

Heuristic Analysis

There are 4 heuristics defined in this project:

- Minimize_opponent_hits
- Simplest_aggressive
- Maximize_winning
- Minimize_losing
- Weighted_combination

1. Minimize_opponent_hits: Student0

I tried something new with this one. Instead of just subtracting the number of opponent moves from my moves and then minimizing the whole thing, I first find the number of blank spaces left on board (NBS)

Then I subtract my moves from NBS to get all the blank spaces which exclude my moves. I am trying to maximize those blank spaces which actually aren't contributing for opponent moves.

I am penalizing more and more on the basis of how much fraction of not_my_moves variable is actually contributing to opponent's move. Contribution is directly proportional to the penalty. There's actually a lot that you can tweak in this heuristic. For e.g. you can add a reward parameter for main player apart from penalty for opponent to make the heuristic more aggressive.

2. Simplest_aggressive: By this heuristic, we are trying to minimize opponent's moves. (Described in lectures) Instead of subtracting the no. of opponent moves (OM) from the main player's moves (PM) we're using a more aggressive approach. Before subtracting OM from PM, we multiply it by 2. This way, we're rewarding the states which have less and less number of OM left which in turn makes it easier for main player to win.

It can be mathematically expressed as:

$$\text{len}(\text{main_player_moves}) - \alpha * \text{len}(\text{opponent's moves})$$

As described above, the value of alpha is chosen as 2.

3. Maximize_winning: By this approach, we're trying to maximize the ratio of main player's moves to opponent's moves.

It can be mathematically expressed as:

$$\text{len}(\text{main_player_moves}) / \text{len}(\text{opponent's moves})$$

4. Minimize_losing: Here, we're trying to minimize the ratio of opponent moves to main player's moves.

$$- \text{len}(\text{opponent's moves}) / \text{len}(\text{main_player_moves})$$

5. Weighted_combination:

This can be expressed as:

$$\alpha * \text{maximize_winning} - \beta * \text{minimize_losing}$$

As we can see that this is much effective heuristic, since it combines both of the above heuristics.

Results:

| Agent | Average Performance |
|-------------|----------------------------|
| ID_Improved | 67.50+71.43+67.14 = 68.69% |
| Student0 | 69.64+71.43+74.29 = 71.78% |
| Student1 | 68.21+67.86+68.21 = 68.09% |
| Student2 | 67.50+69.64+65 = 67.38% |
| Student3 | 67.14+65+67.86 = 66.66% |
| Student4 | 67.50+76.43+72.86 = 72.26% |

Analysis

1. Computational complexity order:

Weighted_combination > Minimize_opponent_hits > Minimize_losing = Maximize_winning > Simplest_aggressive

Minimize_losing and Maximize_winning are computationally equivalent. We can see that Simplest_aggressive heuristic beats both Minimize_losing and Maximize_winning. Probably because it's computationally faster than both. As explained in lectures, the factor that 2 is being multiplied by opponent's moves before subtraction from my_moves, makes it more aggressive. As in, it tries to reach a final state way faster than other 2 mentioned heuristics.

As we can see, for three attempts, average performances of Student4 and Student0 are quite well. Student4 beats all other heuristics, that's why I have submitted it. As I explained in Minimize_opponent_hits heuristic that adding an extra reward parameter apart from penalty would actually make the heuristic more powerful. This will also help it to reach the goal state faster.

In **weighted_combination** heuristic, both heuristics, **maximize_winning** and **minimize_losing** are working together in favor of main player which makes it most powerful. It also helps to reach a final state faster.

Result of tournament.py:

Attempt 1

This script evaluates the performance of the custom heuristic function by comparing the strength of an agent using iterative deepening (ID) search with alpha-beta pruning against the strength rating of agents using other heuristic functions. The `ID_Improved` agent provides a baseline by measuring the performance of a basic agent using Iterative Deepening and the "improved" heuristic (from lecture) on your hardware. The `Student` agent then measures the performance of Iterative Deepening and the custom heuristic against the same opponents.

```
*****
Evaluating: ID_Improved
*****
```

