reported below have been averaged.):

Summary of the game heuristics e1:

i Average evaluation time:

4.4122184369520845

ii Total states visited: 30692.8

iii Average AD: 5.917992758116894

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 5.5, depth 2: 9.4, depth 3: 17.3, depth 4: 88.2, depth 5: 168.0, depth 6: 30404.4}

v Average ARD: 4.98139259217398

vi Total number of moves: 25.5

4. Game wins:

Player e1 wins, ratio: 1, 10.00%

Player e2 wins, ratio: 7, 70.00%

Summary of the game heuristics e2:

i Average evaluation time: 4.512640619451302

ii Total states visited: 12686.2

iii Average AD: 5.900800224661367

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 3.0, depth 2: 3.5, depth 3: 19.9, depth 4: 19.9, depth 5: 219.5, depth 6: 12420.4}

v Average ARD: 5.316787443956176

vi Total number of moves: 25.8

Result - Scoreboard for GameTrace-8651

5. Average gametrace (Note: Incl. 'Total's reported below have been averaged.):

Summary of the game heuristics e1:

i Average evaluation time:

0.8351430925442879

ii Total states visited: 6712.5

iii Average AD: 5.918696571787354

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 6.2, depth 2: 6.1, depth 3: 7.6, depth 4: 26.6, depth 5: 53.5, depth 6: 6612.5}

v Average ARD: 4.519188076028666

vi Total number of moves: 23.2

4. Game wins:

Player e1 wins, ratio: 5, 50.00%

Player e2 wins, ratio: 3, 30.00%

Summary of the game heuristics e2:

i Average evaluation time: 0.8465583390653926

ii Total states visited: 2847.6

iii Average AD: 5.913128937155608

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 1.7, depth 2: 2.2, depth 3: 7.6, depth 4: 5.4, depth 5: 36.4, depth 6: 2794.3}

v Average ARD: 5.347808693130604

vi Total number of moves: 23.1

Result - Scoreboard for GameTrace-8555

5. Average gametrace (Note: Incl. 'Total's reported below have been averaged.):

Summary of the game heuristics e1:

i Average evaluation time:

2.5199283966648904

ii Total states visited: 11130.3

iii Average AD: 3.9942805578714613

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 6.5, depth 2: 1798.4, depth 3: 0.9, depth 4: 3.2, depth 5: 0.9, depth 6: 9320.4}

v Average ARD: 3.4924310473259603

vi Total number of moves: 17.4

4. Game wins:

Player e1 wins, ratio: 1, 10.00%

Player e2 wins, ratio: 9, 90.00%

Summary of the game heuristics e2:

i Average evaluation time: 3.896019821719848

ii Total states visited: 12224.2

iii Average AD: 3.966103607752346

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 3.6, depth 2: 2767.6, depth 3: 22.5, depth 4: 29.9, depth 5: 291.5, depth 6: 9109.1}

v Average ARD: 3.579764649369519

vi Total number of moves: 17.8

Result - Scoreboard for GameTrace-8551

5. Average gametrace (Note: Incl. 'Total's reported below have been averaged.):

Summary of the game heuristics e1:

i Average evaluation time:

0.6420011399846135

ii Total states visited: 4209.5

iii Average AD: 3.986500016451135

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 9.8, depth 2: 1577.5, depth 3: 1.4, depth 4: 5.9, depth 5: 2.7, depth 6: 2612.2}

v Average ARD: 3.3440378440710985

vi Total number of moves: 19.5

4. Game wins:

Player e1 wins, ratio: 3, 30.00%

Player e2 wins, ratio: 7, 70.00%

Summary of the game heuristics e2:

i Average evaluation time: 0.8508205739964122

ii Total states visited: 2585.7

iii Average AD: 3.9819227957516903

iv Total evaluations by depth: {depth 0: 0.0, depth 1: 3.8, depth 2: 1219.2, depth 3: 2.1, depth 4: 3.7, depth 5: 19.3, depth 6: 1337.6}

v Average ARD: 3.5808054155792775

vi Total number of moves: 19.7

Analysis of GameTrace

On average, heuristic e2 takes less time to run than heuristic e1 on smaller board sizes. It also visits less nodes than e1 because it was implemented to be accurate and it is shown in the above results. On the other hand, with higher board sizes, e1 tends to take less time to run than e2. Since e1 takes less computational time (simpler) to evaluate each state than e2, it can evaluate more states than e2 in the same timeframe.

A shallower depth tends to favor e2, since the advantage e1 of fast computation is lessened when e2 has enough time to evaluate most of the reachable states.

The use of alpha-beta allows to search more efficiently for specific states that can contribute to the decision making of the AI than minimax which evaluates all states. Hence, alpha-beta's ARD is larger on average. This can be seen in the scoreboard when comparing the result between the gametrace-4431 and 4435. For example, though the AD were similar, in gametrace-4431 the ARD evaluated for both heuristic using alphabeta were found to be higher than what was observed in the gametrace-4435 which uses minimax. This means each predicted move that were considered have been explored deeper, leading to a more informed decision.

Finally, the winning ratio between e1 and e2 was favored towards e2 when the board sizes were smaller. As the board size increase, the ratio tend to favor the e1 heuristic. e1 performs better on big boards with small time per turns. The advantage it has over e2 at that point is being able to quickly estimate the worth of multiple moves, whereas e2 will tend to lack the time to estimate the values of winning moves.

Team Contributions

Divide tasks with github issues in the second half of MP2.

Heuristics were done separately to make them more unique.

Some contributions on github were done while pair(/team) programming.

Once we had the results, we analyzed the data together.

We built the presentation slides together.