Semester 1 Session 2020/2021

WID3009
Heuristic Analysis Activity

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TABLE OF CONTENTS

SYNOPSIS

The project aims at developing an adversarial search agent to play the game "Isolation". This project report focusses on the heuristics to be used in A* Search for minimax and alphabeta pruning.

Isolation is a deterministic, two-player game of perfect information in which the players alternate turns moving a single piece from one cell to another on a board. Whenever either player occupies a cell, that cell becomes blocked for the remainder of the game. The first player with no remaining legal moves loses, and the opponent is declared the winner.

This project uses a version of Isolation where each agent is restricted to L-shaped movements (like a knight in chess) on a rectangular grid (like a chess or checkerboard). The agents can move to any open cell on the board that is 2rows and 1-column or 2-columns and 1-row away from their current position on the board. Movements are blocked at the edges of the board (the board does not wrap around), however, the player can "jump" blocked or occupied spaces (just like a knight in chess).

Additionally, agents will have a fixed time limit each turn to search for the best move and respond. If the time limit expires during a player's turn, that player forfeits the match, and the opponent wins. These rules are implemented in the isolation. Board class provided in the repository.

CUSTOM HEURISTICS

1. CUSTOM HEURISTIC

The heuristic based on the logic that player should have more moves in comparison to opponent and opponent should have less moves in comparison to player. The depth of the tree also taken into consideration.
It can be mathematically expressed as:

$$\alpha \frac{len(my\ available\ moves)}{len(available\ opponent\ moves)} - \frac{len(available\ opponent\ moves)}{len(my\ available\ moves)}, where\ \alpha \in (1, \infty)$$

Maximizing above equation is equivalent to maximizing:

$$\beta[len(my\ available\ moves)]^2 - [len(my\ available\ moves)]^2 - depth(0.01), where\ \beta \in (1, \infty)$$

The latter form has been implemented in the code with β chosen as 1.5 empirically.

EVALUATING HEURISTICS

The tournament.py script is used to evaluate the effectiveness of heuristic. The script measures relative performance of player in a round-robin tournament against several other pre-defined agents.

The performance of time-limited iterative deepening search is hardware dependent (faster hardware is expected to search deeper than slower hardware in the same amount of time). The script controls for these effects by also measuring the baseline performance of an agent called "ID_Improved" that uses Iterative Deepening and the improved_score heuristic from sample_players.py.

The tournament opponents are listed below:

- Random: An agent that randomly chooses a move each turn.
- MM_Null: CustomPlayer agent using fixed-depth minimax search and the null_score heuristic
- MM_Open: CustomPlayer agent using fixed-depth minimax search and the open_move_score heuristic
- MM_Improved: CustomPlayer agent using fixed-depth minimax search and the improved_score heuristic
- AB_Null: CustomPlayer agent using fixed-depth alpha-beta search and the null_score heuristic
- AB_Open: CustomPlayer agent using fixed-depth alpha-beta search and the open_move_score heuristic
- AB_Improved: CustomPlayer agent using fixed-depth alpha-beta search and the improved_score heuristic
- ID_Improved: CustomPlayer agent using iterative alpha-beta search and the improved_score heuristic
- Student1: CustomPlayer agent using iterative alpha-beta search and the heuristic 1
- Student2: CustomPlayer agent using iterative alpha-beta search and the heuristic 2
- Student3: CustomPlayer agent using iterative alpha-beta search and the heuristic 3
- Student4: CustomPlayer agent using iterative alpha-beta search and the heuristic 4
- Student5: CustomPlayer agent using iterative alpha-beta search and the heuristic 5
- Student6: CustomPlayer agent using iterative alpha-beta search and the heuristic 6
- Student7: CustomPlayer agent using iterative alpha-beta search and the heuristic 7
- MyHeuristic: CustomPlayer agent using iterative alpha-beta search and the custom heuristic

Since, running take a few hours to completed, the number of matches were reduced from 5 to 10.

