

Analysis of Custom Heuristic Functions

1st Heuristic: Difference in moves between players but with bias against opponent moves.

- **Name:** pro_self_score
- **Formula:** $\text{own_moves} - (\text{opp_moves} * .9)$
- **Description:** The idea behind this heuristic is to emphasize the number of player moves over the number of opponent moves. This is more evident during evaluations that return the same values. For example the values [7 - 4], [8 - 5], [6 - 3] would all return 3 but with the above calculation [3.4, 3.5, 3.3], the second option is chosen.
- **Results:**

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 17 to 3
Match 2: ID_Improved vs MM_Null     Result: 15 to 5
Match 3: ID_Improved vs MM_Open     Result: 12 to 8
Match 4: ID_Improved vs MM_Improved Result: 13 to 7
Match 5: ID_Improved vs AB_Null     Result: 14 to 6
Match 6: ID_Improved vs AB_Open     Result: 11 to 9
Match 7: ID_Improved vs AB_Improved Result: 11 to 9

Results:
-----
ID_Improved      66.43%

*****
Evaluating: Student
*****

Playing Matches:
-----
Match 1: Student vs Random      Result: 18 to 2
Match 2: Student vs MM_Null     Result: 17 to 3
Match 3: Student vs MM_Open     Result: 15 to 5
Match 4: Student vs MM_Improved Result: 16 to 4
Match 5: Student vs AB_Null     Result: 15 to 5
Match 6: Student vs AB_Open     Result: 10 to 10
Match 7: Student vs AB_Improved Result: 12 to 8

Results:
-----
Student          73.57%
```

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 17 to 3
Match 2: ID_Improved vs MM_Null     Result: 15 to 5
Match 3: ID_Improved vs MM_Open     Result: 13 to 7
Match 4: ID_Improved vs MM_Improved Result: 11 to 9
Match 5: ID_Improved vs AB_Null     Result: 11 to 9
Match 6: ID_Improved vs AB_Open     Result: 16 to 4
Match 7: ID_Improved vs AB_Improved Result: 9 to 11

Results:
-----
ID_Improved      65.71%

*****
Evaluating: Student
*****

Playing Matches:
-----
Match 1: Student vs Random      Result: 18 to 2
Match 2: Student vs MM_Null     Result: 16 to 4
Match 3: Student vs MM_Open     Result: 12 to 8
Match 4: Student vs MM_Improved Result: 13 to 7
Match 5: Student vs AB_Null     Result: 15 to 5
Match 6: Student vs AB_Open     Result: 15 to 5
Match 7: Student vs AB_Improved Result: 11 to 9

Results:
-----
Student          71.43%
```

This heuristic function performed better against ID_Improved most of the time. The test performed better 7 out of 10 times.

ID_Improved	Student
66.43	73.57
65.71	71.43
63.57	69.29

2nd Heuristic: Difference in moves between players but with bias against player moves

- **Name:** anti_opponent_score
- **Formula:** (own_moves*.9) - opp_moves
- **Description:** The idea behind this heuristic is to emphasize the number of opponent moves over the number of player moves. This is the counterpart of the 1st heuristic. As with the above, this is more evident during evaluations that return the same values. With the same example values [7 - 4], [8 - 5], [6 - 3] would all return 3 but with the above calculation [2.3, 2.2, 2.4], the third option is chosen.
- **Results:**

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 17 to 3
Match 2: ID_Improved vs MM_Null     Result: 15 to 5
Match 3: ID_Improved vs MM_Open     Result: 13 to 7
Match 4: ID_Improved vs MM_Improved Result: 14 to 6
Match 5: ID_Improved vs AB_Null     Result: 15 to 5
Match 6: ID_Improved vs AB_Open     Result: 11 to 9
Match 7: ID_Improved vs AB_Improved Result: 10 to 10

Results:
-----
ID_Improved      67.86%

*****
Evaluating: Student
*****

Playing Matches:
-----
Match 1: Student vs Random      Result: 16 to 4
Match 2: Student vs MM_Null     Result: 15 to 5
Match 3: Student vs MM_Open     Result: 15 to 5
Match 4: Student vs MM_Improved Result: 15 to 5
Match 5: Student vs AB_Null     Result: 13 to 7
Match 6: Student vs AB_Open     Result: 15 to 5
Match 7: Student vs AB_Improved Result: 12 to 8

