# Isolation Heuristic Analysis

## Heuristic #1: Aggressive Improved Score

An adaptation of the original improved score heuristic which takes the difference between number of own moves and opponent moves, the aggressive improved score heuristic takes the difference between number of own moves and two times the number of opponent moves.

**Python Implementation in custom_score:**

```
#Heuristic 1: Aggressive Improved Score
own_moves = len(game.get_legal_moves(player))
opp_moves = len(game.get_legal_moves(game.get_opponent(player)))

return float(own_moves - 2*opp_moves)
```

**Performance:**

```
************************
 Evaluating: ID_Improved
************************

Playing Matches:
----------
  Match 1: ID_Improved vs   Random      Result: 16 to 4
  Match 2: ID_Improved vs   MM_Null     Result: 14 to 6
  Match 3: ID_Improved vs   MM_Open     Result: 14 to 6
  Match 4: ID_Improved vs MM_Improved   Result: 14 to 6
  Match 5: ID_Improved vs   AB_Null     Result: 16 to 4
  Match 6: ID_Improved vs   AB_Open     Result: 15 to 5
  Match 7: ID_Improved vs AB_Improved   Result: 11 to 9


Results:
----------
ID_Improved         71.43%

************************
   Evaluating: Student
************************

Playing Matches:
----------
  Match 1:   Student   vs   Random      Result: 16 to 4
  Match 2:   Student   vs   MM_Null     Result: 15 to 5
  Match 3:   Student   vs   MM_Open     Result: 17 to 3
  Match 4:   Student   vs MM_Improved   Result: 15 to 5
  Match 5:   Student   vs   AB_Null     Result: 16 to 4
  Match 6:   Student   vs   AB_Open     Result: 13 to 7
  Match 7:   Student   vs AB_Improved   Result: 13 to 7


Results:
----------
Student             75.00%
```

```
************************
 Evaluating: ID_Improved
************************

Playing Matches:
----------
  Match 1: ID_Improved vs   Random      Result: 14 to 6
  Match 2: ID_Improved vs   MM_Null     Result: 18 to 2
  Match 3: ID_Improved vs   MM_Open     Result: 13 to 7
  Match 4: ID_Improved vs MM_Improved   Result: 9 to 11
  Match 5: ID_Improved vs   AB_Null     Result: 11 to 9
  Match 6: ID_Improved vs   AB_Open     Result: 12 to 8
  Match 7: ID_Improved vs AB_Improved   Result: 12 to 8


Results:
----------
ID_Improved         63.57%

************************
   Evaluating: Student
************************

Playing Matches:
----------
  Match 1:   Student   vs   Random      Result: 18 to 2
  Match 2:   Student   vs   MM_Null     Result: 17 to 3
  Match 3:   Student   vs   MM_Open     Result: 15 to 5
  Match 4:   Student   vs MM_Improved   Result: 16 to 4
  Match 5:   Student   vs   AB_Null     Result: 16 to 4
  Match 6:   Student   vs   AB_Open     Result: 11 to 9
  Match 7:   Student   vs AB_Improved   Result: 7 to 13


Results:
----------
Student             71.43%
```

| Attempt | Matches | ID_Improved Performance | Heuristic 1 Performance | % Improvement |
|---|---|---|---|---|
| 1 | 5 | 71.43% | 75% | 3.57% |
| 2 | 5 | 63.57% | 71.43% | 7.86% |
| 3 | 5 | 63.57% | 68.57% | 5% |

**Analysis:**
The aggressive improved score heuristic outperforms the standard improved score heuristic by an average of 5.47%. One reason that explains the better performance is that in the L-Shape Isolation game, a more aggressive strategy to deny your opponent potential moves is more rewarding than optimizing for your own potential moves.

An example would be in the situation where after making a move, the player has 7 possible moves and opponent has 5 moves, hence improved score heuristic would return a value of 7-5 = 2. For another move, the player has 6 moves and opponent has 4 moves, the score would be 6-4 = 2. Due to alpha-beta pruning, move 1 would be chosen over move 2.

However, under the aggressive improved score heuristic, move 1 would return a score of 7 – 2*5 = -3, whereas move 2 would return a score of 6 – 2*4 = -2. Hence move 2 would be chosen over move 1.

