Analysis of Heuristics on a Game of Isolation
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1. **Introduction**

We explored a variety of heuristics by investigating into the winning percentages between test agents using the heuristics and the CPU agent.

Isolation is a deterministic, complete-information game where two players alternate turn to move the game piece from one cell to another on a board of fixed size. Whenever a player occupies a cell, such cell becomes inaccessible from that move forward, thereby shrinking the effective size of the board. The first player running out of board places to move loses the game.

In our implementation, the game of Isolation is further restricted with a fixed, limited amount of time for each player to make a move. This unravels the game at a faster pace, as the player now not only has to calculate the number of moves correctly, it also has to do it sufficiently quick so that it does not forfeit the game, which happens when a decision cannot be made before the allotted time ran up.

2. **Overview of Heuristics**

a. Heuristic 1 – Improved Score
This heuristic biases against moves that will result in a small difference between the number of legal moves available to the player and the opponent. That is, a move which results in a large number of player moves while minimizing opponent's moves will be receive a higher score using this heuristic.

In terms of implementation, this heuristic is given by

$$|player's\ moves| - |opponent\ moves|$$

b. Heuristic 2 – Custom Score
This heuristic biases against moves that will result in a small number of legal moves for the players. That is, it recommends a move position that will maximize the number of player's legal moves.

In terms of implementation, this heuristic is given by

$$\alpha \times |player's\ moves| - |opponent\ moves|$$

Where α is empirically chosen to be 1.5 .

c. Heuristic 3 – Custom Score 2
This heuristic considers the position of the player on the board. This is based on the understanding that if a starting position is close to the center of the board, then it is easier for this player with the center position to win against the opponent who is close to the edge of the board. In this way, it is quite easy for the center player to "isolate" the edge player, assuming the center player plays at an optimal level.

In terms of implementation, this heuristic is given by

$$(h - y)^2 + (w - x)^2$$

Where w, h denotes the center of the board along the width and height axes, respectively and, x, y denotes the player's position along the width and height direction, respectively.

d. Heuristic 4 – Custom Score 3
This heuristic was developed after a series of improvements. First, we considered the intermediary heuristic whose logic is that a winning player will have move legal moves than its component. This means that we can then consider the ratio ($\frac{|player\ moves|}{|opponent\ moves|}$). This ratio should be as large as possible when the game is still running (more specifically, when the game is over, this ratio is in its indeterminate form).

Our second step is to recognize that this ratio itself does not tell the full story. We then further consider the difference given by

$$\left(\frac{|player\ moves|}{|opponent\ moves|}\right) - \left(\frac{|opponent\ moves|}{|player\ moves|}\right)$$

In terms of implementation, we use the more convenient form of

$$|player\ moves|^2 - |opponent\ moves|^2$$

3. **Results**

We summaized the tounament results using the various heuristics against various opponent's strategies.

Note that the "AB_Improved" employed the Improved Score strategy (heuristic 1), "AB_Custom" employed the Custom Score strategy (heuristic 2), "AB_Custom_2" emplyed the Customer Score 2 strategy (heuristic 3), and "AB_Custom_3" employed the Custom score 3 strategy (heutistic 4).

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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       8  |   2     8  |   2     9  |   1     9  |   1
   2       MM_Open      8  |   2     9  |   1     6  |   4     7  |   3
   3      MM_Center     8  |   2     8  |   2     8  |   2     8  |   2
   4     MM_Improved    5  |   5     7  |   3     4  |   6     4  |   6
   5       AB_Open      4  |   6     4  |   6     5  |   5     6  |   4
   6      AB_Center     6  |   4     5  |   5     4  |   6     6  |   4
   7     AB_Improved    1  |   9     5  |   5     5  |   5     4  |   6
--------------------------------------------------------------------------
          Win Rate:      57.1%        65.7%        58.6%        62.9%
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4. **Discussion**

Given the heuristics explored, we recommend heuristic 4 based on the winning percentage of the tournament (please see Result section above). This heuristic indeed integrate several other heuristic into one – not only it maximizes the available player's moves when compared to the opponent's moves, it also further maximizes the ratio between the moves of the player's over the opponent's moves.