# AIND Analysing Heuristic For Isolation game

## Heuristics

Heuristic functions are used as guide in making an informed decision when the game tree cannot be explored all the way to a terminal state. They are used to guide the game play towards the end goal. A good heuristic function would lead to moves that increase the likelihood of a win.

## Exploring Heuristics for Isolation Game

As part of this exercise these heuristic functions (and combinations) were explored:

- open_move_heuristic
  - Number of open moves for the player
- delta_move_heuristic
  - Difference in open moves between player and opponent
- central_distance_heuristic
  - Distance of player from center of board which has high degree of freedom
- move_score_heuristic
  - Position scores for the first 3 moves based on data collected from multiple runs
  - game run histories were added to the game object and are saved as pickled data in tournament.py
  - analyse_tournaments.py reads the run-data and generates move_scores.dat which is a set of heat map scores of the board, one for each of the first 3 moves
  - move_score_heuristic selects the highest scored position among the possible legal move for the first 3 moves (more like a opening book but without context)

## Analysis of Heuristics

These were the different heuristic function combination that were evaluated:

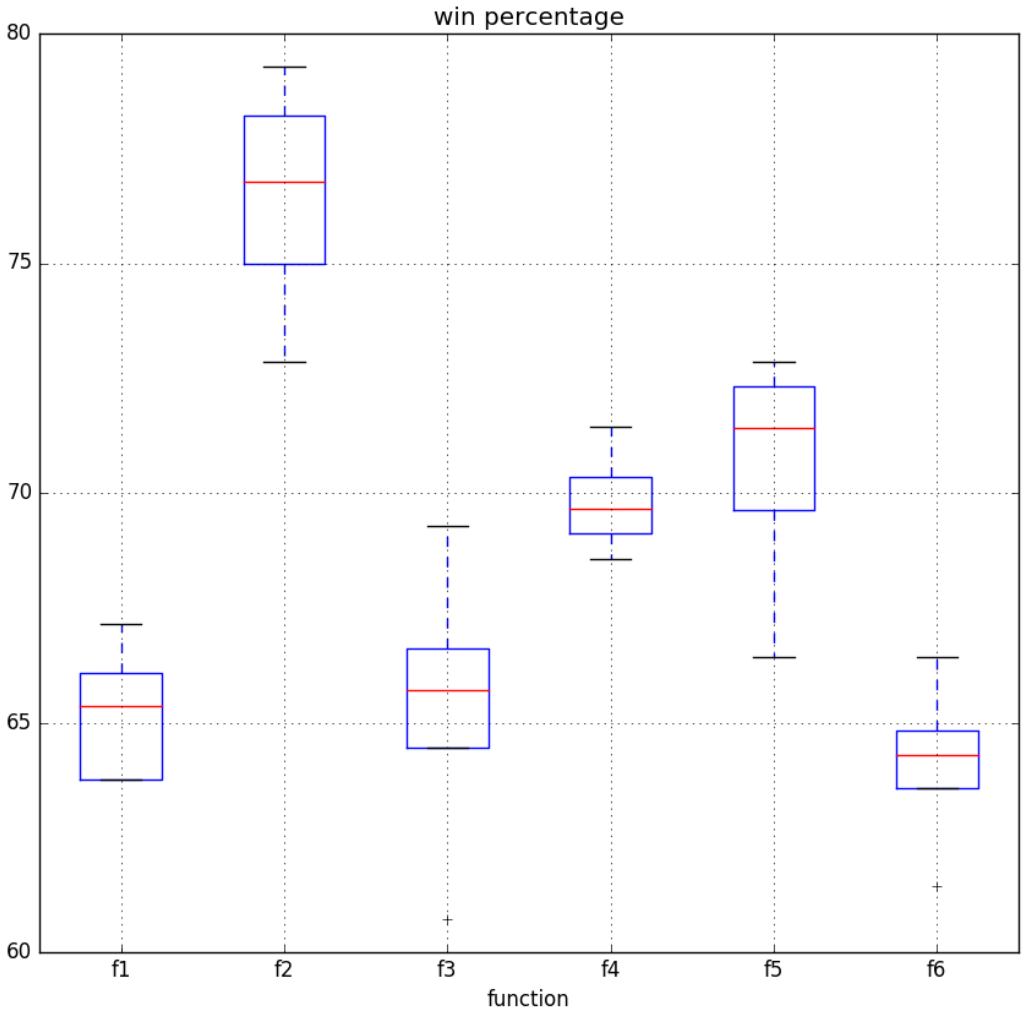
- f1() = 1.5*delta_move_heuristic
- f2() = delta_move_heuristic - central_distance_heuristic
- f3() = delta_move_heuristic + open_move_heuristic
- f4() = -central_distance_heuristic
- f5() = delta_move_heuristic + move_score_heuristic
- f6() = move_score_heuristic - central_distance_heuristic

