Heuristic Analysis

The agent "ID_Improved" uses Iterative Deepening with Alpha-Beta pruning and the `improved_score` scoring function which tries to maximize the difference between the player moves and opponent moves (`own_moves - opp_moves`)

To develop a heuristic that outperforms "ID_Improved" the following strategies where implemented and evaluated:

1) Aggressively maximize the difference based on a weight value assigned to opposition moves
2) Maximize (for self) or Minimize (for the opponent) the board utilization ratio
3) Maximize the difference by taking into account the different location of the possible moves for self and the opponent

ID_Improved performance

The table below summarizes the performance of the basic "`improved_score`" heuristic implemented by the "ID_Improved" playing agent. As observed the performance of this heuristic varies between 60% - 75% success, with the average winning rate around 68%-70%.

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Match 1: ID_Improved vs Random	14 to 6	15 to 5	16 to 4	19 to 1	17 to 3	18 to 2	18 to 2	18 to 2	18 to 2
Match 2: ID_Improved vs MM_Null	13 to 7	16 to 4	13 to 7	14 to 6	18 to 2	16 to 4	15 to 5	15 to 5	18 to 2
Match 3: ID_Improved vs MM_Open	11 to 9	13 to 7	12 to 8	9 to 11	14 to 6	13 to 7	12 to 8	12 to 8	14 to 6
Match 4: ID_Improved vs MM_Improved	12 to 8	12 to 8	15 to 5	12 to 8	10 to 10	12 to 8	11 to 9	15 to 5	12 to 8
Match 5: ID_Improved vs AB_Null	14 to 6	14 to 6	11 to 9	17 to 3	14 to 6	13 to 7	18 to 2	16 to 4	16 to 4
Match 6: ID_Improved vs AB_Open	9 to 11	13 to 7	16 to 4	14 to 6	13 to 7	13 to 7	14 to 6	15 to 5	14 to 6
Match 7: ID_Improved vs AB_Improved	10 to 10	9 to 11	11 to 9	11 to 9	10 to 10	14 to 6	12 to 8	11 to 9	13 to 7
%	59.29	65.71	67.14	68.57	68.57	70.71	71.43	72.86	75

Heuristic 1 performance

The table below summarizes the performance of the first strategy that is described in the lesson, and builds on top of the "`improved_score`" heuristic by aggressively maximizing the difference based on a weight assigned to opponent moves. The basic idea is to deny opponent potential moves rather than optimizing own potential moves. The heuristic was tested with 4 different weight (W = 1.5, 2.0, 3.0, 4.) assigned to the potential opponent moves. As observed the performance of this heuristic varies between 65% - 73%. The weight of W = 1.5 performs similar to the "`improved_score`" heuristic, the W = 2.0 slightly outperforms the "`improved_score`" heuristic, however W = 3.0 and W = 4.0 perform similar to "`improved_score`" heuristic.

	W = 1.5	W 2.0	W = 3.0	W = 4.0
Match 1: Student vs Random	16 to 4	19 to 1	16 to 4	18 to 2
Match 2: Student vs MM_Null	16 to 4	18 to 2	16 to 4	13 to 7
Match 3: Student vs MM_Open	14 to 6	14 to 6	12 to 8	13 to 7
Match 4: Student vs MM_Improved	10 to 10	11 to 9	13 to 7	14 to 6
Match 5: Student vs AB_Null	15 to 5	15 to 5	14 to 6	14 to 6
Match 6: Student vs AB_Open	15 to 5	14 to 6	9 to 11	11 to 9
Match 7: Student vs AB_Improved	9 to 11	11 to 9	12 to 8	16 to 4
%	67.86	72.86	65.71	70.71

Heuristic 2 performance

The table below summarizes the performance of the second strategy that tries to maximize the board utilization. In this strategy, we compare 3 board utilization ratios:

- Own_Moves/Free_spaces – here we select moves in which the agent can reach more board spaces in the next move
- Free_Spaces/Opp_Moves – here we select move in which the opponent can reach less board spaces in the next move
- Own_Moves/Opp_Moves – here we select agent can reach more board spaces opposed to the opponent.

