Analysis of Custom Heuristic Functions

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

- Name: pro_self_score
- Formula: own_moves (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:
                                         Result: 17 to 3
 Match 1: ID_Improved vs
                            Random
 Match 2: ID_Improved vs MM_Null
Match 3: ID_Improved vs MM_Open
                                          Result: 15 to 5
                                          Result: 12 to 8
 Match 4: ID_Improved vs MM_Improved Result: 13 to 7
 Match 5: ID_Improved vs AB_Null
Match 6: ID_Improved vs AB_Open
                                          Result: 14 to 6
                                          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
                      vs MM_Null
 Match 2:
            Student
                                         Result: 17 to 3
 Match 3:
             Student
                            MM Open
                                          Result: 15 to 5
                       vs MM_Improved
 Match 4:
                                         Result: 16 to 4
             Student
                      vs AB_Null
 Match 5:
             Student
                                          Result: 15 to 5
                            AB_Open
 Match 6:
                                          Result: 10 to 10
             Student
                       VS
 Match 7:
             Student
                       vs AB_Improved
                                         Result: 12 to 8
Results:
                    73.57%
Student
```

```
*******
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:
           Student
 Match 1:
                          Random
                                     Result: 18 to 2
                     V5
 Match 2:
            Student
                          MM Null
                                     Result: 16 to 4
           Student
                         MM Open
 Match 3:
                                     Result: 12 to 8
                     V5
 Match 4:
            Student
                     vs MM_Improved
                                     Result: 13 to 7
           Student
Student
 Match 5:
                         AB Null
                                     Result: 15 to 5
                         AB_Open
                                     Result: 15 to 5
 Match 6:
                     V5
           Student
 Match 7:
                     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

- 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
                           MM_Null
 Match 2: ID Improved vs
                                       Result: 15 to 5
                                       Result: 13 to 7
 Match 3: ID_Improved vs
                           MM Open
 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
********
  Evaluating: Student
Playing Matches:
                                       Result: 16 to 4
 Match 1:
            Student
                      V5
                           Random
 Match 2:
            Student
                      V5
                           MM Null
                                       Result: 15 to 5
                           MM Open
                                       Result: 15 to 5
 Match 3:
            Student
                      V5
 Match 4:
            Student
                      vs MM_Improved
                                       Result: 15 to 5
 Match 5:
            Student
                           AB Null
                                       Result: 13 to 7
                      V5
                           AB_Open
                                       Result: 15 to 5
 Match 6:
            Student
                      V5
 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
Match 5: ID_Improved vs AB_Null
                                       Result: 7 to 13
                                        Result: 12 to 8
 Match 6: ID Improved vs
                           AB Open
                                        Result: 11 to 9
                                       Result: 12 to 8
 Match 7: ID_Improved vs AB_Improved
Results:
ID Improved
                   63.57%
*******
  Evaluating: Student
Playing Matches:
 Match 1:
            Student
                           Random
                                        Result: 18 to 2
 Match 2:
            Student
                           MM Null
                                        Result: 15 to 5
                      VS
                                        Result: 11 to 9
 Match 3:
            Student
                      V5
                           MM_Open
 Match 4:
            Student
                      vs MM_Improved
                                        Result: 12 to 8
                           AB_Null
                                        Result: 16 to 4
 Match 5:
            Student
                      V5
 Match 6:
            Student
                      VS
                           AB_Open
                                        Result: 14 to 6
            Student
                      vs AB_Improved
                                        Result: 11 to 9
 Match 7:
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

