HEURISTIC ANALYSIS

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Table of Contents

Heuristics

1. Heuristic 1

```
own_moves - 2 * opp_moves
```

With this evaluation function the player plays aggressively to minimize the moves of the   opponent. This is a superior heuristic which plays more aggressively since coefficient of 2 is used and hence statistically always has better chances of winning

2. Heuristic 2

```
for move in own_moves:
    if is_near_walls(move, walls):
        own_cum_score -= 20
    else:
        own_cum_score += 5

  for move in opp_moves:
    if is_near_walls(move, walls):
        opp_cum_score -= 20
    else:
        opp_cum_score += 5

  return float(own_cum_score - opp_cum_score)
```

With this evaluation function we add a positive score of 5 if the move is away from the walls and a negative 20 if the move is on the walls. We try to avoid the walls to minimize the chances of being cornered.

3. Heuristic 3

```
1.5 * own_moves - opp_moves
```

With this evaluation function, the player plays defensively to maximize its own moves as compared to the opponent.

4. Heuristic 4

```
move_count = game.move_count
    if move_count <= 8:
        return custom_score_4(game, player) + custom_score_3(game,
player)

    else:
        return custom_score_2(game, player)
```

And after tweaking the point at which we switch the heuristics, I found that playing the first 8 moves defensively and rest of the game aggressively has better chances of winning since there are more chance of losing if the move is on walls.

Performance

Win Rate

Performance of all the heuristics can be measured by running the tournament.py

To remove any randomness in the results, I have increased the number of games played in the tournament.

```
(aind) c:\AIND\projects\AIND-Isolation>python tournament.py

This script evaluates the performance of the custom_score evaluation
function against a baseline agent using alpha-beta search and iterative
deepening (ID) called `AB_Improved`. The three `AB_Custom` agents use
ID and alpha-beta search with the custom_score functions defined in
game_agent.py.

                         *************************
                              Playing Matches
                         *************************

Match #    Opponent     AB_Improved   AB_Custom   AB_Custom_2   AB_Custom_3
                        Won | Lost    Won | Lost   Won | Lost    Won | Lost
   1        Random       19 |  1       18 |  2      17 |  3       20 |  0
   2        MM_Open      14 |  6       14 |  6      14 |  6        9 | 11
   3        MM_Center    18 |  2       18 |  2      19 |  1       20 |  0
   4        MM_Improved  14 |  6       16 |  4      14 |  6       13 |  7
   5        AB_Open      11 |  9       11 |  9      10 | 10       10 | 10
   6        AB_Center    11 |  9       12 |  8      14 |  6        8 | 12
   7        AB_Improved   7 | 13       10 | 10       8 | 12       10 | 10
----------------------------------------------------------------------------
        Win Rate:        67.1%         70.7%        68.6%         64.3%

Your agents forfeited 183.0 games while there were still legal moves available to play.
```

```
ID and alpha-beta search with the custom_score functions defined in
game_agent.py.

                   ************************
                         Playing Matches
                   ************************

Match #   Opponent     AB_Improved    AB_Custom    AB_Custom_2   AB_Custom_3
                       Won | Lost    Won | Lost    Won | Lost    Won | Lost
   1       Random      18  |  2      20  |  0      18  |  2      19  |  1
   2       MM_Open     13  |  7      15  |  5      16  |  4      13  |  7
   3       MM_Center   15  |  5      19  |  1      17  |  3      17  |  3
   4       MM_Improved 15  |  5      14  |  6      16  |  4      13  |  7
   5       AB_Open     11  |  9      10  | 10      10  | 10       8  | 12
   6       AB_Center   12  |  8      10  | 10      10  | 10       9  | 11
   7       AB_Improved 11  |  9      11  |  9      11  |  9       7  | 13
----------------------------------------------------------------------------
         Win Rate:      67.9%          70.7%         70.0%         61.4%

Your agents forfeited 183.0 games while there were still legal moves available to play.
```