In other words, the heuristic prefers a more aggressive gameplay of choosing a move that denies the opponent a greater number of moves, even if it means lowering the number of potential moves for the player.

This kind of gameplay is evident if you think about the player going after the opponent rather than moving to a position away from the opponent (where the number of possible moves for oneself is greater).

## Heuristic #2: Border/Non-Border Differentiated Move Scoring

While the improved score heuristic score each legal move exactly the same (one point), it is difficult to conceive that all legal moves are equal. This heuristic differentiates all moves between those that are at the edge of the board (border) and moves that are not at the edge. Legal moves at the edge are worth one point while those away are worth two points. The hypothesis for this heuristic is that moves away from the edge of the board will allow greater mobility and hence are more valuable.

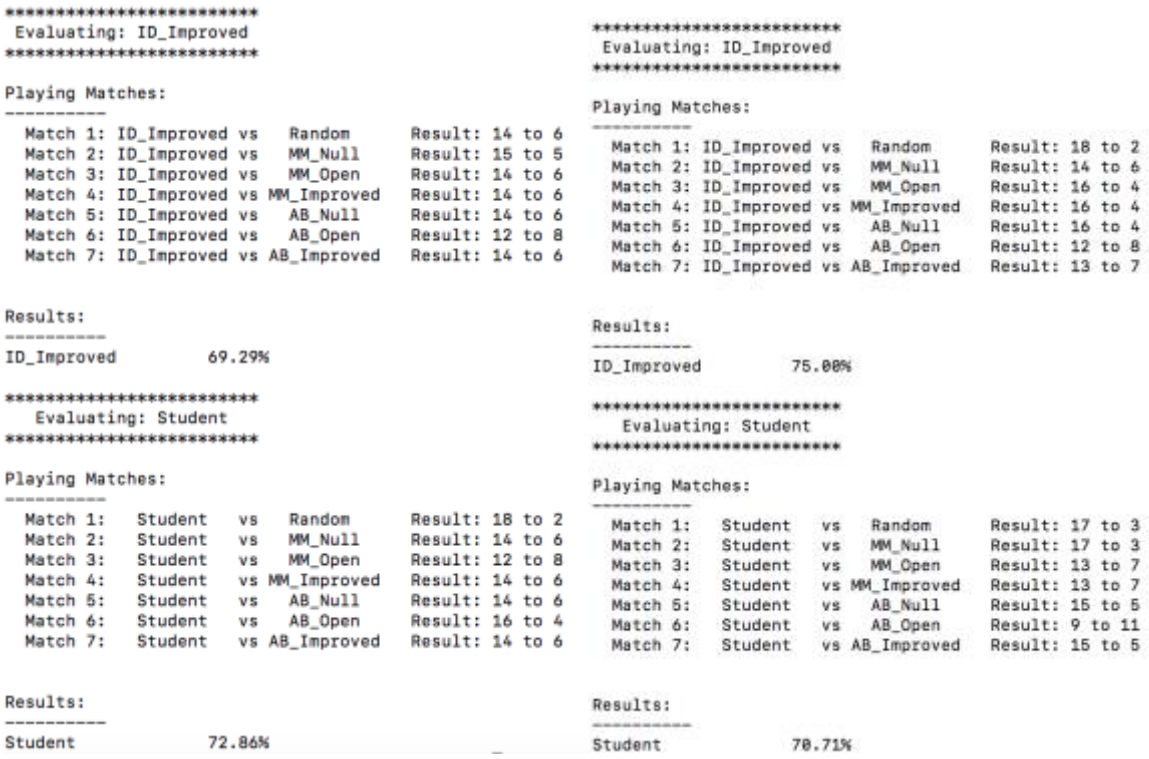
**Python Implementation in custom_score:**

```
#Heuristic 2: Border/Non-Border Differentiated Move Scoring
border_moves = [(0,0), (0,1), (0,2), (0,3), (0,4), (0,5), (0,6),
                (1,0), (1,6), (2,0), (2,6), (3,0), (3,6), (4,0),
                (4,6), (5,0), (5,6), (6,0), (6,1), (6,2), (6,3),
                (6,4), (6,5), (6,6)]
own_score = 0
opp_score = 0
for each_move in game.get_legal_moves(player):
    if each_move in border_moves:
        own_score = own_score + 1
    else:
        own_score = own_score + 2

for each_move in game.get_legal_moves(game.get_opponent(player)):
    if each_move in border_moves:
        opp_score = opp_score + 1
    else:
        opp_score = opp_score + 2

return float(own_score - opp_score)
```