Playing Matches:

```
-----
Match 1: ID_Improved vs   Random      Result: 33 to 7
Match 2: ID_Improved vs   MM_Null     Result: 27 to 13
Match 3: ID_Improved vs   MM_Open     Result: 27 to 13
Match 4: ID_Improved vs MM_Improved   Result: 26 to 14
Match 5: ID_Improved vs   AB_Null     Result: 26 to 14
Match 6: ID_Improved vs   AB_Open     Result: 27 to 13
Match 7: ID_Improved vs AB_Improved   Result: 23 to 17
```

Results:

```
-----
ID_Improved          67.50%
```

```
*****
Evaluating: Student0
*****
```

Playing Matches:

| | | | | |
|----------|----------|----|-------------|------------------|
| Match 1: | Student0 | vs | Random | Result: 34 to 6 |
| Match 2: | Student0 | vs | MM_Null | Result: 33 to 7 |
| Match 3: | Student0 | vs | MM_Open | Result: 26 to 14 |
| Match 4: | Student0 | vs | MM_Improved | Result: 25 to 15 |
| Match 5: | Student0 | vs | AB_Null | Result: 28 to 12 |
| Match 6: | Student0 | vs | AB_Open | Result: 23 to 17 |
| Match 7: | Student0 | vs | AB_Improved | Result: 26 to 14 |

Results:

Student0 69.64%

Evaluating: Student1

Playing Matches:

| | | | | |
|----------|----------|----|-------------|------------------|
| Match 1: | Student1 | vs | Random | Result: 34 to 6 |
| Match 2: | Student1 | vs | MM_Null | Result: 30 to 10 |
| Match 3: | Student1 | vs | MM_Open | Result: 25 to 15 |
| Match 4: | Student1 | vs | MM_Improved | Result: 24 to 16 |
| Match 5: | Student1 | vs | AB_Null | Result: 26 to 14 |
| Match 6: | Student1 | vs | AB_Open | Result: 25 to 15 |
| Match 7: | Student1 | vs | AB_Improved | Result: 27 to 13 |

Results:

Student1 68.21%

Evaluating: Student2

Playing Matches:

| | | | | |
|----------|----------|----|-------------|------------------|
| Match 1: | Student2 | vs | Random | Result: 33 to 7 |
| Match 2: | Student2 | vs | MM_Null | Result: 29 to 11 |
| Match 3: | Student2 | vs | MM_Open | Result: 20 to 20 |
| Match 4: | Student2 | vs | MM_Improved | Result: 27 to 13 |
| Match 5: | Student2 | vs | AB_Null | Result: 35 to 5 |
| Match 6: | Student2 | vs | AB_Open | Result: 21 to 19 |
| Match 7: | Student2 | vs | AB_Improved | Result: 24 to 16 |

Results:

Student2 67.50%

Evaluating: Student3

Playing Matches:

| | | | | |
|----------|----------|----|-------------|------------------|
| Match 1: | Student3 | vs | Random | Result: 30 to 10 |
| Match 2: | Student3 | vs | MM_Null | Result: 30 to 10 |
| Match 3: | Student3 | vs | MM_Open | Result: 24 to 16 |
| Match 4: | Student3 | vs | MM_Improved | Result: 27 to 13 |
| Match 5: | Student3 | vs | AB_Null | Result: 29 to 11 |
| Match 6: | Student3 | vs | AB_Open | Result: 25 to 15 |
| Match 7: | Student3 | vs | AB_Improved | Result: 23 to 17 |

Results:

Student3 67.14%

Evaluating: Student4

Playing Matches:

| | | | | |
|----------|----------|----|-------------|------------------|
| Match 1: | Student4 | vs | Random | Result: 32 to 8 |
| Match 2: | Student4 | vs | MM_Null | Result: 32 to 8 |
| Match 3: | Student4 | vs | MM_Open | Result: 28 to 12 |
| Match 4: | Student4 | vs | MM_Improved | Result: 25 to 15 |
| Match 5: | Student4 | vs | AB_Null | Result: 29 to 11 |
| Match 6: | Student4 | vs | AB_Open | Result: 21 to 19 |
| Match 7: | Student4 | vs | AB_Improved | Result: 22 to 18 |

Results:

Student4 67.50%

Attempt 2

This script evaluates the performance of the custom heuristic function by comparing the strength of an agent using iterative deepening (ID) search with

alpha-beta pruning against the strength rating of agents using other heuristic functions. The `ID_Improved` agent provides a baseline by measuring the performance of a basic agent using Iterative Deepening and the "improved" heuristic (from lecture) on your hardware. The `Student` agent then measures the performance of Iterative Deepening and the custom heuristic against the same opponents.

```
*****
Evaluating: ID_Improved
*****
```