As observed the performance of this heuristic varies between 59% - 67%. The ratios Own_Moves/Free_spaces and Free_Spaces/Opp_Moves that only attempt to maximize (for the agent without taking the opponent moves into account) or minimize (for the opponent without taking own moves into account) the number of reachable positions perform less optimally as opposed to the ratio Own_Moves/Opp_Moves that takes into account both own_moves and opponent_moves

	NUM_OWN_MOVES/ NUM_FREE_SPACES	NUM_FREE_SPACES/ NUM_OPPONENT_MOVES	NUM_OWN_MOVES/ NUM_OPPONENT_MOVES
Match 1: Student vs Random	16 to 4	14 to 6	17 to 3
Match 2: Student vs MM_Null	12 to 8	15 to 5	17 to 3
Match 3: Student vs MM_Open	12 to 8	10 to 10	12 to 8
Match 4: Student vs MM_Improved	10 to 10	11 to 9	10 to 10
Match 5: Student vs AB_Null	11 to 9	16 to 4	14 to 6
Match 6: Student vs AB_Open	12 to 8	13 to 7	12 to 8
Match 7: Student vs AB_Improved	10 to 10	8 to 12	12 to 8
%	59.29	62.14	67.14

Heuristic 3 performance

The analysis of Heuristic 1 and 2 indicates the following:

- Both own_moves and opponent_moves need to be taken into account
- Aggressively trying to deny moves to opponent (by assigning a higher weight to opponent_moves) performs similar to the agent "ID_improved"
- Maximizing own reachable position or minimizing opponent reachable position do not provide any significant benefits

With these learnings, for this heuristic we maximize the difference between the of player moves and opponent moves by taking into account the different location of the possible moves for self and the opponent.

The basic idea to divide the Isolation board into 3 zone: center zone, middle zone and the edge zone. The center zone consists of tiles in the center 5x5 region in the middle of the board, the edge zone consists of tiles in the first and last rows/columns of the board and the middle zone consists of all the remaining tiles. A higher weight (3.0) is given to move positions in the center (as it offer more mobility) and a lower weight (1.0) is given to the move position in the edge (as it offer less mobility). The move position in the middle zone are given a weight that is the average of center and edge positions.

As observed the performance of this heuristic varies between 72% - 76% and outperforms "ID_improved" agent by 4%-7%. This can be attributed to selecting a move that maximizes the difference between player and opponent taking into account the mobility provided by each open move (for both the agent and opponent).

	Run 1	Run 2	Run 3	Run 4	Run 5
Match 1: Student vs Random	17 to 3	19 to 1	18 to 2	17 to 3	18 to 2
Match 2: Student vs MM_Null	18 to 2	14 to 6	20 to 0	18 to 2	17 to 3
Match 3: Student vs MM_Open	12 to 8	12 to 8	14 to 6	18 to 2	12 to 8
Match 4: Student vs MM_Improved	13 to 7	14 to 6	11 to 9	19 to 1	13 to 7
Match 5: Student vs AB_Null	16 to 4	14 to 6	15 to 5	15 to 5	16 to 4
Match 6: Student vs AB_Open	13 to 7	17 to 3	14 to 6	10 to 10	15 to 5
Match 7: Student vs AB_Improved	11 to 9	12 to 8	12 to 8	9 to 11	15 to 5
%	71.43	72.86	74.29	75.71	75.71

Heuristic 3 consistently outperforms the agent "ID_Improved" and thus is the selected/recommended approach. The reason this outperforms is from the fact that similar to "ID_Improved" it tries to maximize the difference between the moves of two players, however in addition since it also takes into account the board positions for each player moves and weighs them accordingly, the selected move is often that offer better mobility in subsequent moves.