Heuristic Analysis

The goal of this project is to develop an adversarial search agent playing the game of "Isolation". This game is a deterministic in which 2 players alternate turns moving a single piece from one cell to another on a board. Whenever either player occupies a cell, that cell becomes blocked for the rest of the game. The first player that has no legal moves left loses.

This project uses a version of "Isolation" where each agent is restricted to L-shaped movements on a square grid, 7X7. Movements are blocked at the edges of the board. Also, the player can jump over blocked or occupied spaces similar to a knight in a chess game. Moreover, both agents have a fixed time limit for each turn to search for the best move and respond. If the time limit expires during the player's turn, the player forfeits the match and the opponent wins.

Heuristic 1 - Minimizing player 2's moves

The first heuristic is used to minimized the opponent's moves. It can be expressed as follow:

$$move_{player_1} = len(get\_legal\_move(player_1)$$

$$move_{player_2} = len(get\_legal\_move(player_2)$$

$$move_{player_1} - a\ x\ move_{player_2} \quad \text{, where } a \text{ is } \in \mathbb{R}$$

Heuristic 2 - Close to center

The player closer to the center has more available legal moves than the player closer to the edges. It can be expressed as follow:

$$player_{1_{distance_{row}}} = abs[center - player_{1_{position[0]}}]$$

$$player_{1_{distance_{col}}} = abs[center - player_{1_{position[1]}}]$$

$$player_{2_{distance_{row}}} = abs[center - player_{2_{position[0]}}]$$

$$player_{2_{distance_{col}}} = abs[center - player_{2_{position[1]}}]$$

$$a\ x\ move_{player_1} - \ move_{player_2} + (player_{1_{distance_{row}}} + \ player_{1_{distance_{col}}}) - (player_{2_{distance_{row}}} + \ player_{2_{distance_{col}}})$$

Heuristic 3 -Maximinzing player 1's moves

The third heuristic is used to maximize player 1 moves. It can be expressed as follow:

$$move_{player_1} = len(get\_legal\_move(player_1)$$

$$move_{player_2} = len(get\_legal\_move(player_2)$$

$$a\ x\ move_{player_1} - \ move_{player_2} \quad \text{, where } a \text{ is } \in \mathbb{R}$$

The tournament script is used to evaluate the effectiveness of three custom heuristics functions. These functions are compared against the Improved heuristic while being executed by an agent using alpha-beta search and iterative deepening search algorithm called AB_Improved.

The opponent uses three agents are used to evaluated different heuristics. The first one is called Random Agent. This agent does not implement any heuristic function. The second on is called MiniMax agent (MM). This agent implements the fixed-depth minimax search algorithm. The last one is called Alpha-Beta Agent (AB). This agent implements the fixed-depth Alpha-Beta pruning search algorithm. Then, MM and AB agents are evaluated with three different heuristics: open move heuristic, center move heuristic and improved heuristic. The open move heuristic outputs a score equal to the number of available moves for the player. The center move heuristic outputs a score equal to the square of the distance from the center of the board to the position of the player. The improved heuristic outputs a score equal to the difference in the number of moves available to the two players.

The performance of the agents is present in the table below:

Table 1: Performance of Agents

Agent	Performance
AB_Improved	58.57%
AB_Custom (a = 1.5)	52.86%
AB_Custom2 (a = 3)	**68.57%**
AB_Custom3 (a= 2.5)	60.00%

The coefficient *a* was chosen randomly and the results are in Annex A.

My recommendation is to use AB_Custom2 with the coefficient a = 3 which is the heuristic that evaluates the position of the player in function to the center of the board.

- AB_custom2 outperforms the AB_Improved by 10%
- Easy to implement since it is a linear equation
- Time of calculation is small since it is a linear equation
- It confirms the he intuition behind the heuristic which is the player closer to the center has more available legal moves than the player closer to the edges

The is no doubt that the heuristics can be improved by increasing the number of tests on coefficient a.

