**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.

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Evaluating: ID\_Improved

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Playing Matches:

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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:

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ID\_Improved 90.71%

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Evaluating: Student

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Playing Matches:

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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:

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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.

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Evaluating: ID\_Improved

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Playing Matches:

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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:

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ID\_Improved 96.43%

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Evaluating: Student

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Playing Matches:

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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:

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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.

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Evaluating: ID\_Improved

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Playing Matches:

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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:

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ID\_Improved 91.43%

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Evaluating: Student

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Playing Matches:

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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:

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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.

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Evaluating: ID\_Improved

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Playing Matches:

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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:

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ID\_Improved 92.86%

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Evaluating: Student

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Playing Matches:

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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:

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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.