RESULTS

The performance of various agents is as follow:

Agent	Performance	Rank
ID_Improved	59.29%	11
Student1	54.29%	12
Student2	59.29%	10
Student3	65.00%	5
Student4	67.86%	2
Student5	60.00%	9
Student6	63.57%	7
Student7	62.86%	8
MyHeuristic	65.71%	3
TeamMember1 (Syafik)	65.00%	4
TeamMember2 (Hakim)	64.29%	6
TeamMember3 (Aqiff)	67.86%	1

All the custom heuristics perform better than ID_Improved by a reasonable margin as can be seen in the above table. Student4 and my team member Aqiff performs better than other including my custom heuristic.

APPENDICES

A. APPENDIX: EVALUATION RESULT

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   Random      Result: 16 to 4
  Match 2: ID_Improved vs   MM_Null     Result: 14 to 6
  Match 3: ID_Improved vs   MM_Open     Result: 9 to 11
  Match 4: ID_Improved vs MM_Improved   Result: 7 to 13
  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        59.29%

*************************
  Evaluating: Student1
*************************

Playing Matches:
----------
  Match 1:  Student1   vs    Random      Result: 15 to 5
  Match 2:  Student1   vs    MM_Null     Result: 12 to 8
  Match 3:  Student1   vs    MM_Open     Result: 8 to 12
  Match 4:  Student1   vs MM_Improved    Result: 7 to 13
  Match 5:  Student1   vs    AB_Null     Result: 13 to 7
  Match 6:  Student1   vs    AB_Open     Result: 11 to 9
  Match 7:  Student1   vs AB_Improved    Result: 10 to 10


Results:
----------
Student1           54.29%
```

```
*************************
  Evaluating: Student2
*************************

Playing Matches:
----------
  Match 1:  Student2   vs    Random      Result: 17 to 3
  Match 2:  Student2   vs    MM_Null     Result: 13 to 7
  Match 3:  Student2   vs    MM_Open     Result: 10 to 10
  Match 4:  Student2   vs MM_Improved    Result: 9 to 11
  Match 5:  Student2   vs    AB_Null     Result: 14 to 6
  Match 6:  Student2   vs    AB_Open     Result: 10 to 10
  Match 7:  Student2   vs AB_Improved    Result: 10 to 10


Results:
----------
Student2          59.29%

*************************
  Evaluating: Student3
*************************

Playing Matches:
----------
  Match 1:  Student3   vs    Random      Result: 18 to 2
  Match 2:  Student3   vs    MM_Null     Result: 14 to 6
  Match 3:  Student3   vs    MM_Open     Result: 12 to 8
  Match 4:  Student3   vs MM_Improved    Result: 9 to 11
  Match 5:  Student3   vs    AB_Null     Result: 12 to 8
  Match 6:  Student3   vs    AB_Open     Result: 14 to 6
  Match 7:  Student3   vs AB_Improved    Result: 12 to 8


Results:
----------
Student3          65.00%

*************************
  Evaluating: Student4
*************************

Playing Matches:
----------
  Match 1:  Student4   vs    Random      Result: 20 to 0
  Match 2:  Student4   vs    MM_Null     Result: 12 to 8
  Match 3:  Student4   vs    MM_Open     Result: 14 to 6
  Match 4:  Student4   vs MM_Improved    Result: 10 to 10
  Match 5:  Student4   vs    AB_Null     Result: 11 to 9
  Match 6:  Student4   vs    AB_Open     Result: 16 to 4
  Match 7:  Student4   vs AB_Improved    Result: 12 to 8
```

```
Results:
----------
Student4          67.86%


************************
  Evaluating: Student5
************************

Playing Matches:
----------
  Match 1:  Student5   vs   Random      Result: 15 to 5
  Match 2:  Student5   vs   MM_Null     Result: 11 to 9
  Match 3:  Student5   vs   MM_Open     Result: 13 to 7
  Match 4:  Student5   vs MM_Improved   Result: 10 to 10
  Match 5:  Student5   vs   AB_Null     Result: 13 to 7
  Match 6:  Student5   vs   AB_Open     Result: 12 to 8
  Match 7:  Student5   vs AB_Improved   Result: 10 to 10


