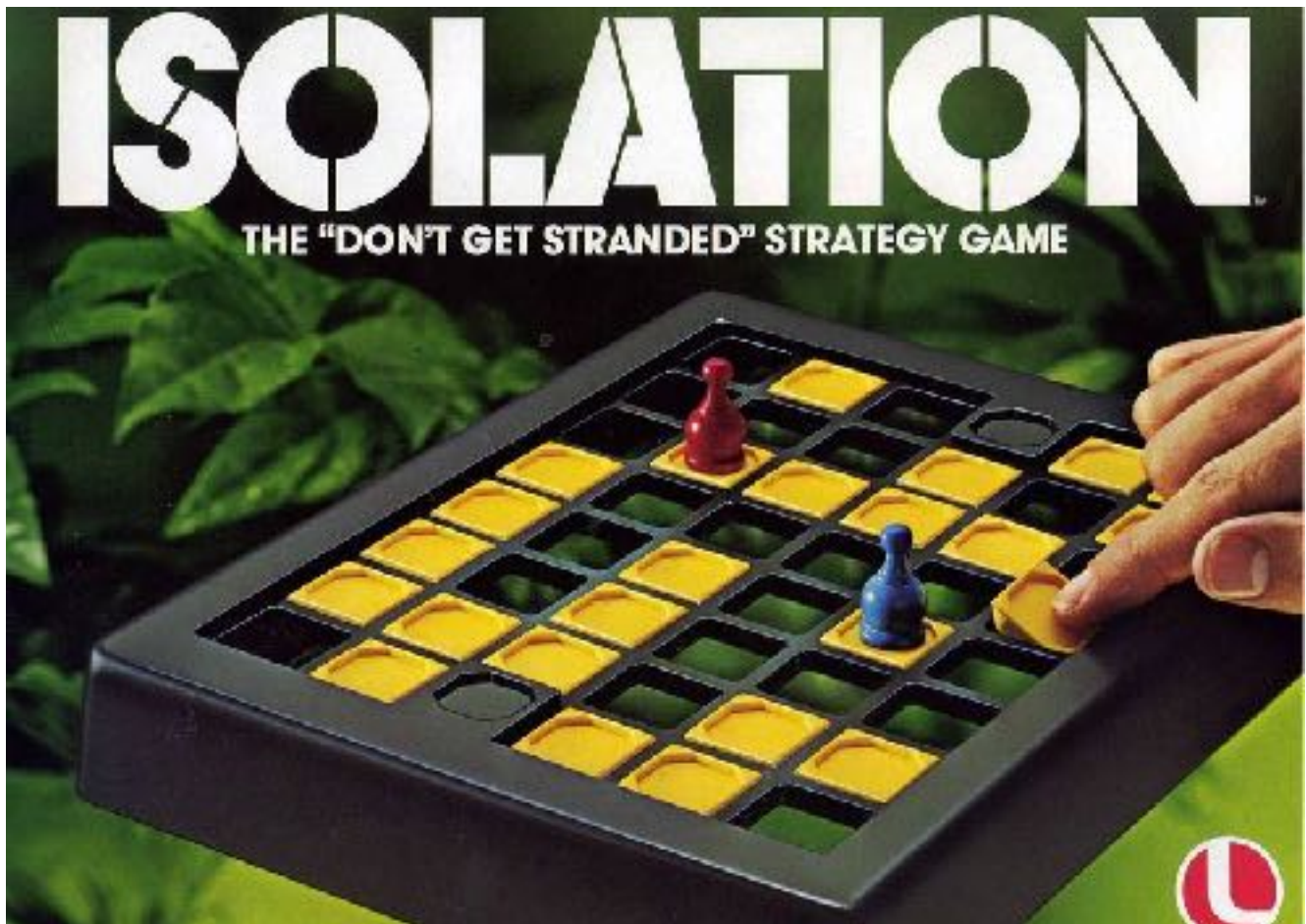# Heuristic Analysis

AI Nano-degree Isolation Project

Zhuo Li - September 24, 2017

Introduction

This report analyzed three heuristics used in the game Isolation. The three heuristics, namely AB_Custom, AB_Custom_2 and AB_Custom_3, are compared against the benchmark heuristic AB_Improved for win rate performance. Each of the heuristic was described and explained in the Heuristics section. Finally, one heuristic was suggested in order to achieve the best performance.

Heuristics

The three heuristics are described in the following section.