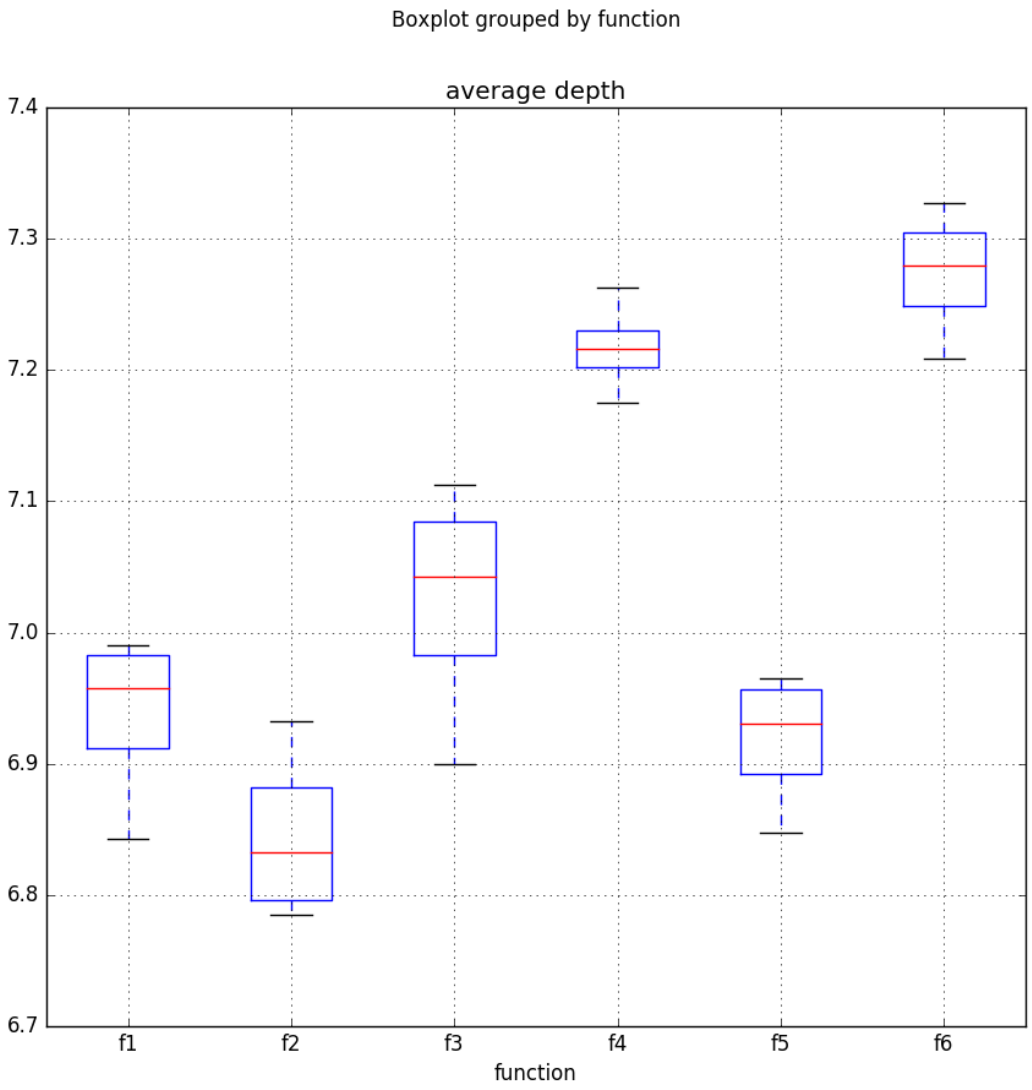
*Summary of different runs:*

| | function | win percentage | average depth |
|---|---|---|---|
| 0 | f1 | 60.00 | 6.980256 |
| 1 | f1 | 65.00 | 6.842556 |
| 2 | f1 | 65.71 | 6.990695 |
| 3 | f1 | 67.14 | 6.935170 |
| 4 | f2 | 79.29 | 6.800217 |
| 5 | f2 | 72.86 | 6.932351 |
| 6 | f2 | 75.71 | 6.864745 |
| 7 | f2 | 77.86 | 6.785366 |
| 8 | f3 | 65.71 | 6.900167 |
| 9 | f3 | 65.71 | 7.010303 |
| 10 | f3 | 69.29 | 7.074845 |
| 11 | f3 | 60.71 | 7.112133 |
| 12 | f4 | 69.29 | 7.219878 |
| 13 | f4 | 70.00 | 7.211612 |
| 14 | f4 | 68.57 | 7.174829 |
| 15 | f4 | 71.43 | 7.262632 |
| 16 | f5 | 70.71 | 6.907199 |
| 17 | f5 | 72.14 | 6.847766 |
| 18 | f5 | 72.86 | 6.953411 |
| 19 | f5 | 66.43 | 6.964679 |
| 20 | f6 | 64.29 | 7.297447 |
| 21 | f6 | 61.43 | 7.262632 |
| 22 | f6 | 66.43 | 7.208886 |
| 23 | f6 | 64.29 | 7.326870 |

**Analysis**

- Single Heuristic function
  - When using a single heuristic, the win percentage variance was less. But the overall performance was not high.
- Multiple Heuristic functions
  - When combined with weights, the win percentage variance was higher. But in some cases the overall performance was higher.
- Search depth
  - contrary to intuition, search depth was shallow for best performing heuristics.
  - Optimizing the code by removing log statements, unnecessary function calls, simplifying heuristic function did not improve the search depth by a significant margin.


Boxplot grouped by function
win percentage
80
75
70
65
60
f1
f2
f3
f4
f5
f6
function




## Recommended Heuristic

*f2() = delta_move_heuristic - central_distance_heuristic*

- win percentage is consistently higher than other heuristics
- thought the average depth explored is the least, the computed value seems to be a more accurate prediction of ideal value
- intuitively central distance penalizes position on the edges of the board and open moves give an indication of the rounds available for the player

## Reference

1. Knight Tour Heuristic: https://support.sas.com/resources/papers/proceedings15/3060-2015.pdf
2. Artificial Intelligence for Games - Ian Millington, John Funge

## APPENDIX

### Run Data

f1() = 1.5*delta_move_heuristic

