Heuristic Analysis

Three Heuristics

The following three heuristics were implemented

1. **Heuristic**: Euclidean distance from the centre.
2. **Heuristic**: Distance from EACH empty board position.
3. **Heuristic**: Aggressive minimizing of enemy moves.

Brief Summary

```
**************************
    Playing Matches
**************************
```

Match #	Opponent	AB_Improved		AB_Custom		AB_Custom_2		AB_Custom_3	
		Won	Lost	Won	Lost	Won	Lost	Won	Lost
1	Random	7	3	10	0	10	0	10	0
2	MM_Open	4	6	7	3	6	4	7	3
3	MM_Center	9	1	7	3	10	0	8	2
4	MM_Improved	4	6	4	6	6	4	4	6
5	AB_Open	3	7	6	4	6	4	5	5
6	AB_Center	3	7	5	5	6	4	6	4
7	AB_Improved	4	6	6	4	5	5	6	4
	Win Rate:	48.6%		64.3%		70.0%		65.7%	

Heuristic One (H1)

```python
if game.is_loser(player):
    return float("-inf")

if game.is_winner(player):
    return float("inf")


# Distance from centre
w, h = game.width / 2., game.height / 2.
y, x = game.get_player_location(player)
score = float(math.sqrt(((h - y)**2 + (w - x)**2)))
return score
```

AB_Custom	
Won	Lost
10	0
7	3
7	3
4	6
6	4
5	5
6	4
64.3%	

AB_Custom	
Won	Lost
10	0
7	3
5	5
6	4
5	5
4	6
4	6
58.6%	

Heuristic one was a little bit of a twist compared to direct comparison to the centre as in MM_Center. It took the square root of the actual X,Y coordinates to get a Euclidean distance.

In a previous test a 5-5 score represented on the upper right shows when the MM_center faced itself. But surprisingly, H1 fared better than MM_center. The possible difference is that the scoring is VERY high in MM_center as opposed to in H1 - where the maximum distance will rarely exceed 3. Providing less benefit for REALLY long distance positions which may trap the player.

Heuristic Two (H2)

```
    if game.is_loser(player):
        return float("-inf")

    if game.is_winner(player):
        return float("inf")

    totalScore = 0
    #empty_board_places = len(game.get_blank_spaces())

    y, x = game.get_player_location(player)
    for h,w in game.get_blank_spaces():
        score = ((h - y)**2 + (w - x)**2)
        totalScore = totalScore + score


    return float(totalScore)
```

```
AB_Custom_2
 Won | Lost
 10  |   0
  6  |   4
 10  |   0
  6  |   4
  6  |   4
  6  |   4
  5  |   5
-------------
   70.0%
```

H2 was based on the empty board spots, and compared them to the position of the player. The more places there was, and the further the distance there was, the higher the score.

The intuition behind this heuristic was that a move which allowed more board places with a further distance increased the likelihood of a more prolonged game - resulting in a possible win. H2 preformed the best of the three heuristics, and faired greatest against the MM_center.

Heuristic Three (H3)

```
    if game.is_loser(player):
        return float("-inf")

    if game.is_winner(player):
        return float("inf")

    # My moves
    my_moves = len(game.get_legal_moves(player))

    # Enemy Moves
    # Punish if enemy has more moves - this tries to minimize
    enemy_moves = len(game.get_legal_moves(game.get_opponent(player)))
    return float(my_moves*my_moves - 1.7*enemy_moves*enemy_moves)
```

```
AB_Custom_3
 Won | Lost
 10  |   0
  7  |   3
  8  |   2
  4  |   6
  5  |   5
  6  |   4
  6  |   4
-------------
   65.7%
```

H3 was based of a more defensive play - minimizing the amount of moves an enemy could have. The larger the amount of moves the enemy could do, the worst the score was. The 1.7 multiplier was more of a twist - trying 1.3, 1.5 and 1.7 - 1.7 outputted the best result. A possible addition to this is graphing the change between 1- 4 and plotting the differences to see a change!

Report, Summary and Recommendation

Based on results, H2 would be best to use. With a 70% win rate, and without ‘ever’ losing in total 10 games per match (draw at worst) it is the most recommended heuristic. However, when examining all 3 at once, they are all relatively close.

- H2 primary difference was how it beat MM_center completely. If we remove MM_center from this, as shown below - **the other two heuristics performed very similar - in fact, JUST by ONE win H2 performed better.**

```
                    **************************
                        Playing Matches
                    **************************

Match #   Opponent    AB_Improved   AB_Custom   AB_Custom_2  AB_Custom_3
                       Won | Lost   Won | Lost   Won | Lost   Won | Lost
    1       Random      7  |  3     10  |  0     10  |  0     10  |  0
    2       MM_Open     4  |  6      7  |  3      6  |  4      7  |  3
    3      MM_Center    9  |  1      7  |  3     10  |  0      8  |  2
    4     MM_Improved   4  |  6      4  |  6      6  |  4      4  |  6
    5       AB_Open     3  |  7      6  |  4      6  |  4      5  |  5
    6      AB_Center    3  |  7      5  |  5      6  |  4      6  |  4
    7     AB_Improved   4  |  6      6  |  4      5  |  5      6  |  4
--------------------------------------------------------------------------
          Win Rate:      48.6%        64.3%        70.0%        65.7%
```

- H2 plays a more defensive style, ensuring the game last longer and bases the distance from the player. This is better attuned than ‘center’ play as the more available places from the player - the better. Moving into corners can be dangerous for example, and this may prevent further movement especially if the opponent is aiming to minimize your movements.
- A greater improvement to test would be to have multiple more opponents over time. It may be a counter heuristic.
- A final reason to recommend H2 besides its results, is the fact it has yet to lose (only draw and win!) (5-5 is its worst score)