Heuristic Analysis for Isolation Game

Overview

In this report, we first introduce three heuristics for the isolation game on 7×7 board in which each player can move in the same way as the knight of the chess. We then analyze the performance of the three models based on the iterative deepening mini-max algorithm with α-β pruning and these three heuristics. Our analysis shows that two of our three models outperform the model based on the same algorithm with the improved open space score heuristic.

Heuristics

Here we introduce three heuristics we use for the isolation games. Our heuristics are mainly based on the number of the possible moves by the current player and that by the opponent. The followings are the definitions of the evaluation functions for the three heuristics we use for our analysis:

- **Heuristic 1 (Best One)**
  Asymmetric Improved Open Move Score Heuristic (Varying Ratio)

  The evaluation function is given by

  $$(\text{\# of possible moves by player}) - 0.5 \times \frac{\text{\# of blank spaces}}{\text{\# of spaces } (=49)} \times (\text{\# of possible moves by opponent})$$

  In the above expression, the coefficient in front of the second term varies depending on how many blank spaces there are at that point. As a game proceeds, the number of the possible moves by the player becomes more and more relevant for the evaluation compared to that of the opponent. We call the model based on this heuristic by AB_Custom model.

- **Heuristic 2**
  Asymmetric Improved Open Move Score Heuristic (Fixed Ratio)

  The evaluation function is given by

  $$(\text{\# of possible moves by player}) - 0.5 \times (\text{\# of possible moves by opponent})$$

  In this case, the ratio between the first and the second term is fixed. Compared to the usual improved open space score heuristic (for which the evaluation function is given by (the number of the possible moves by the player) - (the number of the possible moves by the opponent)), the number of the possible move by the opponent is less relevant for the evaluation. We call the model based on this heuristic by AB_Custom1 model.

- **Heuristic 3**
  Center Score + Asymmetric Improved Open Move Score Heuristic (Fixed Ratio)

  The evaluation function is given as follows: if the number of the blank spaces is larger than 60% of the total number of spaces ($= 49 \times 0.6 = 29.4$), then the evaluation function is

  $$(\text{distance of the player from the center of the board})^2$$

  otherwise it is given by

  $$(\text{\# of possible moves by current player}) - 0.5 \times (\text{\# of possible moves by opponent})$$

  This means, at the early stage of the game, the center score heuristic is used for the evaluation and then the asymmetric improved open score heuristic (with fixed ratio) is used later. We call the model based on this heuristic by AB_Custom2 model.

Performance

To see the performance of AB_Custom, AB_Custom2 and AB_Custom3 models, we have played the games by setting the models based on random choice, depth-limited mini-max algorithm and iterative deepening mini-max algorithm with α-β pruning as the opponents. For the heuristics of the opponents based on the mini-max algorithm (with/without α-β pruning), we have used the open move score heuristic (evaluation function = the number of the possible moves by the player), the center score heuristic (evaluation function = the squared distance of the current player from the center of the board) and the improved open move score heuristic.

With each opponent, each of our three models played 10 games. To compare with the performance of our models, we have also played games between these opponents and the model based on the iterative deepening mini-max algorithm with α-β pruning with the improved open move score heuristic (called AB_Improved model).

For the computer to run the games, we have used MacBook (12 inch, early 2016), 1.1 GHz Intel Core m3, 8 GB RAM, OS Sierra.

The result of the games is summarized in Fig. 1. The win rates are visualized as a bar plot in Fig. 2. Judging from the win rate, our models with Heuristic 1 (win rate 74.3%) and Heuristic 3 (win rate 72.9%) outperform AB_Improved model (win rate 68.6%). On the other hand, the performance of the model with Heuristic 2 is worse (win rate 65.7 %) than that of AB_Improved model.

Observations

Judging from the above analysis on the performance, the best heuristic we recommend is **Heuristic 1**. The first reason is that the model with this heuristic achieved the best winning rate. On top of this, this model wins AB_Improved model by 7 to 3 (which is the highest rate among AB_Improved, AB_Custom, AB_Custom2 and AB_Custom3). It is also worthwhile to note that this model shows the win rate greater than or equal to 50 % against all the opponents (while the model with Heuristic 3 lost against AB_Improved model 6 times out of 10 games). The fact that Heuristic 1 works well indicates that as the game proceeds it is important that the current player itself have more possible moves and that the number of the possible moves by the opponent becomes less relevant.

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     Playing Matches
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Match #	Opponent	AB_Improved		AB_Custom		AB_Custom_2		AB_Custom_3	
		Won	Lost	Won	Lost	Won	Lost	Won	Lost
1	Random	9	1	10	0	10	0	9	1
2	MM_Open	6	4	6	4	7	3	7	3
3	MM_Center	10	0	10	0	10	0	10	0
4	MM_Improved	6	4	9	1	7	3	9	1
5	AB_Open	5	5	5	5	4	6	6	4
6	AB_Center	6	4	5	5	5	5	6	4
7	AB_Improved	6	4	7	3	3	7	4	6
	Win Rate:	68.6%		74.3%		65.7%		72.9%	

Figure 1: Result of games with our heuristics. The meanings of the abbreviations in the names of the opponents are as follows: Random = random choice, MM = depth-limited mini-max, AB = iterative deepening mini-max with α-β pruning, Open = open space score heuristic, Center = center score heuristic, Improved = improved open space score heuristic.

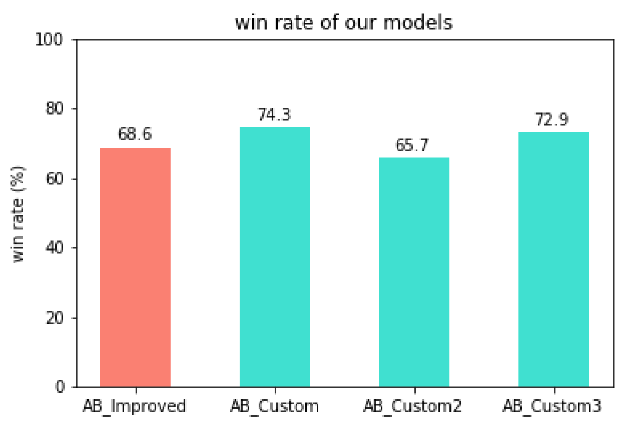

Figure 2: Bar plot for win rates of our models. The red bar represents AB_Improved model with which we compare the performance of our models (green colored bars).