```
 Match 1:   Student   vs   Random      Result: 19 to 1
 Match 2:   Student   vs   MM_Null     Result: 15 to 5
 Match 3:   Student   vs   MM_Open     Result: 11 to 9
 Match 4:   Student   vs MM_Improved   Result: 12 to 8
 Match 5:   Student   vs   AB_Null     Result: 11 to 9
 Match 6:   Student   vs   AB_Open     Result: 11 to 9
 Match 7:   Student   vs AB_Improved   Result: 12 to 8
Student            65.00%
avg search depth:  6.842555618938961

 Match 1:   Student   vs   Random      Result: 17 to 3
 Match 2:   Student   vs   MM_Null     Result: 15 to 5
 Match 3:   Student   vs   MM_Open     Result: 12 to 8
 Match 4:   Student   vs MM_Improved   Result: 11 to 9
 Match 5:   Student   vs   AB_Null     Result: 14 to 6
 Match 6:   Student   vs   AB_Open     Result: 12 to 8
 Match 7:   Student   vs AB_Improved   Result: 11 to 9
Student            65.71%
avg search depth:  6.990695128626163

 Match 1:   Student   vs   Random      Result: 20 to 0
 Match 2:   Student   vs   MM_Null     Result: 16 to 4
 Match 3:   Student   vs   MM_Open     Result: 11 to 9
 Match 4:   Student   vs MM_Improved   Result: 7 to 13
 Match 5:   Student   vs   AB_Null     Result: 17 to 3
 Match 6:   Student   vs   AB_Open     Result: 12 to 8
 Match 7:   Student   vs AB_Improved   Result: 11 to 9
Student            67.14%
avg search depth:  6.93517017828201

 Match 1:   Student   vs   Random      Result: 15 to 5
 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: 9 to 11
 Match 5:   Student   vs   AB_Null     Result: 11 to 9
 Match 6:   Student   vs   AB_Open     Result: 10 to 10
```

Match 7: Student vs AB_Improved Result: 13 to 7
Student 60.00%
avg search depth: 6.98025613660619

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f2() = delta_move_heuristic - central_distance_heuristic
Match 1: Student vs Random Result: 19 to 1
Match 2: Student vs MM_Null Result: 17 to 3
Match 3: Student vs MM_Open Result: 14 to 6
Match 4: Student vs MM_Improved Result: 16 to 4
Match 5: Student vs AB_Null Result: 17 to 3
Match 6: Student vs AB_Open Result: 15 to 5
Match 7: Student vs AB_Improved Result: 13 to 7
Student 79.29%
avg search depth: 6.800217155266015