Annex A

Match	Opponent	AB_Improved		AB_Custom (a = 0)		AB_Custom_2=0		AB_Custom_3 (a = 0)	
		W	L	W	L	W	L	W	L
1	Random	7	3	8	2	9	1	10	0
2	MM_Open	4	6	4	6	3	7	4	6
3	MM_Center	6	4	4	6	4	6	10	0
4	MM_Improved	8	2	4	6	3	7	5	5
5	AB_Open	3	7	4	6	3	7	6	4
6	AB_Center	6	4	4	6	5	5	6	4
7	AB_Improved	4	6	5	5	3	7	4	6
Win Rate		54.29%		47.14%		42.86%		**64.29%**	

Match	Opponent	AB_Improved		AB_Custom (a = 0.5)		AB_Custom_2 (a= 0.5)		AB_Custom_3 (a =1)	
		W	L	W	L	W	L	W	L
1	Random	9	1	6	4	7	3	9	1
2	MM_Open	5	5	6	4	5	5	7	3
3	MM_Center	9	1	8	2	8	2	6	4
4	MM_Improved	3	7	2	8	2	8	5	5
5	AB_Open	5	5	3	7	3	7	3	7
6	AB_Center	5	5	2	8	2	8	4	6
7	AB_Improved	3	7	4	6	4	6	5	5
Win Rate		**55.71%**		44.29%		44.29%		**55.71%**	

Match	Opponent	AB_Improved		AB_Custom (a = 1)		AB_Custom_2 (a= 1)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	9	1	9	1	8	2	8	2
2	MM_Open	6	4	8	2	6	4	5	5
3	MM_Center	6	4	7	3	7	3	5	5
4	MM_Improved	4	6	6	4	4	6	8	2
5	AB_Open	7	3	4	6	4	6	4	6
6	AB_Center	6	4	3	7	5	5	6	4
7	AB_Improved	5	5	5	5	6	4	3	7
Win Rate		**61.43%**		60.00%		57.14%		55.71%	

Match	Opponent	AB_Improved		AB_Custom (a = 1.5)		AB_Custom_2 (a= 1.5)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	7	3	5	5	7	3	6	4
2	MM_Open	6	4	4	6	7	3	6	4
3	MM_Center	6	4	8	2	9	1	9	1
4	MM_Improved	6	4	6	4	7	3	7	3
5	AB_Open	5	5	2	8	6	4	4	6
6	AB_Center	6	4	7	3	6	4	5	5
7	AB_Improved	6	4	6	4	4	6	6	4
Win Rate		60.00%		54.29%		**65.71%**		**61.43%**	

Match	Opponent	AB_Improved		AB_Custom (a = 1.5)		AB_Custom_2 (a=2)		AB_Custom_3 (a =2)	
		W	L	W	L	W	L	W	L
1	Random	7	3	8	2	10	0	9	1
2	MM_Open	8	2	7	3	3	7	5	5
3	MM_Center	5	5	6	4	6	4	4	6
4	MM_Improved	4	6	6	4	5	5	6	4
5	AB_Open	4	6	5	5	5	5	4	6
6	AB_Center	5	5	4	6	3	7	7	3
7	AB_Improved	6	4	2	8	4	6	3	7
Win Rate		55.71%		54.29%		51.43%		54.29%	

Match	Opponent	AB_Improved		AB_Custom (a = 1.5)		AB_Custom_2 (a=3)		AB_Custom_3 (a =2.5)	
		W	L	W	L	W	L	W	L
1	Random	8	2	7	3	9	1	8	2
2	MM_Open	6	4	7	3	7	3	5	5
3	MM_Center	5	5	7	3	8	2	6	4
4	MM_Improved	4	6	4	6	7	3	7	3
5	AB_Open	7	3	5	5	6	4	5	5
6	AB_Center	5	5	4	6	6	4	5	5
7	AB_Improved	6	4	3	7	5	5	6	4
Win Rate		58.57%		52.86%		**68.57%**		**60.00%**	

Match	Opponent	AB_Improved		AB_Custom (a = 2)		AB_Custom_2 (a=3)		AB_Custom_3 (a =2.5)	
		W	L	W	L	W	L	W	L
1	Random	8	2	8	2	7	3	7	3
2	MM_Open	4	6	6	4	8	2	7	3
3	MM_Center	8	2	8	2	8	2	7	3
4	MM_Improved	3	7	6	4	2	8	3	7
5	AB_Open	4	6	6	4	5	5	3	7
6	AB_Center	7	3	5	5	6	4	5	5
7	AB_Improved	5	5	4	6	7	3	7	3
Win Rate		55.71%		**61.43%**		**61.43%**		55.71%	

Match	Opponent	AB_Improved		AB_Custom (a = 2)		AB_Custom_2 (a=3)		AB_Custom_3 (a =3)	
		W	L	W	L	W	L	W	L
1	Random	5	5	4	6	4	6	5	5
2	MM_Open	5	5	5	5	5	5	7	3
3	MM_Center	7	3	5	5	6	4	7	3
4	MM_Improved	6	4	3	7	5	5	5	5
5	AB_Open	5	5	4	6	6	4	5	5
6	AB_Center	5	5	5	5	8	2	4	6
7	AB_Improved	4	6	6	4	4	6	3	7
Win Rate		52.86%		45.71%		**54.29%**		51.43%	

