Heuristic analysis

Let's analyze performance of CustomPlayer agent from the game_agent.py and different heuristic functions by running tournament.py. First, the script runs CustomPlayer agent with improved score heuristic function. Second, it runs CustomPlayer agent with custom_score heuristic function defined in the game_agent.py. There are three experiments with different implementations of custom_score heuristic functions: null score, open move score and improved score.

Null score

This heuristic presumes no knowledge for non-terminal states, and returns the same uninformative value for all other states.

```
**************************
 Evaluating: ID_Improved
**************************
Playing Matches:
----------
  Match 1: ID_Improved vs   Random            Result: 19 to 1
  Match 2: ID_Improved vs   MM_Null           Result: 19 to 1
  Match 3: ID_Improved vs   MM_Open           Result: 16 to 4
  Match 4: ID_Improved vs   MM_Improved       Result: 18 to 2
  Match 5: ID_Improved vs   AB_Null           Result: 18 to 2
  Match 6: ID_Improved vs   AB_Open           Result: 19 to 1
  Match 7: ID_Improved vs   AB_Improved       Result: 18 to 2
Results:
----------
ID_Improved       90.71%

**************************
   Evaluating: Student
**************************
Playing Matches:
----------
  Match 1:   Student   vs   Random            Result: 17 to 3
  Match 2:   Student   vs   MM_Null           Result: 16 to 4
  Match 3:   Student   vs   MM_Open           Result: 16 to 4
  Match 4:   Student   vs   MM_Improved       Result: 10 to 10
  Match 5:   Student   vs   AB_Null           Result: 19 to 1
  Match 6:   Student   vs   AB_Open           Result: 11 to 9
  Match 7:   Student   vs   AB_Improved       Result: 11 to 9
Results:
----------
Student          71.43%
```

From the statistical information above, we can conclude that improved score heuristic function outperforms null score heuristic one by approximately 20%. So that, improved score function is much more preferable than null score one, as the difference in winning rate is significant.

Open move score

The basic evaluation function described in lecture that outputs a score equal to the number of moves open for your computer player on the board.

```
**************************
 Evaluating: ID_Improved
**************************
Playing Matches:
----------
  Match 1: ID_Improved vs   Random           Result: 20 to 0
  Match 2: ID_Improved vs   MM_Null          Result: 20 to 0
  Match 3: ID_Improved vs   MM_Open          Result: 18 to 2
  Match 4: ID_Improved vs MM_Improved        Result: 20 to 0
  Match 5: ID_Improved vs   AB_Null          Result: 20 to 0
  Match 6: ID_Improved vs   AB_Open          Result: 18 to 2
  Match 7: ID_Improved vs AB_Improved        Result: 19 to 1
Results:
----------
ID_Improved        96.43%

**************************
   Evaluating: Student
**************************
Playing Matches:
----------
  Match 1:   Student   vs   Random           Result: 20 to 0
  Match 2:   Student   vs   MM_Null          Result: 20 to 0
  Match 3:   Student   vs   MM_Open          Result: 13 to 7
  Match 4:   Student   vs MM_Improved        Result: 20 to 0
  Match 5:   Student   vs   AB_Null          Result: 19 to 1
  Match 6:   Student   vs   AB_Open          Result: 17 to 3
  Match 7:   Student   vs AB_Improved        Result: 15 to 5
Results:
----------
Student           88.57%
```

From the second run, we see that the winning rate of the improved score heuristic function is increased by 5.72%. As there is no information about mean and standard deviation, we can assume that 96.43% lies in one standard deviation from the mean. The more interesting fact is about the winning rate of the open move heuristic function. It is 88.57%, which is much higher than the winning rate of the null score heuristic function, but lower than improved score heuristic function (in average). So that, we can inductively conclude that improved score heuristic function performs better than open move score heuristic function.

Improved score

The "Improved" evaluation function discussed in lecture that outputs a score equal to the difference in the number of moves available to the two players.

```
**************************
 Evaluating: ID_Improved
**************************
Playing Matches:
----------
  Match 1: ID_Improved vs   Random            Result: 20 to 0
  Match 2: ID_Improved vs   MM_Null           Result: 19 to 1
  Match 3: ID_Improved vs   MM_Open           Result: 19 to 1
  Match 4: ID_Improved vs MM_Improved         Result: 17 to 3
  Match 5: ID_Improved vs   AB_Null           Result: 19 to 1
  Match 6: ID_Improved vs   AB_Open           Result: 17 to 3
  Match 7: ID_Improved vs AB_Improved         Result: 17 to 3
Results:
----------
ID_Improved       91.43%

**************************
   Evaluating: Student
**************************
Playing Matches:
----------
  Match 1:   Student   vs   Random          Result: 19 to 1
  Match 2:   Student   vs   MM_Null         Result: 20 to 0
  Match 3:   Student   vs   MM_Open         Result: 19 to 1
  Match 4:   Student   vs MM_Improved       Result: 17 to 3
  Match 5:   Student   vs   AB_Null         Result: 19 to 1
  Match 6:   Student   vs   AB_Open         Result: 18 to 2
  Match 7:   Student   vs AB_Improved       Result: 16 to 4
Results:
----------
Student           91.43%
```

From the third experiment, we see that the winning rates of the ID_Improved and Student agents are the same, because both of them use improved score heuristic function.

Deep score

Deep score has almost the same strategy as improved score: it calculates difference between current legal moves and legal moves of one level deep forecasted states.

```
**************************
 Evaluating: ID_Improved
**************************
Playing Matches:
----------
  Match 1: ID_Improved vs   Random          Result: 19 to 1
  Match 2: ID_Improved vs   MM_Null         Result: 20 to 0
  Match 3: ID_Improved vs   MM_Open         Result: 17 to 3
  Match 4: ID_Improved vs MM_Improved       Result: 19 to 1
  Match 5: ID_Improved vs   AB_Null         Result: 20 to 0
  Match 6: ID_Improved vs   AB_Open         Result: 17 to 3
  Match 7: ID_Improved vs AB_Improved       Result: 18 to 2
Results:
----------
ID_Improved        92.86%

**************************
   Evaluating: Student
**************************
Playing Matches:
----------
  Match 1:   Student   vs   Random          Result: 19 to 1
  Match 2:   Student   vs   MM_Null         Result: 20 to 0
  Match 3:   Student   vs   MM_Open         Result: 17 to 3
  Match 4:   Student   vs MM_Improved       Result: 17 to 3
  Match 5:   Student   vs   AB_Null         Result: 19 to 1
  Match 6:   Student   vs   AB_Open         Result: 19 to 1
  Match 7:   Student   vs AB_Improved       Result: 17 to 3
Results:
----------
Student          91.43%
```

From the last experiment with deep score heuristic function, we can conclude that there is not significant difference between winning rates of improved score and deep score.

Conclusion

For the game of isolation where each agent is restricted to L-shaped movements with given four heuristic functions, we can conclude that improved score function should be used for the agent because of the following reasons:

1. Null score heuristic function has lowest winning rate. Its winning rate is 71.43% for the agent with iterative deepening (ID) and alpha-beta pruning (ABP).
2. Open move score has much better performance than null score function, 88.57%. But still it's winning rate is less than the winning rate of the improved score and the deep score.
3. Both improved score and deep score have the highest winning rates among presented heuristic functions, more than 90%. The preference is given to improved score function, because it gives at least the same performance as deep score function and has easier implementation which uses fewer computation steps comparing to deep score heuristic function.

Furthermore, all the agents without ID always lose, even if ID_Improved/Student uses null score heuristic function. It means that ID is highly correlated with winning rate.