Isolation Agent Heuristic Analysis

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1 Evaluation functions

For this project I experimented with a large number of evaluation functions with varying degrees of success. A few interesting ideas stood out to me, resulting in four particular evaluation functions that I want to talk about in this report.

1.1 Score with center bias

The first evaluation function came from the recognition that the IDImproved agent heuristic is already very strong and it is worth investigating improving it further. To do that, we identify how close to the center the current position is. If it's the same position as the center position we add a small bias of 1. If not, we check if the center position is still legal. If it is, we investigate all possible moves from the current position and check if they fall within the center square, adding a bias of 0.5(smaller, because being able to reach the center is not as good as being in the center). Alternatively, if the center position is not legal, we calculate the cumulative manhattan distance from each possible next position, to the center position and take the average. If the average is less than 1.1 (meaning, that we're pretty close to the center), we add a bias of 0.5. Otherwise, we return the difference in the number of moves as in IDImproved.

1.2 Score best square

The next idea came from the fact that the center square is not necessarily the best square on the board. The best square is the one which has the biggest number of potential moves from it. To find this square, we simply iterate through all blank squares, trying all the legal moves from them and saving the one which has the most possible moves. To break ties, we chose a square which is closest to the center. Once we have the best position, we can take a similar approach to the one we took in the center bias function. However, for this function, we're completely ignoring the the number of current possible moves for either player. Instead, we calculate the cumulative distance for each legal move of the current player to the best square. We also do the same thing for the opponent. Finally, we subtract the current player distance from the opponent distance to get the final result, because bigger distance from the center square means worse results.

1.3 Score best square improved v1

The next function combines ideas from the previous two and adds a few improvements. To improve the best square function we speed the calculation by ignoring the ties when we count the number of possible legal moves to find the best position on the board. As long as we pick one of the squares which has the maximum number of possible moves, we are happy. Secondly,like with the center bias function, we treat the distance as a bias. However, the way we do that is not by using a constant factor. We take the difference between the average distance for the opponent and the current player to the best square, and we add that to the IDImproved score. By doing that, we still add value to the number of possible positions from the current position. However we also make sure that we give some bias to how good strategically the next position is going to be.

1.4 Score best square improved v2

The final evaluation function tries to improve upon the previous one. It calculates the best square and the distances in a similar fashion. However, we also check if there is an immediate move that leads directly to the best square. If only one of the players has a move to that square we make sure to add extra bias to how good or bad the position is. The reasoning behind this is that if the current player doesn't have access to the best move, but the opponent does, the opponent is likely to take that move next, which is the main weakness of our heuristic to measure the closeness to the best square.

2 Performance Data

To gather performance data, I created a Custom Player for each of my agents and modified the tournament utility to be able to make them fight each other. The name of the players are CentreBias, BestSquare, Student and SmarterBestSquare and use functions 1.1, 1.2, 1.3 and 1.4 respectively. Here is an example run of 20 games for each possible combination:

```
(aind) >  aind-isolation python tournament.py

This script evaluates the performance of the custom heuristic function by
comparing the strength of an agent using iterative deepening (ID) search with
alpha-beta pruning against the strength rating of agents using other heuristic
functions.  The ‘ID_Improved‘ agent provides a baseline by measuring the
performance of a basic agent using Iterative Deepening and the ”improved”
heuristic (from lecture) on your hardware.  The ‘Student‘ agent then measures
the performance of Iterative Deepening and the custom heuristic against the
same opponents.


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

Playing Matches:
----------
  Match 1: ID_Improved vs   Student      Result: 9 to 11
  Match 2: ID_Improved vs BestSquare     Result: 14 to 6
  Match 3: ID_Improved vs CentreBias     Result: 9 to 11
  Match 4: ID_Improved vs SmarterBestSquare      Result: 7 to 13
  Match 5: ID_Improved vs   Random       Result: 18 to 2
  Match 6: ID_Improved vs   MM_Open      Result: 13 to 7
  Match 7: ID_Improved vs MM_Improved    Result: 11 to 9
  Match 8: ID_Improved vs   AB_Open      Result: 15 to 5
  Match 9: ID_Improved vs AB_Improved    Result: 11 to 9


Results:
----------
ID_Improved             59.44%

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

Playing Matches:
----------
  Match 1:    Student    vs BestSquare     Result: 13 to 7
  Match 2:    Student    vs CentreBias     Result: 10 to 10
  Match 3:    Student    vs SmarterBestSquare      Result: 10 to 10
  Match 4:    Student    vs ID_Improved    Result: 9 to 11
  Match 5:    Student    vs   Random       Result: 17 to 3
  Match 6:    Student    vs   MM_Open      Result: 12 to 8
  Match 7:    Student    vs MM_Improved    Result: 15 to 5
  Match 8:    Student    vs   AB_Open      Result: 13 to 7
  Match 9:    Student    vs AB_Improved    Result: 13 to 7
```

```

Results:
----------
Student                62.22%

*************************
 Evaluating: BestSquare
*************************

Playing Matches:
----------
  Match 1: BestSquare  vs   Student      Result: 6 to 14
  Match 2: BestSquare  vs CentreBias     Result: 11 to 9
  Match 3: BestSquare  vs SmarterBestSquare      Result: 11 to 9
  Match 4: BestSquare  vs ID_Improved    Result: 8 to 12
  Match 5: BestSquare  vs   Random       Result: 19 to 1
  Match 6: BestSquare  vs   MM_Open      Result: 12 to 8
  Match 7: BestSquare  vs MM_Improved    Result: 13 to 7
  Match 8: BestSquare  vs   AB_Open      Result: 13 to 7
  Match 9: BestSquare  vs AB_Improved    Result: 12 to 8


Results:
----------
BestSquare             58.33%

*************************
 Evaluating: CentreBias
*************************

Playing Matches:
----------
  Match 1: CentreBias  vs   Student      Result: 9 to 11
  Match 2: CentreBias  vs BestSquare     Result: 14 to 6
  Match 3: CentreBias  vs SmarterBestSquare      Result: 7 to 13
  Match 4: CentreBias  vs ID_Improved    Result: 10 to 10
  Match 5: CentreBias  vs   Random       Result: 15 to 5
  Match 6: CentreBias  vs   MM_Open      Result: 15 to 5
  Match 7: CentreBias  vs MM_Improved    Result: 10 to 10
  Match 8: CentreBias  vs   AB_Open      Result: 11 to 9
  Match 9: CentreBias  vs AB_Improved    Result: 11 to 9


Results:
----------
CentreBias             56.67%

*************************
Evaluating: SmarterBestSquare
*************************

Playing Matches:
----------
  Match 1: SmarterBestSquare vs   Student        Result: 11 to 9
  Match 2: SmarterBestSquare vs BestSquare       Result: 12 to 8
  Match 3: SmarterBestSquare vs CentreBias       Result: 11 to 9
  Match 4: SmarterBestSquare vs ID_Improved      Result: 8 to 12
  Match 5: SmarterBestSquare vs   Random         Result: 16 to 4
  Match 6: SmarterBestSquare vs   MM_Open        Result: 13 to 7
  Match 7: SmarterBestSquare vs MM_Improved      Result: 13 to 7
  Match 8: SmarterBestSquare vs   AB_Open        Result: 11 to 9
  Match 9: SmarterBestSquare vs AB_Improved      Result: 14 to 6


Results:
----------
SmarterBestSquare      60.56%
```

