Heuristic analysis

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1 Evaluation heuristics

The following evaluation heuristics were implemented:

Combined: Combination of improved heuristics and density. The objective is to look for positions that are located in low density area. To limit time impact of computing density, the density function is only used if the number of moves is above 20 (i.e when we are approaching the end of the game).

Diff_density: Difference in number of free space around player and opponent. It allows to prefer to go to places where there are a lot of free spaces.

Slow: Similar to ID_Improved but penalised with a sleep of 10ms. The objective is to measure the impact of a slow heuristic.

Distance: The score is based on l1-norm (taxicab distance) between player and the board center. The objective is to encourage position near the center of the board.

2 Results

Tournament.py was used to run the evaluation of heuristics (raw output is provided in section 3). The analysis was run with the variable *NUM_MATCHES* set to 100 to get 400 games per opponent. This allowed to have more accurate results. To accelerate the evaluation process the Python multiprocessing library was used. Thus allowing to run the matches on 4 CPU core at the same time. The six default opponents (*Random*, *MM_Null*, *MM_Open*, *MM_Improved*, *AB_Null*, *AB_Open*, *AB_Improved*) were used.

	winning rate
Combined	**77.57%**
Diff_density	74.32%
Distance	70.39%
ID_Improved	74.86%
Slow	32.07%

Table 1: Average wining rate for the different heuristics

	Combined	Diff_density	Distance	ID_Improved	Slow
AB_Improved	**68.25%**	61.75%	54.00%	62.75%	17.75%
AB_Null	78.50%	**80.00%**	76.75%	79.00%	31.75%
AB_Open	**71.00%**	61.50%	64.00%	66.75%	21.75%
MM_Improved	**70.25%**	66.00%	59.75%	68.00%	17.50%
MM_Null	85.75%	**86.75%**	83.25%	82.75%	44.75%
MM_Open	**75.00%**	71.50%	66.50%	72.00%	22.50%
Random	**94.25%**	92.75%	88.50%	92.75%	68.50%

Table 2: Winning rates for each heuristic versus each opponent. Highest winning rates are highlighted in bold.

Table 1 show the average winning rate of each heuristic. The *Combined* evaluation heuristic provides the best average winning rate (77.57%) which is 3.25% better than the *ID_Improved* heuristic. The Slow heuristic has the lowest score. This highlights the impact of a slow heuristic, and it could be explained by the fact that the *Slow* heuristic does not allow to reach high depth due to timeout.

Table 2 show the winning rate of each heuristic versus each opponent. *Combined* heuristic is the winning heuristic here (5 out of 7 best results).

As highlight in figure 1 the *Combined* and *ID_improved* are the two heuristics that provide the lowest variation against opponents, thus we can consider them as the more stable. We can also observe that the four heuristics (*Combined*, *Diff_density*, *Distance*, *ID_Improved*) have close distributions in terms of winning rate.

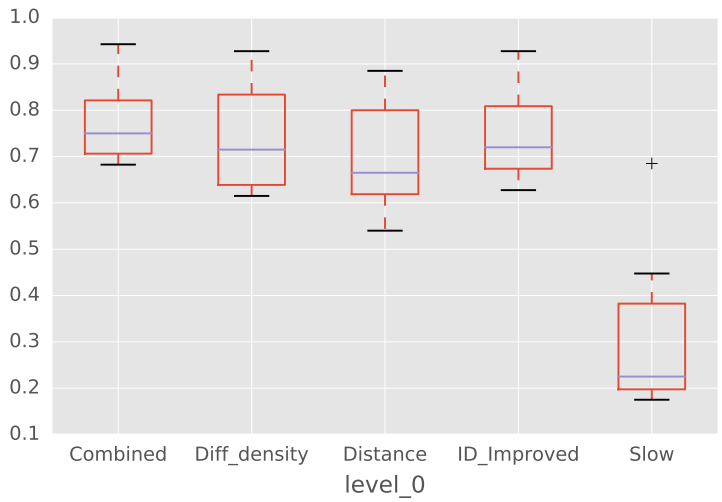

Figure 1: Box-plot for the different heuristics

The results show that the *Combined* heuristic offers the best results in terms of stability, average performance, and median performance, thus we can recommend its use as the default heuristic for the game. However, this recommendation should be taken with care as the improvement is low compared to *ID_Improved*, a better heuristic may exist but we did not find it.

3 Annexe

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*************************
Evaluating: Distance
*************************

Playing Matches:
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  Match 1: Distance vs   Random       Result: 354 to 46
  Match 2: Distance vs   MM_Null      Result: 333 to 67
  Match 3: Distance vs   MM_Open      Result: 266 to 134
  Match 4: Distance vs MM_Improved    Result: 239 to 161
  Match 5: Distance vs   AB_Null      Result: 307 to 93
  Match 6: Distance vs   AB_Open      Result: 256 to 144
  Match 7: Distance vs AB_Improved    Result: 216 to 184


Results:
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Distance     70.39%

*************************
Evaluating: Combined
*************************

Playing Matches:
----------
  Match 1: Combined vs   Random        Result: 377 to 23
  Match 2: Combined vs   MM_Null       Result: 343 to 57
  Match 3: Combined vs   MM_Open       Result: 300 to 100
  Match 4: Combined vs MM_Improved     Result: 281 to 119
  Match 5: Combined vs   AB_Null       Result: 314 to 86
  Match 6: Combined vs   AB_Open       Result: 284 to 116
  Match 7: Combined vs AB_Improved     Result: 273 to 127


Results:
----------
Combined     77.57%

*************************
Evaluating: Diff_density
*************************

Playing Matches:
----------
  Match 1: Diff_density vs   Random     Result: 371 to 29
  Match 2: Diff_density vs   MM_Null    Result: 347 to 53
  Match 3: Diff_density vs   MM_Open    Result: 286 to 114
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  Match 4: Diff_density vs MM_Improved  Result: 264 to 136
  Match 5: Diff_density vs   AB_Null    Result: 320 to 80
  Match 6: Diff_density vs   AB_Open    Result: 246 to 154
  Match 7: Diff_density vs AB_Improved  Result: 247 to 153


Results:
----------
Diff_density        74.32%


*************************
    Evaluating: Slow_ID_Improved
*************************

Playing Matches:
----------
  Match 1: Slow vs   Random      Result: 274 to 126
  Match 2: Slow vs   MM_Null     Result: 179 to 221
  Match 3: Slow vs   MM_Open     Result: 90 to 310
  Match 4: Slow vs MM_Improved   Result: 70 to 330
  Match 5: Slow vs   AB_Null     Result: 127 to 273
  Match 6: Slow vs   AB_Open     Result: 87 to 313
  Match 7: Slow vs AB_Improved   Result: 71 to 329


Results:
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Slow                32.07%


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

Playing Matches:
----------
  Match 1: ID_Improved vs   Random      Result: 371 to 29
  Match 2: ID_Improved vs   MM_Null     Result: 331 to 69
  Match 3: ID_Improved vs   MM_Open     Result: 288 to 112
  Match 4: ID_Improved vs MM_Improved   Result: 272 to 128
  Match 5: ID_Improved vs   AB_Null     Result: 316 to 84
  Match 6: ID_Improved vs   AB_Open     Result: 267 to 133
  Match 7: ID_Improved vs AB_Improved   Result: 251 to 149


Results:
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ID_Improved         74.86%
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