Match	Opponent	AB_Improved		AB_Custom (a = 2)		AB_Custom_2 (a=3)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	7	3	6	4	8	2	9	1
2	MM_Open	6	4	8	2	4	6	5	5
3	MM_Center	7	3	4	6	7	3	5	5
4	MM_Improved	7	3	5	5	6	4	6	4
5	AB_Open	6	4	5	5	7	3	3	7
6	AB_Center	4	6	9	1	4	6	4	6
7	AB_Improved	3	7	6	4	4	6	4	6
Win Rate		57.14%		**61.43%**		57.14%		51.43%	

Match	Opponent	AB_Improved		AB_Custom (a = 2)		AB_Custom_2 (a=4)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	8	2	8	2	7	3	6	4
2	MM_Open	5	5	6	4	4	6	4	6
3	MM_Center	7	3	6	4	6	4	6	4
4	MM_Improved	6	4	5	5	8	2	4	6
5	AB_Open	6	4	5	5	6	4	6	4
6	AB_Center	6	4	4	6	7	3	5	5
7	AB_Improved	6	4	5	5	6	4	4	6
Win Rate		**62.86%**		55.71%		**62.86%**		50.00%	

Match	Opponent	AB_Improved		AB_Custom (a = 2)		AB_Custom_2 (a=20)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	10	0	8	2	9	1	7	3
2	MM_Open	5	5	7	3	8	2	7	3
3	MM_Center	9	1	7	3	9	1	7	3
4	MM_Improved	4	6	7	3	4	6	6	4
5	AB_Open	5	5	4	6	5	5	3	7
6	AB_Center	6	4	5	5	7	3	5	5
7	AB_Improved	6	4	6	4	5	5	5	5
Win Rate		**64.29%**		62.86%		**67.14%**		57.14%	

Match	Opponent	AB_Improved		AB_Custom (a = 2)		AB_Custom_2 (a=10)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	7	3	5	5	7	3	9	1
2	MM_Open	7	3	6	4	7	3	5	5
3	MM_Center	6	4	6	4	7	3	9	1
4	MM_Improved	7	3	5	5	8	2	4	6
5	AB_Open	6	4	3	7	8	2	2	8
6	AB_Center	7	3	5	5	8	2	4	6
7	AB_Improved		10		10		10		10
Win Rate		57.14%		42.86%		64.29%		47.14%	

Match	Opponent	AB_Improved		AB_Custom (a = 2)		AB_Custom_2 (a=10)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	7	3	5	5	7	3	9	1
2	MM_Open	7	3	6	4	7	3	5	5
3	MM_Center	6	4	6	4	7	3	9	1
4	MM_Improved	7	3	5	5	8	2	4	6
5	AB_Open	6	4	3	7	8	2	2	8
6	AB_Center	7	3	5	5	8	2	4	6
7	AB_Improved	4	6	3	7	6	4	4	6
Win Rate		62.86%		47.14%		**72.86%**		52.86%	

Match	Opponent	AB_Improved		AB_Custom (a = 1.5)		AB_Custom_2 (a=10)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	8	2	7	3	8	2	8	2
2	MM_Open	7	3	6	4	6	4	7	3
3	MM_Center	9	1	8	2	8	2	8	2
4	MM_Improved	8	2	8	2	6	4	6	4
5	AB_Open	4	6	5	5	5	5	4	6
6	AB_Center	5	5	4	6	6	4	6	4
7	AB_Improved	5	5	5	5	4	6	6	4
Win Rate		**65.71%**		61.43%		61.43%		64.29%	

Match	Opponent	AB_Improved		AB_Custom (a = 2)		AB_Custom_2 (a= 1.5)		AB_Custom_3 (a =1.5)	
		W	L	W	L	W	L	W	L
1	Random	5	5	7	3	10	0	6	4
2	MM_Open	6	4	5	5	8	2	4	6
3	MM_Center	6	4	8	2	7	3	7	3
4	MM_Improved	7	3	5	5	5	5	3	7
5	AB_Open	5	5	5	5	4	6	5	5
6	AB_Center	4	6	7	3	6	4	4	6
7	AB_Improved	6	4	4	6	5	5	5	5
Win Rate		55.71%		58.57%		64.29%		48.57%	