And finally, here is a table of winrate percentages, where each Custom Agent was put against the other agents over 200 games overnight to determine to try and eliminate random skew in the results, ordered by winrate:

Agent	Winrate
Student	63.67%
SmarterBestSquare	61.39%
ID Improved	60.3%
CentreBias	58.39%
BestSquare	48.56%

3 Conclusions and the evaluation function picked

The results show that the evaluation function described in 1.3 is a clear winner in the tournament in terms of overall results, and that's why it was picked to be the main evaluation function for this submission.

Individually, it is also the best function overall as it manages to beat the biggest number of agents in it's own tournament.

Let's define a win as having a bigger winrate over N number of games and loss as the opposite of that. As you can see below IDImproved lost to both Student and SmarterBestSquare. Student lost only to SmarterBestSquare and SmarterBestSquare lost to both CentreBias and Student.

Even though SmarterBestSquare has the potential to beat Student in a 1v1 tournament, it is more specific and exploitable by other agents and focuses too much on the best position heuristic I described above. It also takes more time for extra computations, which given the exponential nature of the problem, can be very expensive making SmarterBestSquare a risky choice against faster agents.

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

Playing Matches:
----------

  Match 1: ID_Improved vs BestSquare     Result: 125 to 75
  Match 2: ID_Improved vs CentreBias     Result: 105 to 95
  Match 3: ID_Improved vs SmarterBestSquare      Result: 95 to 105
  Match 4: ID_Improved vs   Student      Result: 97 to 103
  Match 5: ID_Improved vs   Random       Result: 177 to 23
  Match 6: ID_Improved vs   MM_Open      Result: 130 to 70
  Match 7: ID_Improved vs MM_Improved    Result: 122 to 78
  Match 8: ID_Improved vs   AB_Open      Result: 118 to 82
  Match 9: ID_Improved vs AB_Improved    Result: 117 to 83
```

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

Playing Matches:
----------

  Match 1:   Student   vs ID_Improved    Result: 111 to 89
  Match 2:   Student   vs BestSquare     Result: 139 to 61
  Match 3:   Student   vs CentreBias     Result: 112 to 88
  Match 4:   Student   vs SmarterBestSquare      Result: 98 to 102
  Match 5:   Student   vs   Random       Result: 173 to 27
  Match 6:   Student   vs   MM_Open      Result: 142 to 58
  Match 7:   Student   vs MM_Improved    Result: 125 to 75
  Match 8:   Student   vs   AB_Open      Result: 128 to 72
  Match 9:   Student   vs AB_Improved    Result: 118 to 82
```

```
*************************
Evaluating: SmarterBestSquare
*************************

Playing Matches:
----------
  Match 1: SmarterBestSquare vs ID_Improved     Result: 100 to 100
  Match 2: SmarterBestSquare vs BestSquare      Result: 124 to 76
  Match 3: SmarterBestSquare vs CentreBias      Result: 98 to 102
  Match 4: SmarterBestSquare vs   Student       Result: 99 to 101
  Match 5: SmarterBestSquare vs   Random        Result: 170 to 30
  Match 6: SmarterBestSquare vs   MM_Open       Result: 140 to 60
  Match 7: SmarterBestSquare vs MM_Improved     Result: 132 to 68
  Match 8: SmarterBestSquare vs   AB_Open       Result: 119 to 81
  Match 9: SmarterBestSquare vs AB_Improved     Result: 123 to 77
```