Playing Matches:

```
-----
Match 1: ID_Improved vs Random      Result: 35 to 5
Match 2: ID_Improved vs MM_Null     Result: 29 to 11
Match 3: ID_Improved vs MM_Open     Result: 25 to 15
Match 4: ID_Improved vs MM_Improved Result: 26 to 14
Match 5: ID_Improved vs AB_Null     Result: 33 to 7
Match 6: ID_Improved vs AB_Open     Result: 26 to 14
Match 7: ID_Improved vs AB_Improved Result: 26 to 14
```

Results:

```
-----
ID_Improved      71.43%
```

```
*****
Evaluating: Student0
*****
```

Playing Matches:

```
-----
Match 1: Student0 vs Random      Result: 34 to 6
Match 2: Student0 vs MM_Null     Result: 36 to 4
Match 3: Student0 vs MM_Open     Result: 28 to 12
Match 4: Student0 vs MM_Improved Result: 23 to 17
Match 5: Student0 vs AB_Null     Result: 32 to 8
Match 6: Student0 vs AB_Open     Result: 23 to 17
Match 7: Student0 vs AB_Improved Result: 24 to 16
```

Results:

```
-----
Student0        71.43%
```

```
*****
```

Evaluating: Student1

Playing Matches:

| | | | | |
|----------|----------|----|-------------|------------------|
| Match 1: | Student1 | vs | Random | Result: 35 to 5 |
| Match 2: | Student1 | vs | MM_Null | Result: 31 to 9 |
| Match 3: | Student1 | vs | MM_Open | Result: 24 to 16 |
| Match 4: | Student1 | vs | MM_Improved | Result: 25 to 15 |
| Match 5: | Student1 | vs | AB_Null | Result: 27 to 13 |
| Match 6: | Student1 | vs | AB_Open | Result: 25 to 15 |
| Match 7: | Student1 | vs | AB_Improved | Result: 23 to 17 |

Results:

Student1 67.86%

Evaluating: Student2

Playing Matches:

| | | | | |
|----------|----------|----|-------------|------------------|
| Match 1: | Student2 | vs | Random | Result: 31 to 9 |
| Match 2: | Student2 | vs | MM_Null | Result: 35 to 5 |
| Match 3: | Student2 | vs | MM_Open | Result: 27 to 13 |
| Match 4: | Student2 | vs | MM_Improved | Result: 23 to 17 |
| Match 5: | Student2 | vs | AB_Null | Result: 30 to 10 |
| Match 6: | Student2 | vs | AB_Open | Result: 25 to 15 |
| Match 7: | Student2 | vs | AB_Improved | Result: 24 to 16 |

Results:

Student2 69.64%

Evaluating: Student3

Playing Matches:

| | | | | |
|----------|----------|----|-------------|------------------|
| Match 1: | Student3 | vs | Random | Result: 31 to 9 |
| Match 2: | Student3 | vs | MM_Null | Result: 28 to 12 |
| Match 3: | Student3 | vs | MM_Open | Result: 25 to 15 |
| Match 4: | Student3 | vs | MM_Improved | Result: 24 to 16 |
| Match 5: | Student3 | vs | AB_Null | Result: 27 to 13 |
| Match 6: | Student3 | vs | AB_Open | Result: 23 to 17 |

Match 7: Student3 vs AB_Improved Result: 24 to 16

Results:

Student3 65.00%

Evaluating: Student4

Playing Matches:

Match 1: Student4 vs Random Result: 36 to 4
Match 2: Student4 vs MM_Null Result: 36 to 4
Match 3: Student4 vs MM_Open Result: 30 to 10
Match 4: Student4 vs MM_Improved Result: 30 to 10
Match 5: Student4 vs AB_Null Result: 37 to 3
Match 6: Student4 vs AB_Open Result: 22 to 18
Match 7: Student4 vs AB_Improved Result: 23 to 17

Results:

Student4 76.43%

Attempt 3

This script evaluates the performance of the custom heuristic function by comparing the strength of an agent using iterative deepening (ID) search with alpha-beta pruning against the strength rating of agents using other heuristic functions. The `ID_Improved` agent provides a baseline by measuring the performance of a basic agent using Iterative Deepening and the "improved" heuristic (from lecture) on your hardware. The `Student` agent then measures the performance of Iterative Deepening and the custom heuristic against the same opponents.