Results:
----------
Student5          60.00%


************************
  Evaluating: Student6
************************

Playing Matches:
----------
  Match 1:  Student6   vs   Random      Result: 16 to 4
  Match 2:  Student6   vs   MM_Null     Result: 15 to 5
  Match 3:  Student6   vs   MM_Open     Result: 10 to 10
  Match 4:  Student6   vs MM_Improved   Result: 11 to 9
  Match 5:  Student6   vs   AB_Null     Result: 14 to 6
  Match 6:  Student6   vs   AB_Open     Result: 14 to 6
  Match 7:  Student6   vs AB_Improved   Result: 9 to 11


Results:
----------
Student6          63.57%


************************
  Evaluating: Student7
************************

Playing Matches:
----------
  Match 1:  Student7   vs   Random      Result: 18 to 2
  Match 2:  Student7   vs   MM_Null     Result: 14 to 6
  Match 3:  Student7   vs   MM_Open     Result: 7 to 13
  Match 4:  Student7   vs MM_Improved   Result: 11 to 9
  Match 5:  Student7   vs   AB_Null     Result: 13 to 7
  Match 6:  Student7   vs   AB_Open     Result: 11 to 9
```

```
  Match 7:  Student7   vs AB_Improved   Result: 14 to 6


Results:
----------
Student7            62.86%


************************
 Evaluating: MyHeuristic
************************

Playing Matches:
----------
  Match 1: MyHeuristic vs    Random     Result: 15 to 5
  Match 2: MyHeuristic vs    MM_Null    Result: 15 to 5
  Match 3: MyHeuristic vs    MM_Open    Result: 11 to 9
  Match 4: MyHeuristic vs MM_Improved   Result: 9 to 11
  Match 5: MyHeuristic vs    AB_Null    Result: 14 to 6
  Match 6: MyHeuristic vs    AB_Open    Result: 13 to 7
  Match 7: MyHeuristic vs AB_Improved   Result: 15 to 5


Results:
----------
MyHeuristic         65.71%


************************
  Evaluating: TeamMember1
************************

Playing Matches:
----------
  Match 1:  TeamMember1   vs    Random     Result: 16 to 4
  Match 2:  TeamMember1   vs    MM_Null    Result: 14 to 6
  Match 3:  TeamMember1   vs    MM_Open    Result: 14 to 6
  Match 4:  TeamMember1   vs MM_Improved   Result: 11 to 9
  Match 5:  TeamMember1   vs    AB_Null    Result: 12 to 8
  Match 6:  TeamMember1   vs    AB_Open    Result: 12 to 8
  Match 7:  TeamMember1   vs AB_Improved   Result: 12 to 8

 Results:
----------
TeamMember1         65.00%


************************
  Evaluating: TeamMember2
************************

Playing Matches:
----------
  Match 1:  TeamMember2   vs    Random     Result: 14 to 6
  Match 2:  TeamMember2   vs    MM_Null    Result: 16 to 4
```

```
  Match 3:  TeamMember2    vs    MM_Open    Result: 12 to 8
  Match 4:  TeamMember2    vs MM_Improved  Result: 8 to 12
  Match 5:  TeamMember2    vs    AB_Null    Result: 14 to 6
  Match 6:  TeamMember2    vs    AB_Open    Result: 15 to 5
  Match 7:  TeamMember2    vs AB_Improved  Result: 11 to 9


 Results:
----------
TeamMember2            64.29%


************************
  Evaluating: TeamMember3
************************


Playing Matches:
----------
  Match 1:  TeamMember3    vs    Random     Result: 18 to 2
  Match 2:  TeamMember3    vs    MM_Null    Result: 15 to 5
  Match 3:  TeamMember3    vs    MM_Open    Result: 10 to 10
  Match 4:  TeamMember3    vs MM_Improved  Result: 9 to 11
  Match 5:  TeamMember3    vs    AB_Null    Result: 18 to 2
  Match 6:  TeamMember3    vs    AB_Open    Result: 12 to 8
  Match 7:  TeamMember3    vs AB_Improved  Result: 13 to 7


 Results:
----------
TeamMember3            67.86%
```