- Name: free score
- Formula: (own moves*.9) opp moves or own moves (opp moves * .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
                                      Result: 12 to 8
 Match 6: ID_Improved vs
                          AB_Open
 Match 7: ID_Improved vs AB_Improved
                                     Result: 14 to 6
Results:
ID Improved
                   70.00%
*******
  Evaluating: Student
Playing Matches:
                                      Result: 18 to 2
 Match 1:
            Student
                          Random
 Match 2:
            Student
                          MM Null
                                      Result: 19 to 1
                     V5
                     vs MM Open
                                      Result: 16 to 4
 Match 3:
            Student
 Match 4:
            Student
                     vs MM_Improved Result: 14 to 6
                          AB_Null
 Match 5:
            Student
                                      Result: 18 to 2
                          AB Open
                                      Result: 12 to 8
 Match 6:
            Student
                     V5
 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
                                     Result: 12 to 8
 Match 4: ID_Improved vs MM_Improved
 Match 5: ID_Improved vs
                          AB_Null
                                      Result: 16 to 4
 Match 6: ID_Improved vs AB_Open
                                      Result: 12 to 8
                                     Result: 11 to 9
 Match 7: ID_Improved vs AB_Improved
Results:
ID Improved
                  67.86%
*******
  Evaluating: Student
Playing Matches:
 Match 1:
            Student vs
                          Random
                                      Result: 17 to 3
 Match 2:
                          MM_Null
                                     Result: 18 to 2
            Student
                     V5
                                     Result: 13 to 7
 Match 3:
            Student
                          MM_Open
                     vs MM Improved
 Match 4:
            Student
                                     Result: 14 to 6
                     vs AB_Null
                                     Result: 14 to 6
 Match 5:
            Student
            Student
                          AB_Open
                                      Result: 11 to 9
 Match 6:
                     vs AB_Improved
 Match 7:
            Student
                                      Result: 13 to 7
Results:
                   71.43%
Student
```

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
                                      Result: 17 to 3
                     V5
                          Random
 Match 2:
                          MM Anti
                                      Result: 11 to 9
             Anti
                          MM Free
                                      Result: 12 to 8
 Match 3:
             Anti
                     VS
 Match 4:
             Anti
                     vs MM_Pro
                                      Result: 12 to 8
                     vs AB_Anti
vs AB_Free
 Match 5:
             Anti
                                      Result: 13 to 7
             Anti
 Match 6:
                                      Result: 11 to 9
 Match 7:
             Anti
                          AB Pro
                                      Result: 12 to 8
Results:
Anti
                   62.86%
 *********
   Evaluating: Free
Playing Matches:
 Match 1:
                                      Result: 17 to 3
                          Random
             Free
                     V5
 Match 2:
             Free
                         MM_Anti
                                      Result: 10 to 10
                          MM_Free
MM_Pro
 Match 3:
             Free
                     V5
                                      Result: 12 to 8
                                      Result: 15 to 5
 Match 4:
             Free
                          AB Anti
                                      Result: 14 to 6
 Match 5:
             Free
                     V5
                                      Result: 13 to 7
 Match 6:
             Free
                     VS
                          AB_Free
 Match 7:
             Free
                          AB_Pro
                                      Result: 14 to 6
Results:
                   67.86%
 ree
```

anti_opponent_score vs free_score

```
*******
    Evaluating: Pro
Playing Matches:
                                     Result: 18 to 2
 Match 1:
              Pro
                          Random
                     VS
 Match 2:
                          MM Anti
                                     Result: 15 to 5
             Pro
 Match 3:
              Pro
                          MM Free
                                      Result: 14 to 6
 Match 4:
                          MM_Pro
AB_Anti
             Pro
                                     Result: 13 to 7
                     V5
 Match 5:
              Pro
                                     Result: 11 to 9
                          AB Free
 Match 6:
              Pro
                                      Result: 10 to 10
                     VS
 Match 7:
             Pro
                          AB_Pro
                                     Result: 13 to 7
                     VS
Results:
                  67.14%
Pro
********
Evaluating: Anti
Playing Matches:
 Match 1:
                          Random
                                     Result: 17 to 3
 Match 2:
                          MM_Anti
                                     Result: 13 to 7
            Anti
                     VS
 Match 3:
             Anti
                          MM_Free
                                     Result: 10 to 10
                          MM Pro
 Match 4:
                                     Result: 14 to 6
            Anti
                     V5
            Anti
                          AB_Anti
                                     Result: 13 to 7
 Match 5:
                          AB_Free
AB_Pro
 Match 6:
             Anti
                                     Result: 11 to 9
 Match 7:
            Anti
                                     Result: 12 to 8
                     VS
Results:
Anti
                  64.29%
```

```
********
 Evaluating: Pro
Playing Matches:
 Match 1:
              Pro
                     vs Random
                                     Result: 16 to 4
 Match 2:
              Pro
                          MM Anti
                                      Result: 12 to 8
                     VS
                          MM_Free
                                      Result: 17 to 3
 Match 3:
              Pro
 Match 4:
              Pro
                          MM Pro
                                      Result: 12 to 8
                     VS
                          AB_Anti
AB_Free
             Pro
                                     Result: 11 to 9
 Match 5:
 Match 6:
              Pro
                                      Result: 12 to 8
                          AB Pro
 Match 7:
              Pro
                                     Result: 12 to 8
                     VS
Results:
                  65.71%
ro
********
   Evaluating: Free
Playing Matches:
 Match 1:
                                     Result: 18 to 2
             Free
                     vs Random
 Match 2:
                     vs MM Anti
                                     Result: 11 to 9
             Free
                                     Result: 14 to 6
 Match 3:
             Free
                         MM_Free
                     V5
                          MM_Pro
AB_Anti
 Match 4:
             Free
                                      Result: 13 to 7
                                      Result: 13 to 7
 Match 5:
             Free
                     V5
                                     Result: 11 to 9
 Match 6:
             Free
                          AB_Free
 Match 7:
                          AB Pro
                                     Result: 14 to 6
             Free
                     V5
Results:
                  67.14%
ree
```

pro_self_score vs anti_opponent_score

pro_self_score vs free_score