**Performance:**



```
************************
 Evaluating: ID_Improved
************************

Playing Matches:
----------
  Match 1: ID_Improved vs   Random      Result: 14 to 6
  Match 2: ID_Improved vs   MM_Null     Result: 15 to 5
  Match 3: ID_Improved vs   MM_Open     Result: 14 to 6
  Match 4: ID_Improved vs MM_Improved   Result: 14 to 6
  Match 5: ID_Improved vs   AB_Null     Result: 14 to 6
  Match 6: ID_Improved vs   AB_Open     Result: 12 to 8
  Match 7: ID_Improved vs AB_Improved   Result: 14 to 6


Results:
----------
ID_Improved         69.29%

************************
   Evaluating: Student
************************

Playing Matches:
----------
  Match 1:   Student   vs   Random      Result: 18 to 2
  Match 2:   Student   vs   MM_Null     Result: 14 to 6
  Match 3:   Student   vs   MM_Open     Result: 12 to 8
  Match 4:   Student   vs MM_Improved   Result: 14 to 6
  Match 5:   Student   vs   AB_Null     Result: 14 to 6
  Match 6:   Student   vs   AB_Open     Result: 16 to 4
  Match 7:   Student   vs AB_Improved   Result: 14 to 6


Results:
----------
Student             72.86%
```

```
************************
 Evaluating: ID_Improved
************************

Playing Matches:
----------
  Match 1: ID_Improved vs   Random      Result: 18 to 2
  Match 2: ID_Improved vs   MM_Null     Result: 14 to 6
  Match 3: ID_Improved vs   MM_Open     Result: 16 to 4
  Match 4: ID_Improved vs MM_Improved   Result: 16 to 4
  Match 5: ID_Improved vs   AB_Null     Result: 16 to 4
  Match 6: ID_Improved vs   AB_Open     Result: 12 to 8
  Match 7: ID_Improved vs AB_Improved   Result: 13 to 7


Results:
----------
ID_Improved         75.00%

************************
   Evaluating: Student
************************

Playing Matches:
----------
  Match 1:   Student   vs   Random      Result: 17 to 3
  Match 2:   Student   vs   MM_Null     Result: 17 to 3
  Match 3:   Student   vs   MM_Open     Result: 13 to 7
  Match 4:   Student   vs MM_Improved   Result: 13 to 7
  Match 5:   Student   vs   AB_Null     Result: 15 to 5
  Match 6:   Student   vs   AB_Open     Result: 9 to 11
  Match 7:   Student   vs AB_Improved   Result: 15 to 5


Results:
----------
Student             70.71%
```

| Attempt | Matches | ID_Improved Performance | Heuristic 2 Performance | % Improvement |
|---|---|---|---|---|
| 1 | 5 | 69.29% | 72.86% | 3.57% |
| 2 | 5 | 75% | 70.71% | -4.29% |
| 3 | 5 | 71.43% | 67.14% | -4.29% |
| 4 | 5 | 68.57 | 67.89 | -0.68% |

**Analysis:**

From the testing results, heuristic 2 underperformed ID Improved heuristic by an average of -1.4%. One reason that explains the poorer performance could be that towards the end game, where there are lesser number of legal moves per player, the absolute number of moves outweigh the benefits of legal moves away from the edge. Hence, by optimizing for non-edge moves, the player might end up choosing moves that reduces the maneuverability.

Ways to improve the performance of this heuristic include testing various scoring choices for the edge/non-edge moves, for example 1:1.5 points, or to switch back to the original ID improved heuristic once the number of empty positions on the board is below a certain amount.

**Post-Analysis:**

To find out if performance can be further improved with this heuristic, I reran the same heuristic, changing the ratio of points from 1:2 to 1:1.5.

