

Heuristic Evaluation Functions

The purpose of these functions is that AI will favor moves by providing the first player a lot of choices in terms of legal moves, and few for the opponent player.

1. **Manhattan Distance:** This function is computed for a specific player by measuring the sum of the difference between the player position and the legal moves for that player. The Manhattan Distance heuristic is admissible (optimistic) as it considers each tile independently while the tiles interfere with each other. This function is mapped to **AB_Custom**.
2. **Weighted Difference:** This function is computed by assigned weights to each player, the first player and the opponent player by assigning a weight value of 0.5 to the first player and a weight value of 2 for the opponent player. This function is an amendment to the "Improved" evaluation function discussed in lecture that outputs a score equal to the difference in the number of moves available to the two players. This function is mapped to **AB_Custom_2**.
3. **Mobility:** It attempts to capture the relative difference between the number of possible moves for the first player and the opponent player, with the intent of restricting the opponent's mobility and increasing one's own mobility. This function is mapped to **AB_Custom_3**.

Summary

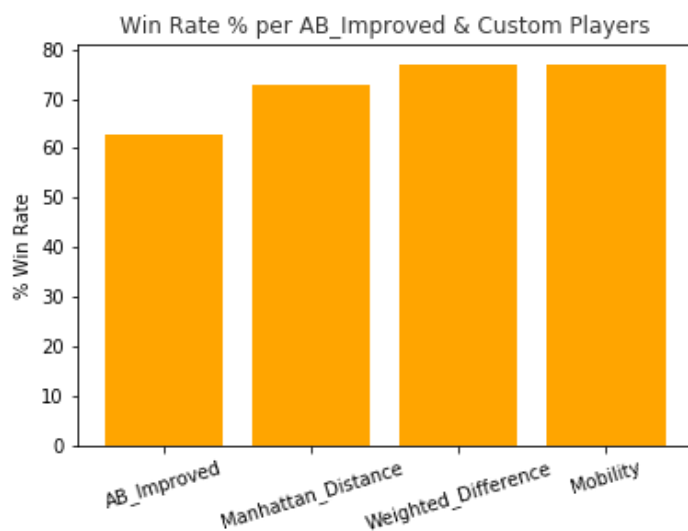
After several attempts of running the tournament, the results showed the following:

- The players that are played with heuristic functions **Manhattan Distance, Weighted Difference, or Mobility** scored better than the opponent players that are played with **Random, Minimax Open, Minimax Center, Minimax Improved**.
- A tie play is noticed when the players with heuristic functions **Manhattan Distance, Weighted Difference, or Mobility**, are played against the player with heuristic function **Alphabeta Pruning Open**.
- Each of the heuristic function **Manhattan Distance, Weighted Difference, or Mobility** provides better win rate percentage than the **Alphabeta Pruning Improved**.

***** Playing Matches *****									
Match #	Opponent	AB_Improved		AB_Custom		AB_Custom_2		AB_Custom_3	
		Won	Lost	Won	Lost	Won	Lost	Won	Lost
1	Random	9	1	10	0	10	0	10	0
2	MM_Open	7	3	8	2	8	2	8	2
3	MM_Center	7	3	9	1	9	1	10	0
4	MM_Improved	6	4	7	3	8	2	9	1
5	AB_Open	6	4	5	5	5	5	5	5
6	AB_Center	6	4	7	3	7	3	6	4
7	AB_Improved	3	7	5	5	7	3	6	4
Win Rate:		62.9%		72.9%		77.1%		77.1%	

Win Rate Players Comparison

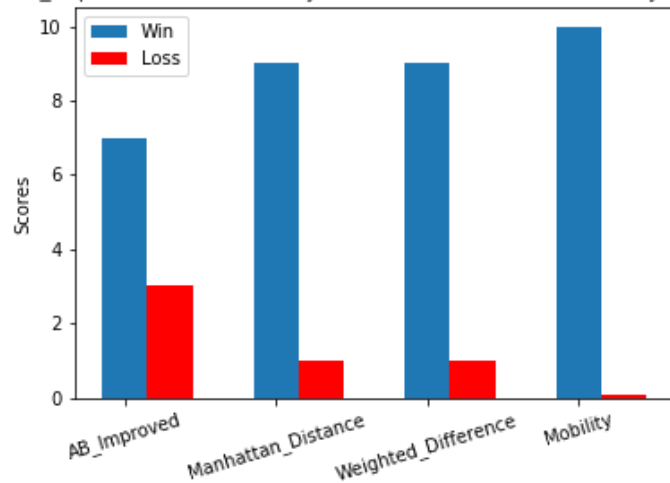
It shows win rate percentages for each player Alpha Beta Pruning Improved, Manhattan Distance, Weighted Difference, or Mobility



Players against Minimax Center Score Comparison

It shows the win scores of each of Alpha Beta Pruning Improved, Manhattan Distance, Weighted Difference, or Mobility versus the loss scores of Minimax Center

AB_Improved & Custom Players Win vs Minimax Center Player Loss



Recommendation

A single tournament has been running using the unit test to evaluate the performance of AB_Improved and AB_Custom Players against the AB_Improved under the following criteria:

