

Heuristic Analysis

The heuristics were tested using a Windows 10 machine with an Intel core i7 processor and 4 GB of RAM. However, they were tested on an Ubuntu 14.06 virtual machine that allocated 2GB of RAM with 1 processor. In average, running the *tournament.py* script takes 10-15 minutes. 5 tests were realized on each heuristic to analyse it's results. From 8 heuristics that where code, the best 3 were selected for this document.

The python code for each heuristic can be found in the `game_agent.py` file in the Isolation project.

Move analysis

The following best case scenarios were considered to determine the rules for the heuristics that were implemented.

When a player is in the centre, 8 moves are available

	0	1	2	3	4	5	6
0							
1			°		°		
2		°				°	
3				O			
4		°				°	
5			°		°		
6							

When a player is adjacent to the centre, 8 moves are also available

	0	1	2	3	4	5	6
0		°		°			
1	°				°		
2			O				
3	°				°		
4		°		°			
5							
6							

When a player is in the corners, it has 2 moves available

	0	1	2	3	4	5	6
0	O						
1			°				
2		°					
3							
4							
5							
6							

When a player is in a wall different than the corners, it has 3-4 moves available

	0	1	2	3	4	5	6
0		O					
1				°		°	
2	°		°		°		
3							O
4					°		
5						°	
6							

When a player is in a box adjacent to a wall, it has 4-5 moves available

	0	1	2	3	4	5	6
0				°			
1		O			°		°
2				°°			
3	°		°			O	
4				°			
5					°		°
6							

From this scenarios, it is observed that playing around the centre leads to have more moves available. The worst place to be at the end of the game seem to be the corners, as they lead to few restricted moves.

Heuristic 2

In this heuristic, the difference between the distance of the 2 players is computed as the score. The hypothesis is: If two players are far from each other, it's better than if they are close, as the opponent move will be less likely to occupy one of the legal moves from the active player.

Run	ID_Improved %	Student %
1	71.43	65.71
2	62.14	70.00
3	76.43	62.86
4	74.29	67.86
5	67.86	62.86
AVG	70.43	65.85

This heuristic does not outperform the baseline provided. This might be due to the fact that proximity between players may not define the game in scenarios where a legal move leads to multiple other legal moves.

```

ID_Improved 76.43%
*****
Evaluating: Student
*****

Evaluating: ID_Improved
*****
Playing Matches:
-----
Match 1: ID_Improved vs Random Result: 13 to 5
Match 2: ID_Improved vs MM_Null Result: 17 to 3
Match 3: ID_Improved vs MM_Open Result: 18 to 2
tournament.py:100: UserWarning: One or more agents lost a
or the function to return, and may need to increase this
warnings.warn(TIMEOUT_WARNING)
Match 4: ID_Improved vs MM_Improved Result: 12 to 8
Match 5: ID_Improved vs AB_Null Result: 15 to 5
Match 6: ID_Improved vs AB_Open Result: 12 to 8
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: 13 to 7
Match 2: Student vs MM_Null Result: 13 to 7
Match 3: Student vs MM_Open Result: 16 to 4
Match 4: Student vs MM_Improved Result: 14 to 6
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

Results:
-----
Student 65.71%
(aind) dserrano1524@ubuntu:~/GIT/AIND-Isolation$

Playing Matches:
-----
Match 1: Student vs Random Result: 13 to 7
Match 2: Student vs MM_Null Result: 15 to 5
Match 3: Student vs MM_Open Result: 14 to 6
tournament.py:100: UserWarning: One or more agents lost a
before time_left() reaches 0 ms. You will need to leave so
n to avoid timeouts during tournament play.
warnings.warn(TIMEOUT_WARNING)
Match 4: Student vs MM_Improved Result: 10 to 10
Match 5: Student vs AB_Null Result: 12 to 8
Match 6: Student vs AB_Open Result: 13 to 7
Match 7: Student vs AB_Improved Result: 11 to 9

Results:
-----
Student 62.86%
(aind) dserrano1524@ubuntu:~/GIT/AIND-Isolation$

```

```

ID_Improved 62.14%
*****
Evaluating: Student
*****

ID_Improved 74.29%
*****
Evaluating: Student
*****

ID_Improved 67.86%
*****
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: 15 to 5
Match 4: Student vs MM_Improved Result: 11 to 9
Match 5: Student vs AB_Null Result: 16 to 4
Match 6: Student vs AB_Open Result: 15 to 5
Match 7: Student vs AB_Improved Result: 9 to 11

Results:
-----
Student 70.00%

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: 11 to 9
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

Results:
-----
Student 67.86%

Playing Matches:
-----
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: 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: 11 to 9
Match 7: Student vs AB_Improved Result: 9 to 11

Results:
-----
Student 62.86%

```

Heuristic 5

In this heuristic, the number of legal moves that are on a wall (max 4) are counted for both the player and the opponent. The score is calculated using the number of legal moves available - the number of moves in the walls as a way to penalize moves that lead to restricted movement. If the opponent has moves in the wall, it is rewarded, as we assume the opponent will avoid those moves.

