Isolation - Heuristic Analysis

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1 Isolation description

Isolation is a game of perfect information, so in any given state there is an optimal value function $v^*(s)$ which determines the outcome of the game.

This function $v^*(s)$ can be calculated using algorithms such as Minimax when the board size is relatively small. As the board size grows, so does the search space, making unfeasible computing the optimal value function.

In the current document, we are discussing the goodness of a set of position evaluation techniques.

2 Student heuristics

2.1 Null score

Null score is basically a random score, because it always returns 0, and so depending on the implementation, the first or last move to be scored is the one that will be chosen. (If we update our best move using a strict greater than, then the first move to be scored will be the chosen). For further metrics about this heuristic, see "2.1 Random Score".

2.2 Random score

Null score always returns a random move, so we expect this heuristic to win 50% of the matches against another random score heuristic. As the game has a huge search space, this heuristic behaves badly against a 'smart heuristic' loosing almost always. (A large search space implies that is difficult to get by change a winning combination).

2.3 Open move score

Open move score assumes that a given state is better than other if it has more legal moves. Although this is true in some cases, it fails when a move to a position with fewer legal moves can result in more legal moves.

To put in context, suppose we following states:

1. There are 3 available moves, but there are no legal moves from them
2. There is only one move, but there are legal moves from that one.

Open move score would give a better score to 1) without taking in account that there are no legal moves from that states.

2.4 Center score distance

The center score, as its name states, it is the distance between the player position and the center of the board (in this case, the euclidean distance).

The idea behind this heuristic comes from the fact that central positions have more legal moves than non-central positions (if you are towards are wall, the number of movements is limited because you cannot pass the wall).

2.5 Improved score

Improved score is a simple yet powerful heuristic that differs in the ones presented above in the fact that takes in account the opponent position.

In isolation game, we can use two different strategies:

1. Maximize the number of moves of the player.
2. Try to minimize the number of moves of the opponent.

This heuristic is approximated as "own_moves - opp_moves" where own_moves and opp_moves is the number of legal moves in a given state.

2.6 Lock opponent score

Lock opponent score is a variation of the improved score, but the heuristic enforces to minimize the number of moves of the opponent by weighting the opp_moves values (in our case, we multiply it by 2)

2.7 Ratio score

Ratio score is another heuristic function based on improved score. The heuristic is calculated as follows "$own\_moves \div opp\_moves''$.

The difference with the improved score is how the scores are scaled. For example, in the improved score, the following tuples are equivalent.

(own_moves = 1, opp_moves = 3), (own_moves = 2, opp_moves = 4) which results in -2

But in the ratio score, those tuples returns different values and the second is better than the first one. Basically, the scores get worse as we approach to 0.

2.8 Look ahead improved score

Look ahead improved score is a heuristic based on improved score, but instead of taking in account the current position, we use the best next move for each player.

2.9 Look ahead improved score v2

Look ahead improved score v2 is a heuristic which is calculated as follows:
"$(sum(own\_la\_frequencies) - own\_moves) - (sum(opp\_la\_frequencies) - opp\_moves)$"
where:

1. own_moves : Own player - The number of moves in the current position
2. own_la_frequencies: Own player - Represent the frequency of every reachable node (in 3 steps)
3. opp_moves : Opponent player - The number of moves in the current position
4. opp_la_frequencies: Opponent player - Represent the frequency of every reacheable node (in 3 steps)

This heuristic encourages those moves which results in more moves, in other words, it enforces the player to go from closed areas to open areas.
As we are taking in account the opponent moves, the heuristic also encourages to lock the opponent in closed areas.

2.10 Look ahead improved score v3

Look ahead improved score v3 is a heuristic which is calculated as follows:
"$sum(own\_moves) - sum(opp\_moves) + (min(own\_moves) \div max(opp\_moves, 1))$"
where:

1. own_moves : Own player - Represent the frequency of every reacheable node (in 3 steps)
2. opp_moves : Opponent player - Represent the frequency of every reacheable node (in 3 steps)

This heuristic is similar to the look ahead improved score, but encourages the positions in which there are loops. Basically, the positions in which there are loops are open areas, so it is similar to count the blank spaces around the player.
As we are taking in account the opponent moves, the heuristic also encourages to lock the opponent in closed areas.

3 Results

The heuristics described so far were tested against the ones provides in the assigment with the following results:

Match #	Opponent	AB_Improved		AB_Custom		AB_Custom_2		AB_Custom_3	
		Won	Lost	Won	Lost	Won	Lost	Won	Lost
1	Random	38	12	39	11	44	6	41	9
2	MM_Open	32	18	35	15	41	9	33	17
3	MM_Center	37	13	37	13	39	11	37	13
4	MM_Improved	33	17	32	18	34	16	33	17
5	AB_Open	27	23	27	23	26	24	27	23
6	AB_Center	23	27	28	22	33	17	34	16
7	AB_Improved	25	25	27	23	24	26	26	24
	Win Rate:	61.4%		64.3%		68.9%		66.0%	

All the heuristics have been evaluated in 50 matches where the first two movements were placed randomly.

The results show that all our agents have beaten the agent ID improved in the total percentage.

The agent that showed a better behavior was the agent AB_Custom_2, obtaining a score of 68.9%, which corresponds to the heuristic Look ahead improved score v2. In my opinion, the 8% improvement over the AB_Improved_ID heuristic is due to the following reasons:

1. The heuristic performs a lightweight lookahead of 3 positions which allow us to overcome the problem that a position with more moves can result in positions with fewer moves (As explained in Open move score).

2. The heuristic encourages the positions in open areas. As we perform a look ahead of 3 positions, we will be able to reach open areas 2 steps back.

3. We are taking in account the moves of the opponent, so the heuristic also tries to minimize the number of moves of the opponent. (We utilize a lookahead of 3 positions as well)