UNIVERSITY OF MALAYA

Heuristic Analysis Report

For an Adversarial Game Playing Agent for Isolation

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1. Synopsis

The project aims at developing an adversarial search agent to play the game “Isolation”. This project report focusses on the heuristic to be used in A* Search for minimax and alpha-beta 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 a player occupies a cell, that cell becomes blocked for the reminder 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/checkerboard). The agent can move to any open cell on the board that is 2-rows 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.

2. Custom heuristic

2.1 Default Heuristic

The heuristic is based on the logic that the difference between the player's moves and opponent's moves. It can be mathematically expressed as:

$$len(my\ available\ moves) - len(available\ opponent\ moves)$$

2.2 Heuristic 1: Minimizing Opponent's Moves

The heuristic is based on the logic that opponent's moves should be minimized. It can be mathematically expressed as:

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

The value of α was empirically chosen as 1.5

2.3 Heuristic 2: Maximizing Player's Moves

The heuristic is based on the logic that player's moves should be maximized. It can be mathematically expressed as:

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

The value of α was empirically chosen as 1.5

2.4 Heuristic 3: Maximizing Ratio of Player to Opponent Moves

The heuristic is based on the logic that player should have more moves in comparison to opponent. It can be mathematically expressed as:

$$\frac{len(my\ available\ moves)}{len(available\ opponent\ moves)}$$

2.5 Heuristic 4: Minimizing Ratio of Opponent to Player Moves

The heuristic is based on the logic that opponent should have less moves in comparison to player. It can be mathematically expressed as:

$$-\frac{len(available\ opponent\ moves)}{len(my\ available\ moves)}$$

2.6 Heuristic 5: Combining Heuristic 3 and 4

Can be mathematically expressed as:

$$\frac{len(my\ available\ moves)}{len(available\ opponent\ moves)} - \frac{len(available\ opponent\ moves)}{len(my\ available\ moves)}$$

Maximizing above equation is equivalent to maximizing:

$$[len(my\ available\ moves)]^2 - [len(available\ opponent\ moves)]^2$$

2.7 Heuristic 6: Weighted combination of Heuristic 3 and 4

Can be mathematically expressed as:

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

Maximizing above equation is equivalent to maximizing:

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

2.8 Heuristic 7: Weighted combination of Heuristic 3 and 4

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:

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

2.9 Custom Heuristic

The heuristic is based on the logic that for each player and opponent's moves are considered. First, we will iterate for each move for player and make it move and increment the initial value of the player's moves. The action is then repeated for the opponent. At the end, the logic used can be mathematically expressed as:

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

The value of α was empirically chosen as 3.

3. Evaluating Heuristic

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

• 17080476: CustomPlayer agent using iterative alpha-beta search and the Custom Heuristic

Since, running only a few matches gave different results, the number of matches is set to 10, with all group members agreed to it because faster execution time. Timeout value is 150 which is the default value.

4. Results

Results are compared between the baseline default (ID_Improved), 7 students and 3 of my group members. The results as follow:

Agent	Performance	Rank	Rank (Group members)
ID_Improved	60.36%	9	
Student1	65.71%	4	
Student2	68.57%	1	
Student3	62.86%	8	
Student4	64.64%	5	
Student5	63.57%	7	
Student6	66.07%	3	
Student7	64.29%	6	
17080476	67.86%	2	3
Alif	68.21%		2
Amin	66.79%		4
Fedellic	79.64%		1

The custom heuristic performs better than ID_Imporved by a reasonable margin which can be seen in the table. Heuristic 5

5. Appendices

```
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: 35 to 5
  Match 2: ID_Improved vs   MM_Null     Result: 26 to 14
  Match 3: ID_Improved vs   MM_Open     Result: 23 to 17
  Match 4: ID_Improved vs MM_Improved   Result: 16 to 24
  Match 5: ID_Improved vs   AB_Null     Result: 23 to 17
  Match 6: ID_Improved vs   AB_Open     Result: 25 to 15
  Match 7: ID_Improved vs AB_Improved   Result: 21 to 19


Results:
----------
ID_Improved         60.36%

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

Playing Matches:
----------
  Match 1:  Student1   vs   Random      Result: 35 to 5
  Match 2:  Student1   vs   MM_Null     Result: 24 to 16
  Match 3:  Student1   vs   MM_Open     Result: 22 to 18
  Match 4:  Student1   vs MM_Improved   Result: 25 to 15
  Match 5:  Student1   vs   AB_Null     Result: 29 to 11
  Match 6:  Student1   vs   AB_Open     Result: 26 to 14
  Match 7:  Student1   vs AB_Improved   Result: 23 to 17


Results:
----------
Student1            65.71%
```