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: 13 to 7
Match 4: Student vs MM_Improved Result: 11 to 9
Match 5: Student vs AB_Null Result: 15 to 5
Match 6: Student vs AB_Open Result: 13 to 7
Match 7: Student vs AB_Improved Result: 14 to 6
Student 72.86%
avg search depth: 6.932351336606656

Match 1: Student vs Random Result: 19 to 1
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: 12 to 8
Match 5: Student vs AB_Null Result: 19 to 1
Match 6: Student vs AB_Open Result: 15 to 5
Match 7: Student vs AB_Improved Result: 11 to 9
Student 75.71%
avg search depth: 6.864745011086474

Match 1: Student vs Random Result: 19 to 1
Match 2: Student vs MM_Null Result: 19 to 1
Match 3: Student vs MM_Open Result: 14 to 6
Match 4: Student vs MM_Improved Result: 14 to 6
Match 5: Student vs AB_Null Result: 15 to 5
Match 6: Student vs AB_Open Result: 16 to 4

```
  Match 7:   Student    vs AB_Improved   Result: 12 to 8
 Student            77.86%
 avg search depth:  6.785365853658536

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f3() = delta_move_heuristic + open_move_heuristic
  Match 1:   Student    vs    Random      Result: 19 to 1
  Match 2:   Student    vs    MM_Null     Result: 16 to 4
  Match 3:   Student    vs    MM_Open     Result: 12 to 8
  Match 4:   Student    vs MM_Improved    Result: 8 to 12
  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: 13 to 7
Student            65.71%
avg search depth:  6.900167317345232

  Match 1:   Student    vs    Random      Result: 19 to 1
  Match 2:   Student    vs    MM_Null     Result: 19 to 1
  Match 3:   Student    vs    MM_Open     Result: 9 to 11
  Match 4:   Student    vs MM_Improved    Result: 7 to 13
  Match 5:   Student    vs    AB_Null     Result: 15 to 5
  Match 6:   Student    vs    AB_Open     Result: 11 to 9
  Match 7:   Student    vs AB_Improved    Result: 12 to 8
Student            65.71%
avg search depth:  7.010303377218088

  Match 1:   Student    vs    Random      Result: 16 to 4
  Match 2:   Student    vs    MM_Null     Result: 16 to 4
  Match 3:   Student    vs    MM_Open     Result: 11 to 9
  Match 4:   Student    vs MM_Improved    Result: 11 to 9
  Match 5:   Student    vs    AB_Null     Result: 15 to 5
  Match 6:   Student    vs    AB_Open     Result: 13 to 7
  Match 7:   Student    vs AB_Improved    Result: 15 to 5
Student            69.29%
avg search depth:  7.074845244794598

  Match 1:   Student    vs    Random      Result: 16 to 4
  Match 2:   Student    vs    MM_Null     Result: 17 to 3
  Match 3:   Student    vs    MM_Open     Result: 6 to 14
  Match 4:   Student    vs MM_Improved    Result: 6 to 14
  Match 5:   Student    vs    AB_Null     Result: 14 to 6
  Match 6:   Student    vs    AB_Open     Result: 12 to 8
```

```
  Match 7:   Student    vs AB_Improved       Result: 14 to 6
Student             60.71%
avg search depth:  7.11213341000575

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f4() = -central_distance_heuristic
  Match 1:   Student    vs    Random       Result: 19 to 1
  Match 2:   Student    vs    MM_Null      Result: 14 to 6
  Match 3:   Student    vs    MM_Open      Result: 13 to 7
  Match 4:   Student    vs MM_Improved    Result: 9 to 11
  Match 5:   Student    vs    AB_Null      Result: 14 to 6
  Match 6:   Student    vs    AB_Open      Result: 14 to 6
  Match 7:   Student    vs AB_Improved    Result: 14 to 6
Student             69.29%
avg search depth:  7.21987784564131

  Match 1:   Student    vs    Random       Result: 17 to 3
  Match 2:   Student    vs    MM_Null      Result: 19 to 1
  Match 3:   Student    vs    MM_Open      Result: 11 to 9
  Match 4:   Student    vs MM_Improved    Result: 10 to 10
  Match 5:   Student    vs    AB_Null      Result: 14 to 6
  Match 6:   Student    vs    AB_Open      Result: 12 to 8
  Match 7:   Student    vs AB_Improved    Result: 15 to 5
Student             70.00%
avg search depth:  7.2116115029842645

  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: 8 to 12
  Match 4:   Student    vs MM_Improved    Result: 12 to 8
  Match 5:   Student    vs    AB_Null      Result: 15 to 5
  Match 6:   Student    vs    AB_Open      Result: 12 to 8
  Match 7:   Student    vs AB_Improved    Result: 14 to 6
Student             68.57%
avg search depth:  7.174829157175399


  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: 13 to 7
  Match 4:   Student    vs MM_Improved    Result: 11 to 9
  Match 5:   Student    vs    AB_Null      Result: 17 to 3
```

```
  Match 6:   Student    vs    AB_Open      Result: 16 to 4
  Match 7:   Student    vs AB_Improved    Result: 10 to 10
Student             71.43%
avg search depth:  7.262631871182676
```