1. Heuristic AB_Custom: Minimizing opponents moves with weight

Since the game Isolation rule indicates that player who has no legal moves will be the loser, the most straight forward strategy will be to minimize the opponents legal moves. The strategy can be expressed as:

$$score = a * player\_moves - b * opponent\_moves,$$

where a and b are the weights. This expression can be further simplified to:

$$score = player\_moves - w * opponent\_moves,$$

where a and b will be replaced by w. Bigger weight factor will force the player to become more aggressive and trying to aggressively minimizing the opponent's moves. However, this weight factor is not always proportional to the win rate, especially against different other strategy opponents. Thus, a careful selection of the best weight factor is needed. A variable weight can also be considered:

$$\frac{opponent\_moves}{player\_moves + 1}$$

2. Heuristic AB_Custom_2: Minimizing common moves with weight

Another way to describe the strategy from heuristic one would be to consider the number of common moves available between the player and the opponent. If the opponent takes one of the common moves, it would mean that the player will have fewer legal moves left and vice versa. Hence, in order to minimize the opponent's available moves, we can also take into account the common moves. The strategy can be expressed as:

$$score = player\_moves - opponent\_moves - w * common\_moves.$$

Again, we can choose the weight size. Bigger weight factor will force the player to become more cautious to the common moves and always try to avoid having to many common moves shared with the opponent. However, this weight factor is not always proportional to the win rate, especially against different other strategy opponents. Thus, a careful selection of the best weight factor is needed.

3. Heuristic AB_Custom_3: Center opening & minimizing opponents moves with weight

Center moves are defined as moves that can lead to the most future legal moves. For a 5 x 5 isolation games, all center moves are shown in Fig 2 highlighted. We can define these moves with the following condition:

$$\forall x, \forall y, 2 \leq x < board\_width - 2, 2 \leq y < board\_width - 2,$$

where x, y represent the coordination of moves. In the game of Isolation, center moves will provide the most next step legal moves, hence, a good strategy is to occupy these center moves before the opponent does and gain more future moves. Since the board will be filled with the game development. Hence, these center moves will more valuable and more likely lead to win in the early stage of the game than in the late stage.
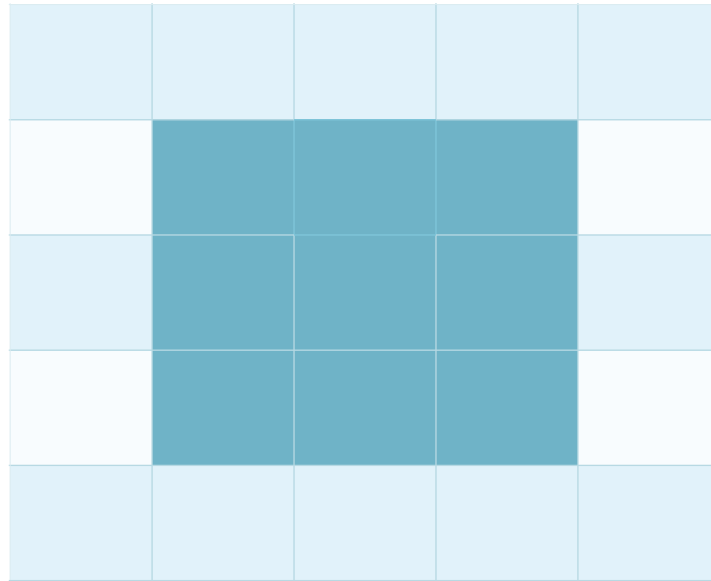

Fig 1. 5 x 5 Isolation Game Board

The strategy here is to give the early stage center moves a very high score in order to make the player tend to choose these moves and the rest of the moves will switch back to the minimizing opponent's moves strategy. Two factors can affect the performance of this heuristic, which are the number of moves to be considered as early stage and the score we are giving to these center moves. Thus, a careful selection is needed for the best performance.

Results and Conclusion

The three heuristics played the game Isolation against seven known heuristics for 10 games each and the statistics are shown in Fig 1. AB_Improved is the heuristic that scores based on the difference of the player's moves and the opponent's moves. AB_Custom is the minimizing the opponent's moves with the weight set to be the ratio of the opponent's moves and the player moves. AB_Custom_2 is the heuristic that evaluates the common moves with the weight set to be the ratio of the opponent's moves and the player moves. AB_Custom_3 is the center opening heuristic with the center moves score set to be *150 - opponent_moves* and the early stage factor (how many turns after the game has started to be considered as the early stage) is set to *2*.

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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	7	3	7	3	9	1
2	MM_Open	7	3	6	4	7	3	7	3
3	MM_Center	6	4	8	2	7	3	8	2
4	MM_Improved	3	7	6	4	6	4	5	5
5	AB_Open	4	6	3	7	7	3	6	4
6	AB_Center	6	4	5	5	6	4	8	2
7	AB_Improved	5	5	7	3	5	5	4	6
	Win Rate:	57.1%		60.0%		64.3%		67.1%	

Fig 2. Results again known agents

From the result we can see that the benchmark AB_Improved has a overall win rate of 57.1% against 7 different opponent strategies; AB_Custom has a overall win rate of 60.0% against 7 different opponent strategies; AB_Custom_2 has a overall win rate of 64.3% against 7 different opponent strategies; AB_Custom_3 has a overall win rate of 67.1% against 7 different opponent strategies. Hence, the final heuristic selection among the four heuristics will be AB_Custom_3, which is the center opening evaluation. The reason for the recommendation is firstly, the center opening heuristic has the highest win rate among the four. Secondly, the center opening heuristic lets the player gain huge advantage in the early stage, thus leads to better results. Finally, the center opening heuristic is more flexible than the rest of the heuristics due to the fact that it has two variable weights. Through adjusting those weights, the agent can always out performance the other heuristics.