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

Playing Matches:
----------
  Match 1:  Student2   vs   Random      Result: 30 to 10
  Match 2:  Student2   vs   MM_Null     Result: 31 to 9
  Match 3:  Student2   vs   MM_Open     Result: 28 to 12
  Match 4:  Student2   vs MM_Improved   Result: 21 to 19
  Match 5:  Student2   vs   AB_Null     Result: 30 to 10
  Match 6:  Student2   vs   AB_Open     Result: 26 to 14
  Match 7:  Student2   vs AB_Improved   Result: 26 to 14


Results:
----------
Student2            68.57%

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

Playing Matches:
----------
  Match 1:  Student3   vs   Random      Result: 37 to 3
  Match 2:  Student3   vs   MM_Null     Result: 30 to 10
  Match 3:  Student3   vs   MM_Open     Result: 20 to 20
  Match 4:  Student3   vs MM_Improved   Result: 18 to 22
  Match 5:  Student3   vs   AB_Null     Result: 24 to 16
  Match 6:  Student3   vs   AB_Open     Result: 24 to 16
  Match 7:  Student3   vs AB_Improved   Result: 23 to 17


Results:
----------
Student3            62.86%

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

Playing Matches:
----------
  Match 1:  Student4   vs   Random      Result: 34 to 6
  Match 2:  Student4   vs   MM_Null     Result: 30 to 10
  Match 3:  Student4   vs   MM_Open     Result: 21 to 19
  Match 4:  Student4   vs MM_Improved   Result: 21 to 19
  Match 5:  Student4   vs   AB_Null     Result: 28 to 12
  Match 6:  Student4   vs   AB_Open     Result: 25 to 15
  Match 7:  Student4   vs AB_Improved   Result: 22 to 18


Results:
----------
Student4            64.64%
```

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

Playing Matches:
----------
  Match 1:  Student5   vs   Random      Result: 33 to 7
  Match 2:  Student5   vs   MM_Null     Result: 28 to 12
  Match 3:  Student5   vs   MM_Open     Result: 23 to 17
  Match 4:  Student5   vs MM_Improved   Result: 20 to 20
  Match 5:  Student5   vs   AB_Null     Result: 26 to 14
  Match 6:  Student5   vs   AB_Open     Result: 21 to 19
  Match 7:  Student5   vs AB_Improved   Result: 27 to 13


Results:
----------
Student5            63.57%

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

Playing Matches:
----------
  Match 1:  Student6   vs   Random      Result: 33 to 7
  Match 2:  Student6   vs   MM_Null     Result: 28 to 12
  Match 3:  Student6   vs   MM_Open     Result: 27 to 13
  Match 4:  Student6   vs MM_Improved   Result: 21 to 19
  Match 5:  Student6   vs   AB_Null     Result: 29 to 11
  Match 6:  Student6   vs   AB_Open     Result: 23 to 17
  Match 7:  Student6   vs AB_Improved   Result: 24 to 16


Results:
----------
Student6            66.07%

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

Playing Matches:
----------
  Match 1:  Student7   vs   Random      Result: 38 to 2
  Match 2:  Student7   vs   MM_Null     Result: 29 to 11
  Match 3:  Student7   vs   MM_Open     Result: 17 to 23
  Match 4:  Student7   vs MM_Improved   Result: 18 to 22
  Match 5:  Student7   vs   AB_Null     Result: 27 to 13
  Match 6:  Student7   vs   AB_Open     Result: 28 to 12
  Match 7:  Student7   vs AB_Improved   Result: 23 to 17


Results:
----------
Student7            64.29%
```

```
**************************
  Evaluating: 17080476
**************************

Playing Matches:
----------
  Match 1:  17080476   vs   Random      Result: 37 to 3
  Match 2:  17080476   vs   MM_Null     Result: 31 to 9
  Match 3:  17080476   vs   MM_Open     Result: 23 to 17
  Match 4:  17080476   vs MM_Improved   Result: 23 to 17
  Match 5:  17080476   vs   AB_Null     Result: 32 to 8
  Match 6:  17080476   vs   AB_Open     Result: 22 to 18
  Match 7:  17080476   vs AB_Improved   Result: 25 to 15


Results:
----------
17080476          68.93%
```

```
*************************
  Evaluating: 17080476
*************************

Playing Matches:
----------
  Match 1:  17080476   vs   Random      Result: 36 to 4
  Match 2:  17080476   vs   MM_Null     Result: 33 to 7
  Match 3:  17080476   vs   MM_Open     Result: 22 to 18
  Match 4:  17080476   vs MM_Improved   Result: 18 to 22
  Match 5:  17080476   vs   AB_Null     Result: 29 to 11
  Match 6:  17080476   vs   AB_Open     Result: 27 to 13
  Match 7:  17080476   vs AB_Improved   Result: 25 to 15


Results:
----------
17080476          67.86%
```