Heuristic Analysis

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1. Only Defense

1-1. Brief Summary

The best defense is a good offense! (Reference : https://en.wikipedia.org/wiki/The_best_defense_is_a_good_offense) So we can give the higher score when the opponent has less legal moves, regardless of my legal moves. The max legal moves are 8, so simply the score will be (8 - opp_moves).

1-2. Performance Evaluation

	Round 1		Round 2		Round 3	
	ID_Improved	Student	ID_Improved	Student	ID_Improved	Student
Results	**67.86%**	60.00%	63.57%	**66.43%**	**65.71%**	64.29%
Match 1	13 to 7	19 to 1	15 to 5	18 to 2	16 to 4	12 to 8
Match 2	14 to 6	9 to 11	12 to 8	16 to 4	15 to 5	17 to 3
Match 3	13 to 7	9 to 11	15 to 5	11 to 9	12 to 8	11 to 9
Match 4	11 to 9	9 to 11	11 to 9	9 to 11	16 to 4	12 to 8
Match 5	14 to 6	13 to 7	13 to 7	15 to 5	13 to 7	16 to 4
Match 6	16 to 4	11 to 9	12 to 8	11 to 9	9 to 11	11 to 9
Match 7	14 to 6	14 to 6	11 to 9	13 to 7	11 to 9	11 to 9

1-3. Result

It doesn't work as expected. Maybe the one of reasons is that we lost the better position in the first-half of game having more legal moves for me.

2. More Weighted Opponent Moves

2-1. Brief Summary

There is one improved heuristic introduced during the lecture.

> The "Improved" evaluation function discussed in lecture that outputs a score equal to the difference in the number of moves available to the two players. It can be represented as code : ***(own_moves - opp_moves)***.

However, let's revisit the definition of game winner. If the opponent player doesn't have the place to move, then the player wins. So I would like to try to put weight into the opponent moves. If the opponent player has the more places to move, then decrease the score as 2 times of original improved evaluation.

It can be represented as code : ***(own_moves - (2*opp_moves))***

Let's assume that we have the following 2 choices.

	own_moves	**opp_moves**	**Original**	**More Weighted Opponent Moves**
Node 1	6	3	**6 - 3 = 3**	6 - (2*3) = 0
Node 2	3	1	3 - 1 = 2	**3 - (2*1) = 1**

In this situation, the original heuristic will choose the “Node 1” based on the calculation. However, the “Node 2” has only 1 opponent move, so you can easily win if you go with “Node 2”. So new “More Weighted Opponent Moves” heuristic will choose the “Node 2” to win.

2-2. Performance Evaluation

	Round 1		Round 2		Round 3	
	ID_Improved	Student	ID_Improved	Student	ID_Improved	Student
Results	67.14%	**72.86%**	**69.29%**	67.14%	62.14%	**67.86%**
Match 1	15 to 5	19 to 1	14 to 6	18 to 2	15 to 5	16 to 4
Match 2	15 to 5	16 to 4	16 to 4	18 to 2	11 to 9	16 to 4
Match 3	14 to 6	11 to 9	12 to 8	12 to 8	10 to 10	10 to 10
Match 4	14 to 6	16 to 4	15 to 5	8 to 12	11 to 9	11 to 9
Match 5	13 to 7	16 to 4	13 to 7	13 to 7	15 to 5	16 to 4
Match 6	12 to 8	14 to 6	15 to 5	12 to 8	10 to 10	14 to 6
Match 7	11 to 9	10 to 10	12 to 8	13 to 7	15 to 5	12 to 8

2-3. Result
Yes, the result is getting better than first heuristic, but the result is not stable. Maybe the specific situation is not happening frequently and periodically.

3. Avoid Edge

3-1. Brief Summary

It’s the straight-forward and simple rule that there will be less moves in edge of board. Let’s see following board image.

O1 (0 , 0)						
		O2				
	O2		P2		P2	
		P2				P2
				P1 (4 , 4)		
		P2				P2
			P2		P2	

As you can see, if the player is in the edge location (0 , 0), then there are only 2 places available as next place. However, if the player is not in the edge location (4 , 4), then there are 8 places available for next move.

So let's decrease the score if the current location is in the edge as the followings.