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f5() = delta_move_heuristic + move_score_heuristic

```
  Match 1:   Student    vs    Random       Result: 18 to 2
  Match 2:   Student    vs    MM_Null      Result: 16 to 4
  Match 3:   Student    vs    MM_Open      Result: 11 to 9
  Match 4:   Student    vs MM_Improved    Result: 13 to 7
  Match 5:   Student    vs    AB_Null      Result: 13 to 7
  Match 6:   Student    vs    AB_Open      Result: 13 to 7
  Match 7:   Student    vs AB_Improved    Result: 15 to 5
Student             70.71%
avg search depth:  6.907199100112486

  Match 1:   Student    vs    Random       Result: 16 to 4
  Match 2:   Student    vs    MM_Null      Result: 18 to 2
  Match 3:   Student    vs    MM_Open      Result: 16 to 4
  Match 4:   Student    vs MM_Improved    Result: 13 to 7
  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
Student             72.14%
avg search depth:  6.84776613348042

  Match 1:   Student    vs    Random       Result: 17 to 3
  Match 2:   Student    vs    MM_Null      Result: 19 to 1
  Match 3:   Student    vs    MM_Open      Result: 14 to 6
  Match 4:   Student    vs MM_Improved    Result: 15 to 5
  Match 5:   Student    vs    AB_Null      Result: 14 to 6
  Match 6:   Student    vs    AB_Open      Result: 11 to 9
  Match 7:   Student    vs AB_Improved    Result: 12 to 8
Student             72.86%
avg search depth:  6.953410981697171

  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: 11 to 9
  Match 4:   Student    vs MM_Improved    Result: 12 to 8
```

```
 Match 5:   Student    vs    AB_Null     Result: 14 to 6
 Match 6:   Student    vs    AB_Open     Result: 11 to 9
 Match 7:   Student    vs AB_Improved    Result: 12 to 8
Student             66.43%
avg search depth:  6.964678633468442

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f6() = move_score_heuristic - central_distance_heuristic
 Match 1:   Student    vs    Random      Result: 19 to 1
 Match 2:   Student    vs    MM_Null     Result: 12 to 8
 Match 3:   Student    vs    MM_Open     Result: 13 to 7
 Match 4:   Student    vs MM_Improved    Result: 11 to 9
 Match 5:   Student    vs    AB_Null     Result: 13 to 7
 Match 6:   Student    vs    AB_Open     Result: 13 to 7
 Match 7:   Student    vs AB_Improved    Result: 9 to 11
Student             64.29%
avg search depth:  7.297447280799112

 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: 9 to 11
 Match 4:   Student    vs MM_Improved    Result: 12 to 8
 Match 5:   Student    vs    AB_Null     Result: 13 to 7
 Match 6:   Student    vs    AB_Open     Result: 9 to 11
 Match 7:   Student    vs AB_Improved    Result: 11 to 9
Student             61.43%
avg search depth:  7.262631871182676

 Match 1:   Student    vs    Random      Result: 15 to 5
 Match 2:   Student    vs    MM_Null     Result: 18 to 2
 Match 3:   Student    vs    MM_Open     Result: 11 to 9
 Match 4:   Student    vs MM_Improved    Result: 10 to 10
 Match 5:   Student    vs    AB_Null     Result: 15 to 5
 Match 6:   Student    vs    AB_Open     Result: 12 to 8
 Match 7:   Student    vs AB_Improved    Result: 12 to 8
Student             66.43%
avg search depth:  7.208886324293133

 Match 1:   Student    vs    Random      Result: 19 to 1
 Match 2:   Student    vs    MM_Null     Result: 13 to 7
 Match 3:   Student    vs    MM_Open     Result: 10 to 10
 Match 4:   Student    vs MM_Improved    Result: 12 to 8
```

Match 5: Student vs AB_Null Result: 13 to 7
Match 6: Student vs AB_Open Result: 13 to 7
Match 7: Student vs AB_Improved Result: 10 to 10
Student 64.29%
avg search depth: 7.326869806094183