Run	ID_Improved %	Student %
1	59.29	67.86
2	70.71	67.86
3	67.14	66.43
4	71.43	65.71
5	68.57	72.14
AVG	67.43	68.00

In average, this heuristic outperforms the given baseline, however, the average is greatly affected by the Run 1, as it has a very low average score. We can see that, ignoring that scenario, the baseline outperforms Heuristic 5 in 3 out of 4 runs. Further testing might be required to identify this heuristic as a good one.

```

Evaluating: ID_Improved
*****
Playing Matches:
-----
tournament.py:100: UserWarning: One or more agents lost a
or the function to return, and may need to increase this
warnings.warn(TIMEOUT_WARNING)
Match 1: ID_Improved vs Random Result: 15 to 5
Match 2: ID_Improved vs MM_Null Result: 11 to 9
Match 3: ID_Improved vs MM_Open Result: 10 to 10
Match 4: ID_Improved vs MM_Improved Result: 11 to 9
Match 5: ID_Improved vs AB_Null Result: 13 to 7
Match 6: ID_Improved vs AB_Open Result: 12 to 8
Match 7: ID_Improved vs AB_Improved Result: 11 to 9

Results:
-----
ID_Improved 59.29%

Results:
-----
ID_Improved 59.29%
Evaluating: Student
*****
Playing Matches:
-----
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: 11 to 9
Match 4: Student vs MM_Improved Result: 11 to 9
Match 5: Student vs AB_Null Result: 16 to 4
Match 6: Student vs AB_Open Result: 14 to 6
Match 7: Student vs AB_Improved Result: 11 to 9

Results:
-----
Student 67.86%

ID_Improved 70.71%
*****
Evaluating: Student
*****
Playing Matches:
-----
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: 12 to 8
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: 15 to 5
Match 7: Student vs AB_Improved Result: 10 to 10

Results:
-----
Student 67.86%
C:\Users\diego.s\Google Drive\Udacity\Isolation_20170317

```

```

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 18 to 2
Match 2: ID_Improved vs MM_Null     Result: 13 to 7
Match 3: ID_Improved vs MM_Open     Result: 13 to 7
Match 4: ID_Improved vs MM_Improved Result: 11 to 9
Match 5: ID_Improved vs AB_Null     Result: 18 to 2
tournament.py:108: UserWarning: One or more agents lost
or the function to return, and may need to increase this
warnings.warn(TIMEOUT_WARNING)
Match 6: ID_Improved vs AB_Open     Result: 9 to 11
Match 7: ID_Improved vs AB_Improved Result: 12 to 8

Results:
-----
ID_Improved      67.14%

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

Playing Matches:
-----
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: 12 to 8
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: 9 to 11

Results:
-----
Student          66.43%
(aind) dserrano1524@ubuntu:~/GIT/AIND-Isolation$

ID_Improved      71.43%
*****
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: 13 to 7
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: 9 to 11

Results:
-----
Student          65.71%
(aind) dserrano1524@ubuntu:~/GIT/AIND-Isolation$

```

```

ID_Improved      68.57%
*****
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: 13 to 7
Match 4: Student vs MM_Improved Result: 16 to 4
Match 5: Student vs AB_Null     Result: 13 to 7
Match 6: Student vs AB_Open     Result: 10 to 10
Match 7: Student vs AB_Improved Result: 14 to 6

Results:
-----
Student          72.14%
C:\Users\diego.s\Google Drive\Udacity\Isolation_20170317

```

Heuristic 7

In this heuristic, the number of corners, walls (boxes in the edge of the board that are not corners), adjacent walls (boxes beside a wall), and boxes adjacent to the centre (and the centre included) are counted. The score returned is the number of moves available of the player adding the number of boxes adjacent to the centre and boxes adjacent to the walls and subtracting the number of walls and corners, this in an attempt to penalize paths that lead playing on walls and corners and rewarding paths moving in the areas where more moves are available.

Run	ID_Improved %	Student %
1	65.71	70.00
2	67.14	67.86
3	68.57	65.00
4	62.86	71.43
5	70.00	71.43
AVG	66.86	69.14

