Heuristic Analysis Report

Heuristic I – Open Area Heuristic

This heuristic considers the reachable area. It calculates the difference between the number of squares that can be reached by the player within finite moves and the number of squares that can be reached by the opponent.

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

Playing Matches:
----------
  Match 1: ID_Improved vs   Random      Result: 18 to 2
  Match 2: ID_Improved vs   MM_Null     Result: 19 to 1
  Match 3: ID_Improved vs   MM_Open     Result: 20 to 0
  Match 4: ID_Improved vs MM_Improved   Result: 20 to 0
  Match 5: ID_Improved vs   AB_Null     Result: 15 to 5
  Match 6: ID_Improved vs   AB_Open     Result: 10 to 10
  Match 7: ID_Improved vs AB_Improved   Result: 11 to 9


Results:
----------
ID_Improved         80.71%

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

Playing Matches:
----------
  Match 1:   Student   vs   Random      Result: 15 to 5
  Match 2:   Student   vs   MM_Null     Result: 15 to 5
  Match 3:   Student   vs   MM_Open     Result: 20 to 0
  Match 4:   Student   vs MM_Improved   Result: 19 to 1
  Match 5:   Student   vs   AB_Null     Result: 11 to 9
  Match 6:   Student   vs   AB_Open     Result: 12 to 8
  Match 7:   Student   vs AB_Improved   Result: 12 to 8


Results:
----------
Student             74.29%
```

Remarks: Looking at the results, the performance of open area heuristic is not as good as that of improved score.

Heuristic II – Longest path length heuristic

This heuristic focuses on the longest path the player can make. It calculates the difference between the length of the longest path the player can make and the length of the longest path the opponent can make. This heuristic is perfectly accurate if the players are completely separate in the sense that their legal moves don't overlap at all. This heurist is not used stand-alone since the computation is prohibitive in the beginning of the game.

Heuristic III – Open Area & Longest path length heuristic

This heuristic combines the use of open area and longest path length heuristic. The simple logic behind it is that the open area heuristic is used in the early phase of the game and is switched to longest path length heuristic when the games is approaching the end to boost accuracy.

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

Playing Matches:
----------
  Match 1: ID_Improved vs   Random      Result: 16 to 4
  Match 2: ID_Improved vs   MM_Null     Result: 17 to 3
  Match 3: ID_Improved vs   MM_Open     Result: 20 to 0
  Match 4: ID_Improved vs MM_Improved   Result: 20 to 0
  Match 5: ID_Improved vs   AB_Null     Result: 14 to 6
  Match 6: ID_Improved vs   AB_Open     Result: 13 to 7
  Match 7: ID_Improved vs AB_Improved   Result: 12 to 8


Results:
----------
ID_Improved         80.00%

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

Playing Matches:
----------
  Match 1:   Student   vs   Random      Result: 18 to 2
  Match 2:   Student   vs   MM_Null     Result: 18 to 2
  Match 3:   Student   vs   MM_Open     Result: 20 to 0
  Match 4:   Student   vs MM_Improved   Result: 20 to 0
  Match 5:   Student   vs   AB_Null     Result: 13 to 7
  Match 6:   Student   vs   AB_Open     Result: 11 to 9
  Match 7:   Student   vs AB_Improved   Result: 9 to 11


Results:
----------
Student             77.86%
```

Remarks: Combining open area heuristic and longest path length heuristic does boost the performance as hoped. Towards the end of a game, longest path length serves a more accurate estimate of the "goodness" of the board than open area. However, the combined heuristic is still not as good as improved score.

Heuristic III – Move quality score heuristic

This heuristic evaluates the quality of every legal move the player can make according to the relative position of the move in the board. The quality of the move is assessed based on the following three criteria

- Whether the move lies on the edges of the board
- Whether the move lies in the corners of the board
- Whether the move is blocked in certain directions, i.e. left, right, up and down.

It calculates the summation of the quality score of every possible legal move the player can make. The heuristic is based on the simple idea that the more directions the move can go in, the higher quality it has. Different weights are assigned to the above three criteria.

```
************************
 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: 20 to 0
  Match 4: ID_Improved vs MM_Improved   Result: 20 to 0
  Match 5: ID_Improved vs   AB_Null     Result: 10 to 10
  Match 6: ID_Improved vs   AB_Open     Result: 12 to 8
  Match 7: ID_Improved vs AB_Improved   Result: 10 to 10


Results:
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ID_Improved         72.14%

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

Playing Matches:
----------
  Match 1:   Student   vs   Random      Result: 16 to 4
  Match 2:   Student   vs   MM_Null     Result: 20 to 0
  Match 3:   Student   vs   MM_Open     Result: 20 to 0
  Match 4:   Student   vs MM_Improved   Result: 20 to 0
  Match 5:   Student   vs   AB_Null     Result: 14 to 6
  Match 6:   Student   vs   AB_Open     Result: 10 to 10
  Match 7:   Student   vs AB_Improved   Result: 14 to 6


Results:
----------
Student             81.43%
```

Remarks: Move quality score heuristic performs better than that the one used in “ID_Improved”. By evaluating the quality of each legal move, this heuristic is essentially a weighted summation of all the legal moves.

Conclusion

Based on the test results, move quality score heuristic is most recommended heuristic, which is supported by the following observations:

- The performance of move quality score heuristic significantly beats that of improved score
- By assigning different weights to each legal move, the heuristic is essentially a weighted summation of all the legal moves. Therefore, improved score can be naturally treated as a special case of move quality score heuristic where each move is equally treated.
- Ideally, with proper tuning procedure of the move weights, e.g. cross-validation based on grid searching, the performance of move quality score heuristic can be further enhanced.
- Longest path length heuristic can potentially be combined with move quality score heuristic. For example, when the move is only allowed in one direction, the accuracy of longest path length heuristic is more reliable.