Execution Time

Here are the execution times for each heuristic.

```
                   **********************
Match #    Opponent          AB_Improved
                      Won | Lost | Time
   1        Random     19  |  1  | 30.26
   2        MM_Open    18  |  2  | 37.20
   3        MM_Center  15  |  5  | 32.63
   4        MM_Improved 14 |  6  | 36.97
   5        AB_Open     7  | 13  | 73.11
   6        AB_Center  14  |  6  | 68.19
   7        AB_Improved 12 |  8  | 76.11
--------------------------------------------
         Win Rate:     70.7%    |  50.64
```

```
                   **********************
Match #    Opponent          AB_Improved
                      Won | Lost | Time
   1        Random     20  |  0  | 28.46
   2        MM_Open    15  |  5  | 35.94
   3        MM_Center  19  |  1  | 32.08
   4        MM_Improved 17 |  3  | 36.33
   5        AB_Open    12  |  8  | 71.55
   6        AB_Center  11  |  9  | 69.51
   7        AB_Improved 13 |  7  | 76.24
--------------------------------------------
         Win Rate:     76.4%    |  50.02
```

```
                   **********************
Match #    Opponent          AB_Custom
                      Won | Lost | Time
   1        Random     19  |  1  | 32.42
   2        MM_Open    12  |  8  | 33.38
   3        MM_Center  18  |  2  | 29.26
   4        MM_Improved 15 |  5  | 33.39
   5        AB_Open    11  |  9  | 71.91
   6        AB_Center  11  |  9  | 65.67
   7        AB_Improved 13 |  7  | 73.35
--------------------------------------------
         Win Rate:     70.7%    |  48.48
```

```
Match #    Opponent          AB_Custom
                      Won | Lost | Time
   1        Random     20  |  0  | 32.91
   2        MM_Open    15  |  5  | 37.06
   3        MM_Center  20  |  0  | 32.43
   4        MM_Improved 15 |  5  | 36.07
   5        AB_Open     9  | 11  | 70.95
   6        AB_Center  11  |  9  | 66.87
   7        AB_Improved 10 | 10  | 72.29
--------------------------------------------
         Win Rate:     71.4%    |  49.80
```

```
Match #    Opponent       AB_Custom_2
                       Won | Lost | Time
   1         Random     17  |   3  | 28.82
   2        MM_Open     17  |   3  | 36.77
   3      MM_Center     18  |   2  | 32.83
   4    MM_Improved     11  |   9  | 36.64
   5        AB_Open      9  |  11  | 72.39
   6      AB_Center      9  |  11  | 73.35
   7    AB_Improved      9  |  11  | 72.63
------------------------------------------------
        Win Rate:      64.3%    |    50.49
```

```
Match #    Opponent       AB_Custom_2
                       Won | Lost | Time
   1         Random     17  |   3  | 32.66
   2        MM_Open     16  |   4  | 38.70
   3      MM_Center     19  |   1  | 28.86
   4    MM_Improved     12  |   8  | 34.40
   5        AB_Open      7  |  13  | 68.55
   6      AB_Center     13  |   7  | 72.16
   7    AB_Improved     10  |  10  | 71.80
------------------------------------------------
        Win Rate:      67.1%    |    49.59
```

```
Match #    Opponent       AB_Custom_3
                       Won | Lost | Time
   1         Random     18  |   2  | 29.18
   2        MM_Open     13  |   7  | 34.85
   3      MM_Center     18  |   2  | 29.42
   4    MM_Improved     14  |   6  | 35.12
   5        AB_Open      5  |  15  | 67.11
   6      AB_Center     11  |   9  | 64.71
   7    AB_Improved      8  |  12  | 68.67
------------------------------------------------
        Win Rate:      62.1%    |    47.01
```

```
Match #    Opponent       AB_Custom_3
                       Won | Lost | Time
   1         Random     19  |   1  | 27.98
   2        MM_Open     14  |   6  | 35.45
   3      MM_Center     18  |   2  | 30.49
   4    MM_Improved     13  |   7  | 33.22
   5        AB_Open     10  |  10  | 70.59
   6      AB_Center     12  |   8  | 69.39
   7    AB_Improved     11  |   9  | 71.43
------------------------------------------------
        Win Rate:      69.3%    |    48.36
```

Heuristic Recommendation

I would recommend **Heuristic 4** because,

1. **Best Score** : With this heuristic the student player always outperforms AB_Improved.
2. **Better execution time** : From the performance and execution time it's clear that **Heuristic 4** has better execution time. It takes slightly more time to execute in some cases than Heuristic 1 and Heuristic 2, but compared to the win rate it is still doing better.
3. **Combination of best heuristics**: It is a combined value of all other heuristics and performs better than the other individual heuristics almost always.
4. **Strategic switching** : This heuristic is based on my study that in the beginning when the board is more empty than full, we play more defensively with the **intention of not losing**. But towards the end we play more aggressively with the **intention of winning.**