-4	-4	-4	-4	-4	-4	-4
-4	-2	-2	-2	-2	-2	-4
-4	-2				-2	-4
-4	-2				-2	-4
-4	-2				-2	-4
-4	-2	-2	-2	-2	-2	-4
-4	-4	-4	-4	-4	-4	-4

3-2. Performance Evaluation

	Round 1		Round 2		Round 3	
	ID_Improved	Student	ID_Improved	Student	ID_Improved	Student
Results	64.29%	**69.29%**	65.00%	**66.43%**	64.29%	**74.29%**
Match 1	13 to 7	18 to 2	16 to 4	17 to 3	12 to 8	16 to 4
Match 2	13 to 7	15 to 5	14 to 6	12 to 8	15 to 5	19 to 1
Match 3	13 to 7	12 to 8	14 to 6	11 to 9	15 to 5	15 to 5
Match 4	11 to 9	13 to 7	10 to 10	14 to 6	10 to 10	13 to 7
Match 5	12 to 8	15 to 5	14 to 6	16 to 4	12 to 8	16 to 4
Match 6	15 to 5	10 to 10	12 to 8	13 to 7	11 to 9	13 to 7
Match 7	13 to 7	14 to 6	11 to 9	10 to 10	15 to 5	12 to 8

3-3. Result

Finally the player wins all consecutive 3 games. But the second round has similar result with ID_Improved as 65.00% vs 66.43%. For the worst case, let me try to apply one more heuristic approach.

4. Flex Strategy

4-1. Brief Summary

Currently I'm using the same heuristic approach for both at the start of game and at the end of game. Simply the "Avoid Edge" heuristic will be affecting more at the start of game (that means most of places are blank) than at the end of game (that means most of places in central area are not blank any more).

So let's divide the game into 2 parts: (1) the blanks are more than half of total spaces and (2) the blanks are less than half of total spaces. Then use the "Avoid Edge" heuristic at the first half, and use the "More Weighted Opponent Moves" heuristic at the 2nd half.

4-2. Performance Evaluation

	Round 1		Round 2		Round 3	
	ID_Improved	Student	ID_Improved	Student	ID_Improved	Student
Results	62.86%	**70.00%**	65.71%	**68.57%**	67.14%	**72.86%**
Match 1	14 to 6	20 to 0	12 to 8	16 to 4	14 to 6	18 to 2
Match 2	13 to 7	18 to 2	12 to 8	16 to 4	17 to 3	14 to 6
Match 3	12 to 8	16 to 4	11 to 9	12 to 8	15 to 5	14 to 6
Match 4	11 to 9	12 to 8	15 to 5	13 to 7	13 to 7	12 to 8
Match 5	15 to 5	10 to 10	16 to 4	17 to 3	11 to 9	15 to 5
Match 6	12 to 8	11 to 9	14 to 6	12 to 8	12 to 8	15 to 5
Match 7	11 to 9	11 to 9	12 to 8	10 to 10	12 to 8	14 to 6

4-3. Result

The performance looks getting better than previous heuristic approach, but I cannot find out big improvement. Just one point is that this approach is very strong in "Match 1".

5. Conclusion

First of all, I choose the "Flex Strategy" heuristic for my final version. Basically it's the combination of "Avoid Edge" heuristic and "More Weighted Opponent Moves" heuristic. Moreover, I use the 3 consecutive tests as an evidence. I know that only 3 tests are not perfect to prove the new heuristic approaches. However I believe it is very useful check point for the opponent which is not static and change their moves constantly.

The last "Flex Strategy" has the best results for 3 consecutive games with "ID_Improved".

If I have a time to improve the heuristic approach with enough time, then I will try to do the following 2 things.

Firstly, conduct more test with each heuristic approach. Definitely more test will give more understanding and result for each heuristic.

Additionally, try to find out the better and best factor for heuristic with practice and mathematical proven, if possible. As you already know, I used the factor *2 in the "More Weighted Opponent Moves" heuristic to calculate new score and the factor -4 and -2 in the "Avoid Edge" heuristic. It's a just rough idea and confirmed with a few rounds of testing. There will be more effective factors for each case. Hope to enjoy the journey to achieve bigger than 90% winning result for every matches.