The performance is listed below:

| Attempt | Matches | ID_Improved Performance | Heuristic 2 Performance | % Improvement |
|---|---|---|---|---|
| 1 | 5 | 69.29% | 76.43% | 7.14% |
| 2 | 5 | 62.86% | 70.71% | 7.85% |
| 3 | 5 | 72.14% | 74.29% | 2.15% |
| 4 | 20 | 67.68% | 72.32% | 4.64% |

On average the amended heuristic 2 outperforms ID Improved by 5.1%. Through this experiment, the improvement in performance shows that the hypothesis of heuristic 2 is correct and the actual improvement can be optimized by testing the heuristic with different scoring implementations.

## Heuristic #3: Advanced Differentiated Board Scoring

This heuristic further differentiates the positions on the Isolation board into positions that are at the edge of the board and positions that are one next to the edge of the board. Positions at the edge are given one point for a legal move and positions one next to the edge are given 1.2 points. The rest of the positions, which are in the center of the board, are given 1.5 points. This differentiated board scoring rewards positions at the center, which inherently provides greater maneuverability and decrement benefits for positions away from the center, especially at the edge, where at least half of your 8 moves are invalid and out of the board.

**Python Implementation in custom_score:**

```
#Heuristic 3: Advanced Differentiated Board scoring
border_moves = [(0,0), (0,1), (0,2), (0,3), (0,4), (0,5), (0,6),
                (1,0), (1,6), (2,0), (2,6), (3,0), (3,6), (4,0),
                (4,6), (5,0), (5,6), (6,0), (6,1), (6,2), (6,3),
                (6,4), (6,5), (6,6)]

next_to_border_moves = [(1,1), (1,2), (1,3), (1,4), (1,5), (2,1),
                        (2,5), (3,1), (3,5), (4,1), (4,5),
                        (5,1), (5,2), (5,3), (5,4), (5,5)]

own_score = 0
opp_score = 0

for move in game.get_legal_moves(player):
    if move in border_moves:
        own_score += 1
    elif move in next_to_border_moves:
        own_score += 1.2
    else:
        own_score += 1.5

for move in game.get_legal_moves(game.get_opponent(player)):
    if move in border_moves:
        opp_score += 1
    elif move in next_to_border_moves:
        opp_score += 1.2
    else:
        opp_score += 1.5

return float(own_score - opp_score)
```

**Performance:**

```
************************
 Evaluating: ID_Improved
************************

Playing Matches:
----------
  Match 1: ID_Improved vs   Random      Result: 328 to 72
  Match 2: ID_Improved vs   MM_Null     Result: 294 to 106
tournament.py:101: UserWarning: One or more agents lost a matc
ction must return before time_left() reaches 0 ms. You will ne
n, and may need to increase this margin to avoid timeouts duri
  warnings.warn(TIMEOUT_WARNING)
  Match 3: ID_Improved vs   MM_Open     Result: 252 to 148
  Match 4: ID_Improved vs MM_Improved   Result: 226 to 174
  Match 5: ID_Improved vs   AB_Null     Result: 289 to 111
  Match 6: ID_Improved vs   AB_Open     Result: 247 to 153
  Match 7: ID_Improved vs AB_Improved   Result: 230 to 170


Results:
----------
ID_Improved         66.64%

************************
   Evaluating: Student
************************

Playing Matches:
----------
  Match 1:   Student   vs   Random      Result: 357 to 43
  Match 2:   Student   vs   MM_Null     Result: 330 to 70
  Match 3:   Student   vs   MM_Open     Result: 297 to 103
  Match 4:   Student   vs MM_Improved   Result: 276 to 124
  Match 5:   Student   vs   AB_Null     Result: 315 to 85
  Match 6:   Student   vs   AB_Open     Result: 276 to 124
  Match 7:   Student   vs AB_Improved   Result: 259 to 141


Results:
----------
Student             75.36%
```

| Attempt | Matches | ID_Improved Performance | Heuristic 2 Performance | % Improvement |
|---|---|---|---|---|
| 1 | 100 | 66.64% | 75.36% | 8.72% |

**Analysis:**

From the testing results, heuristic 3 outperformed ID Improved heuristic by an average of -8.72% over 100 matches. This performance is also better than heuristic 2. One reason that explains this is that edge-1 moves are not worth as much as a move in the center of the board. Hence the heuristic that captures this can perform even better.

Ways to improve the performance of this heuristic are similar to heuristic 2, including testing various scoring choices for the edge/edge-1/non-edge moves, or to switch back to the original ID improved heuristic once the number of empty positions on the board is below a certain amount.