Evaluating: ID_Improved

Playing Matches:

Match 1: ID_Improved vs Random Result: 35 to 5

| | | | | | |
|----------|-------------|----|-------------|---------|----------|
| Match 2: | ID_Improved | vs | MM_Null | Result: | 29 to 11 |
| Match 3: | ID_Improved | vs | MM_Open | Result: | 28 to 12 |
| Match 4: | ID_Improved | vs | MM_Improved | Result: | 24 to 16 |
| Match 5: | ID_Improved | vs | AB_Null | Result: | 26 to 14 |
| Match 6: | ID_Improved | vs | AB_Open | Result: | 24 to 16 |
| Match 7: | ID_Improved | vs | AB_Improved | Result: | 22 to 18 |

Results:

ID_Improved 67.14%

Evaluating: Student0

Playing Matches:

| | | | | | |
|----------|----------|----|-------------|---------|----------|
| Match 1: | Student0 | vs | Random | Result: | 37 to 3 |
| Match 2: | Student0 | vs | MM_Null | Result: | 34 to 6 |
| Match 3: | Student0 | vs | MM_Open | Result: | 28 to 12 |
| Match 4: | Student0 | vs | MM_Improved | Result: | 27 to 13 |
| Match 5: | Student0 | vs | AB_Null | Result: | 26 to 14 |
| Match 6: | Student0 | vs | AB_Open | Result: | 29 to 11 |
| Match 7: | Student0 | vs | AB_Improved | Result: | 27 to 13 |

Results:

Student0 74.29%

Evaluating: Student1

Playing Matches:

| | | | | | |
|----------|----------|----|-------------|---------|----------|
| Match 1: | Student1 | vs | Random | Result: | 34 to 6 |
| Match 2: | Student1 | vs | MM_Null | Result: | 31 to 9 |
| Match 3: | Student1 | vs | MM_Open | Result: | 26 to 14 |
| Match 4: | Student1 | vs | MM_Improved | Result: | 24 to 16 |
| Match 5: | Student1 | vs | AB_Null | Result: | 28 to 12 |
| Match 6: | Student1 | vs | AB_Open | Result: | 24 to 16 |
| Match 7: | Student1 | vs | AB_Improved | Result: | 24 to 16 |

Results:

Student1 68.21%

Evaluating: Student2

Playing Matches:

Match 1: Student2 vs Random Result: 31 to 9
Match 2: Student2 vs MM_Null Result: 34 to 6
Match 3: Student2 vs MM_Open Result: 25 to 15
Match 4: Student2 vs MM_Improved Result: 21 to 19
Match 5: Student2 vs AB_Null Result: 25 to 15
Match 6: Student2 vs AB_Open Result: 22 to 18
Match 7: Student2 vs AB_Improved Result: 24 to 16

Results:

Student2 65.00%

Evaluating: Student3

Playing Matches:

Match 1: Student3 vs Random Result: 35 to 5
Match 2: Student3 vs MM_Null Result: 28 to 12
Match 3: Student3 vs MM_Open Result: 24 to 16
Match 4: Student3 vs MM_Improved Result: 25 to 15
Match 5: Student3 vs AB_Null Result: 34 to 6
Match 6: Student3 vs AB_Open Result: 24 to 16
Match 7: Student3 vs AB_Improved Result: 20 to 20

Results:

Student3 67.86%

Evaluating: Student4

Playing Matches:

Match 1: Student4 vs Random Result: 36 to 4
Match 2: Student4 vs MM_Null Result: 34 to 6
Match 3: Student4 vs MM_Open Result: 28 to 12
Match 4: Student4 vs MM_Improved Result: 27 to 13

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| | | | | |
|----------|----------|----|-------------|------------------|
| Match 5: | Student4 | vs | AB_Null | Result: 30 to 10 |
| Match 6: | Student4 | vs | AB_Open | Result: 26 to 14 |
| Match 7: | Student4 | vs | AB_Improved | Result: 23 to 17 |

Results:

| | |
|----------|--------|
| Student4 | 72.86% |
|----------|--------|