Results:
-----
Student          72.14%
```

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 16 to 4
Match 2: ID_Improved vs MM_Null     Result: 17 to 3
Match 3: ID_Improved vs MM_Open     Result: 14 to 6
Match 4: ID_Improved vs MM_Improved Result: 7 to 13
Match 5: ID_Improved vs AB_Null     Result: 12 to 8
Match 6: ID_Improved vs AB_Open     Result: 11 to 9
Match 7: ID_Improved vs AB_Improved Result: 12 to 8

Results:
-----
ID_Improved      63.57%

*****
Evaluating: Student
*****

Playing Matches:
-----
Match 1: Student vs Random      Result: 18 to 2
Match 2: Student vs MM_Null     Result: 15 to 5
Match 3: Student vs MM_Open     Result: 11 to 9
Match 4: Student vs MM_Improved Result: 12 to 8
Match 5: Student vs AB_Null     Result: 16 to 4
Match 6: Student vs AB_Open     Result: 14 to 6
Match 7: Student vs AB_Improved Result: 11 to 9

Results:
-----
Student          69.29%
```

This heuristic function performed better against ID_Improved most of the time but a bit worse than the first function. The test performed better 6 out of 10 times.

ID_Improved	Student
67.86	72.14
63.57	69.29
69.29	70.00

3rd Heuristic: Difference in moves between players but with bias determined by free moves

- **Name:** free_score
- **Formula:** $(\text{own_moves} \cdot .9) - \text{opp_moves}$ or $\text{own_moves} - (\text{opp_moves} \cdot .9)$
- **Description:** This heuristic combines the above by taking into account the number of free spaces and comparing it to the total number of moves. The idea is that if the player and the opponent share a lot of moves and there are limited free spaces left, the heuristic would be more partial to reducing the opponent's moves. Conversely, if there are a lot of free spaces, the heuristic would be more inclined towards player moves.
- **Results:**

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 18 to 2
Match 2: ID_Improved vs MM_Null     Result: 15 to 5
Match 3: ID_Improved vs MM_Open     Result: 15 to 5
Match 4: ID_Improved vs MM_Improved Result: 10 to 10
Match 5: ID_Improved vs AB_Null     Result: 14 to 6
Match 6: ID_Improved vs AB_Open     Result: 12 to 8
Match 7: ID_Improved vs AB_Improved Result: 14 to 6

Results:
-----
ID_Improved      70.00%

*****
Evaluating: Student
*****

Playing Matches:
-----
Match 1: Student vs Random      Result: 18 to 2
Match 2: Student vs MM_Null     Result: 19 to 1
Match 3: Student vs MM_Open     Result: 16 to 4
Match 4: Student vs MM_Improved Result: 14 to 6
Match 5: Student vs AB_Null     Result: 18 to 2
Match 6: Student vs AB_Open     Result: 12 to 8
Match 7: Student vs AB_Improved Result: 12 to 8

Results:
-----
Student          77.86%
```

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 18 to 2
Match 2: ID_Improved vs MM_Null     Result: 15 to 5
Match 3: ID_Improved vs MM_Open     Result: 11 to 9
Match 4: ID_Improved vs MM_Improved Result: 12 to 8
Match 5: ID_Improved vs AB_Null     Result: 16 to 4
Match 6: ID_Improved vs AB_Open     Result: 12 to 8
Match 7: ID_Improved vs AB_Improved Result: 11 to 9

Results:
-----
ID_Improved      67.86%

*****
Evaluating: Student
*****

Playing Matches:
-----
Match 1: Student vs Random      Result: 17 to 3
Match 2: Student vs MM_Null     Result: 18 to 2
Match 3: Student vs MM_Open     Result: 13 to 7
Match 4: Student vs MM_Improved Result: 14 to 6
Match 5: Student vs AB_Null     Result: 14 to 6
Match 6: Student vs AB_Open     Result: 11 to 9
Match 7: Student vs AB_Improved Result: 13 to 7

Results:
-----
Student          71.43%
```

This heuristic function performed better against ID_Improved and the two previous functions. It also consistently produces the highest score out of the three. I ran the test ten times and it got a higher result for nine of them and with consistently higher scores (>70%).