This heuristic outperforms the baseline in 4/5 scenarios. This is an expected result as penalizing paths that lead to corners and walls and favouring paths near the centre leads to paths where more moves are available. However, more work is needed over this heuristic, as it barely outperforms the baseline.

```
Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 17 to 3
Match 2: ID_Improved vs MM_Null      Result: 14 to 6
Match 3: ID_Improved vs MM_Open      Result: 8 to 12
Match 4: ID_Improved vs MM_Improved  Result: 13 to 7
Match 5: ID_Improved vs AB_Null      Result: 12 to 8
Match 6: ID_Improved vs AB_Open      Result: 15 to 5
Match 7: ID_Improved vs AB_Improved  Result: 13 to 7

Results:
-----
ID_Improved      65.71%

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

Playing Matches:
-----
Match 1: Student vs Random      Result: 17 to 3
Match 2: Student vs MM_Null      Result: 14 to 6
Match 3: Student vs MM_Open      Result: 15 to 5
Match 4: Student vs MM_Improved  Result: 15 to 5
tournament.py:100: UserWarning: One or more agents lost a match
or the function to return, and may need to increase this margin.
warnings.warn(TIMEOUT_WARNING)
Match 5: Student vs AB_Null      Result: 13 to 7
Match 6: Student vs AB_Open      Result: 15 to 5
Match 7: Student vs AB_Improved  Result: 9 to 11

Results:
-----
Student          70.00%
(aind) dserrano1524ubuntu:~/GIT/AIND-Isolation$

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 16 to 4
Match 2: ID_Improved vs MM_Null      Result: 13 to 7
Match 3: ID_Improved vs MM_Open      Result: 14 to 6
Match 4: ID_Improved vs MM_Improved  Result: 11 to 9
Match 5: ID_Improved vs AB_Null      Result: 16 to 4
Match 6: ID_Improved vs AB_Open      Result: 13 to 7
Match 7: ID_Improved vs AB_Improved  Result: 13 to 7

Results:
-----
ID_Improved      68.57%

*****
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: 12 to 8
Match 4: Student vs MM_Improved  Result: 10 to 10
Match 5: Student vs AB_Null      Result: 12 to 8
Match 6: Student vs AB_Open      Result: 14 to 6
Match 7: Student vs AB_Improved  Result: 10 to 10

Results:
-----
Student          65.00%
C:\Users\diego.s\Google Drive\Udacity\Isolation_20170317

*****
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: 17 to 3
Match 4: ID_Improved vs MM_Improved  Result: 8 to 12
Match 5: ID_Improved vs AB_Null      Result: 13 to 7
Match 6: ID_Improved vs AB_Open      Result: 14 to 6
Match 7: ID_Improved vs AB_Improved  Result: 13 to 7

Results:
-----
ID_Improved      67.14%

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

Playing Matches:
-----
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: 14 to 6
Match 4: Student vs MM_Improved  Result: 12 to 8
tournament.py:100: UserWarning: One or more agents lost a match
or the function to return, and may need to increase this margin.
warnings.warn(TIMEOUT_WARNING)
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: 10 to 10

Results:
-----
Student          67.86%
(aind) dserrano1524ubuntu:~/GIT/AIND-Isolation$

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 17 to 3
Match 2: ID_Improved vs MM_Null      Result: 15 to 5
Match 3: ID_Improved vs MM_Open      Result: 11 to 9
Match 4: ID_Improved vs MM_Improved  Result: 11 to 9
Match 5: ID_Improved vs AB_Null      Result: 13 to 7
Match 6: ID_Improved vs AB_Open      Result: 11 to 9
Match 7: ID_Improved vs AB_Improved  Result: 10 to 10

Results:
-----
ID_Improved      62.86%

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

Playing Matches:
-----
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: 14 to 6
Match 4: Student vs MM_Improved  Result: 13 to 7
Match 5: Student vs AB_Null      Result: 20 to 0
Match 6: Student vs AB_Open      Result: 9 to 11
Match 7: Student vs AB_Improved  Result: 13 to 7

Results:
-----
Student          71.43%
C:\Users\diego.s\Google Drive\Udacity\Isolation_20170317

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

Playing Matches:
-----
Match 1: ID_Improved vs Random      Result: 17 to 3
Match 2: ID_Improved vs MM_Null      Result: 19 to 1
Match 3: ID_Improved vs MM_Open      Result: 11 to 9
Match 4: ID_Improved vs MM_Improved  Result: 15 to 5
Match 5: ID_Improved vs AB_Null      Result: 12 to 8
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      70.00%

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

Playing Matches:
-----
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: 13 to 7
Match 4: Student vs MM_Improved  Result: 15 to 5
Match 5: Student vs AB_Null      Result: 15 to 5
Match 6: Student vs AB_Open      Result: 15 to 5
Match 7: Student vs AB_Improved  Result: 8 to 12

Results:
-----
Student          71.43%
C:\Users\diego.s\Google Drive\Udacity\Isolation_20170317
```

Results

Heuristic	ID_Improved % (AVG)	Student (AVG)
heuristic_2	70.43	65.85
heuristic_5	67.43	68.00
heuristic_7	66.86	69.14

After running 5 times the tournament script for each heuristic, the recommended heuristic is heuristic_7, as it has been proven to be the best performing one. This is the only heuristic that beats the baseline on 4 out of 5 runs. This was expected as it is the heuristic that takes into account the position of the player in the board and the amount of moves available. Nevertheless, more work is needed over this heuristic as a 2.28% improvement might not be relevant. Running the tests on a machine with better specs might change widely the results.