**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.