ID_Improved	Student
70.00	77.86
67.86	71.43
65.71	77.14
66.43	76.43
75.00	77.14
72.86	65.71
69.29	70.00
68.57	72.14

Conclusion:

Out of all three custom heuristic functions, the third one is the best choice. The reasons are as follows:

- Out of the three, the *free_score* function is the most consistent in defeating ID_Improved. It scores higher about nine out of ten times. Of course, this is only based on the limited runs I have performed so it is far from definitive.
- The *free_score* function produced the highest score among all the functions tested including ID_Improved in all of the runs which is 77.86%. It also frequently produces scores above 70%.
- It won against the other two functions after modifying tournament.py to make them compete against each other. (See results in the images below)

```
*****
Evaluating: Anti
*****

Playing Matches:
-----
Match 1:  Anti   vs  Random   Result: 17 to 3
Match 2:  Anti   vs  MM_Anti  Result: 11 to 9
Match 3:  Anti   vs  MM_Free  Result: 12 to 8
Match 4:  Anti   vs  MM_Pro   Result: 12 to 8
Match 5:  Anti   vs  AB_Anti  Result: 13 to 7
Match 6:  Anti   vs  AB_Free  Result: 11 to 9
Match 7:  Anti   vs  AB_Pro   Result: 12 to 8

Results:
-----
Anti                               62.86%

*****
Evaluating: Free
*****

Playing Matches:
-----
Match 1:  Free   vs  Random   Result: 17 to 3
Match 2:  Free   vs  MM_Anti  Result: 10 to 10
Match 3:  Free   vs  MM_Free  Result: 12 to 8
Match 4:  Free   vs  MM_Pro   Result: 15 to 5
Match 5:  Free   vs  AB_Anti  Result: 14 to 6
Match 6:  Free   vs  AB_Free  Result: 13 to 7
Match 7:  Free   vs  AB_Pro   Result: 14 to 6

Results:
-----
Free                               67.86%
```

anti_opponent_score vs free_score

```

*****
Evaluating: Pro
*****

Playing Matches:
-----
Match 1:    Pro    vs    Random    Result: 18 to 2
Match 2:    Pro    vs    MM_Anti   Result: 15 to 5
Match 3:    Pro    vs    MM_Free   Result: 14 to 6
Match 4:    Pro    vs    MM_Pro    Result: 13 to 7
Match 5:    Pro    vs    AB_Anti   Result: 11 to 9
Match 6:    Pro    vs    AB_Free   Result: 10 to 10
Match 7:    Pro    vs    AB_Pro    Result: 13 to 7

Results:
-----
Pro          67.14%

*****
Evaluating: Anti
*****

Playing Matches:
-----
Match 1:    Anti   vs    Random    Result: 17 to 3
Match 2:    Anti   vs    MM_Anti   Result: 13 to 7
Match 3:    Anti   vs    MM_Free   Result: 10 to 10
Match 4:    Anti   vs    MM_Pro    Result: 14 to 6
Match 5:    Anti   vs    AB_Anti   Result: 13 to 7
Match 6:    Anti   vs    AB_Free   Result: 11 to 9
Match 7:    Anti   vs    AB_Pro    Result: 12 to 8

Results:
-----
Anti         64.29%

```

pro_self_score vs anti_opponent_score

```

*****
Evaluating: Pro
*****

Playing Matches:
-----
Match 1:    Pro    vs    Random    Result: 16 to 4
Match 2:    Pro    vs    MM_Anti   Result: 12 to 8
Match 3:    Pro    vs    MM_Free   Result: 17 to 3
Match 4:    Pro    vs    MM_Pro    Result: 12 to 8
Match 5:    Pro    vs    AB_Anti   Result: 11 to 9
Match 6:    Pro    vs    AB_Free   Result: 12 to 8
Match 7:    Pro    vs    AB_Pro    Result: 12 to 8

Results:
-----
Pro          65.71%

*****
Evaluating: Free
*****

Playing Matches:
-----
Match 1:    Free   vs    Random    Result: 18 to 2
Match 2:    Free   vs    MM_Anti   Result: 11 to 9
Match 3:    Free   vs    MM_Free   Result: 14 to 6
Match 4:    Free   vs    MM_Pro    Result: 13 to 7
Match 5:    Free   vs    AB_Anti   Result: 13 to 7
Match 6:    Free   vs    AB_Free   Result: 11 to 9
Match 7:    Free   vs    AB_Pro    Result: 14 to 6

Results:
-----
Free         67.14%

```

pro_self_score vs free_score