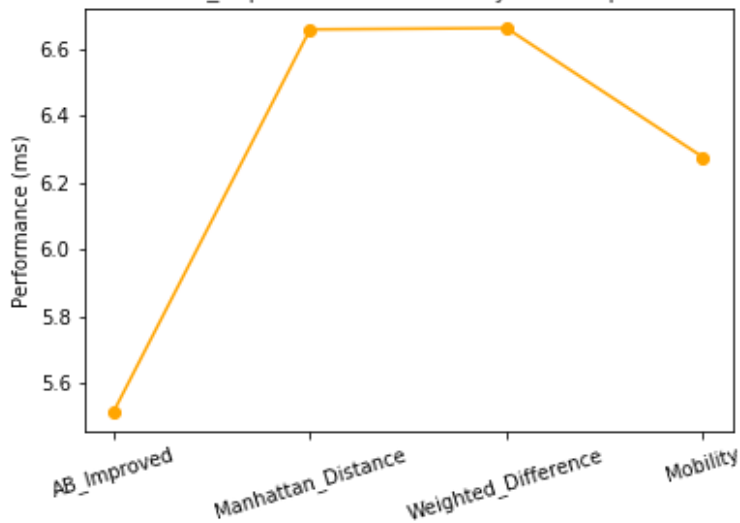
1. Search depth: The optional value is used. In this case, the search depth is three.
2. Score function: The score evaluation function changes according to the running case.
3. Timeout: The optional value is used. In this case, it is 10 milliseconds.
4. The game players were initialized with the same positions for studying the patterns of the play as shown in the diagram below:

	0	1	2	3	4	5	6
0	:	:	:	:	:	:	:
1	:	:	:	:	:	2	:
2	:	:	:	1	:	:	:
3	:	:	:	:	:	:	:
4	:	:	:	:	:	:	:
5	:	:	:	:	:	:	:
6	:	:	:	:	:	:	:

This performance has been selected because the evaluation is time consuming for the games played with Alphabeta Pruning. The performance results showed that there is a significant difference when any of the players played against the AB_Improved player. It also showed that the obtained performance is better when the players played with the same score evaluation function as in the case of AB_Improved.

Thus, I'd recommend the **mobility** as a score evaluation function as it performed better in terms of performance compared to the **Manhattan Distance**, and **Weighted Difference methods**.

Game Performance of AB_Improved & Custom Players vs Alphabeta Improved Player



In addition, when running the tournament several times, the mobility usually provides **better win rates** results than the rest of the methods as shown in the below diagrams.

***** Playing Matches *****									
Match #	Opponent	AB_Improved		AB_Custom		AB_Custom_2		AB_Custom_3	
		Won	Lost	Won	Lost	Won	Lost	Won	Lost
1	Random	9	1	10	0	10	0	10	0
2	MM_Open	7	3	8	2	8	2	8	2
3	MM_Center	7	3	9	1	9	1	10	0
4	MM_Improved	6	4	7	3	8	2	9	1
5	AB_Open	6	4	5	5	5	5	5	5
6	AB_Center	6	4	7	3	7	3	6	4
7	AB_Improved	3	7	5	5	7	3	6	4
Win Rate:		62.9%		72.9%		77.1%		77.1%	

***** Playing Matches *****									
Match #	Opponent	AB_Improved		AB_Custom		AB_Custom_2		AB_Custom_3	
		Won	Lost	Won	Lost	Won	Lost	Won	Lost
1	Random	10	0	10	0	10	0	10	0
2	MM_Open	8	2	9	1	7	3	6	4
3	MM_Center	9	1	8	2	10	0	9	1
4	MM_Improved	8	2	7	3	5	5	9	1
5	AB_Open	5	5	4	6	7	3	5	5
6	AB_Center	4	6	6	4	5	5	5	5
7	AB_Improved	4	6	5	5	5	5	7	3
Win Rate:		68.6%		70.0%		70.0%		72.9%	

When studying the patterns of the first and second players on the board with using the four methods, it was noticed that the game usually ends on the same half of the board for the **AB_Pruning, Manhattan Distance, and Weighted Difference** as shown in the diagrams for (a), (b), and (c) respectively while on contrary, the game usually ends on different halves of the board in case of **Mobility** as shown in the diagram for (d) below that allows more moves for the

first player against the opponent player which conforms to the definition of the mobility that is stated above.

a) AB_Pruning Game Board:

	0	1	2	3	4	5	6
0	-	2	-	-	-	-	-
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	1	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-

b) Manhattan Distance versus AB_Pruning Game Board:

	0	1	2	3	4	5	6
0	1	-	-	-	4	-	-
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	2	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-

c) Weighted Difference versus AB_Pruning Game Board:

	0	1	2	3	4	5	6
0	-	-	-	-	1	-	-
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	2
6	-	-	-	-	-	-	-

d) Mobility versus AB_Pruning Game Board:

	0	1	2	3	4	5	6
0	-	-	-	-	4	-	-
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	1	-	-	-	-	2	-
6	-	-	-	-	-	-	-

References

1. <https://heuristicswiki.wikispaces.com/Manhattan+Distance>
2. <https://kartikkukreja.wordpress.com/2013/03/30/heuristic-function-for-reversiiothello/>