Isolation Game Agent – Christine Payne

1   Heuristic Analysis

Initially, we consider several different types of heuristics. Custom, Custom_2, Next_Step, and Stage all use a function check_future_steps(), which looks ahead to consider how long a run the player would have if they chose this move. This is similar to the overall minimax search, except that it ignores moves the opponent might make, and it also does not make a copy of the board at each step. This is an effort to make a fast estimate as to whether a move would leave open several future moves or would be near a dead end.

Next_Step uses this heuristic for the entire game (I expected this would perform badly, since early on few moves would be near a dead end, and it would give little insight how to pick a good one). Custom, Custom_2, and Stage are all similar where they start out using a Distance From Center metric, then as the game progresses they use the number of legal moves (for the player minus for the opponent) and then end with this check_future_steps heuristic. Progression through the game is determined by the number of empty spaces on the board.

Diff_Dist, Dist_Diff, and Diff_dist_sum all use combinations only of Dist (distance from the center) and Diff (number of legal moves for the player minus for the opponent). Distance is measured either by traditional Pythagorean (the square of x and square of y) or by counting the number of steps from the middle square (number of squares up or down, plus number of squares left or right).

Diff_Dist uses Diff for the first half of the game, and Dist for the second. Dist_Diff is the opposite. Diff_dist_sum uses a weighted sum of the two throughout the whole game.

Prior to these tests, we also had tried variations of weighting own legal moves remaining vs opponent legal moves remaining (inside of what we call Diff). We did not find any repeatable advantage over a simple OWN_MOVES - LEGAL_MOVES

Because we found a large amount of variation in each tournament run, we changed the number of games to be 100 or 80 per face-off, and in some cases we ran the whole tournament twice.

```
Two different tournaments of 100 games per match. Win rates:
                First tournament    Second tournament
AB_Improved           66.7%               67.3%
Custom                68.0%               67.4%
Custom_2              67.1%               65.4%
Diff_Dist             58.3%               59.6%
Dist_Diff             66.6%               64.7%
Diff_dist_sum         68.0%               68.4%
Next_Step             62.3%               63.1%
Stage                 68.9%               67.4%
```

At this point, we stop considering the worst performing heuristics (Diff_Dist, and Next_Step). We try out a variation of Stage. The main heuristics stay the same, but we adjust weightings in each.

```
One tournament of 100 matches per face-off
AB_Improved             64.7%
Custom                  64.1%
Diff_Dist_sum           67.0%
Mod_Stages              66.3%
```

We consider if it is better to use squared distance (Pythagorean distance) as in the heuristic given to us in sample_players rather than counting the number of steps away from the center.

```
One tournament of 60 matches per face-off
AB_Improved             66.9%
Diff_Dist_sum           70.2%
Diff_SqDist             63.3%
```

At this point, Diff_Dist_sum seems to be the only heuristic that is consistently out-performing AB_Improved. We now focus on the relative weights for Diff and Dist. Initially we used a positive version of Dist (meaning a higher score is given to squares further from the center). While this is counter-intuitive, we noticed that AB_Center consistently performed well, so we aimed to include some of that success. (Since the minimax algorithm looks several steps ahead, we thought perhaps looking for a corner square

many steps ahead pushes one to choose a central square early on.) Now in these variations, we consider weighting Dist negatively (giving a higher score to squares closest to the center).

```
60 Matches
Diff+ (w*Dist)
-----------------------------------
Name               w        Win Rate
AB_Improved                 68.1%
DD_pt_8           .8        65.5%
DD_half           .5        65.5%
Diff_dist_sum     .3        66.7%
DD_subt          -.3        68.6%
DD_full_subt     -.6        72.4%
```

Now we explore making Dist even more heavily negative. We also add a variation of the Stages algorithm (where we us diff, dist, and check_future_steps() at different stages of the game).

```
60 Matches
AB_Improved        64.5%
DD_full_subt       66.2%        (w = -.6)
DD_dbl_sub         66.7%        (w = -2)
Adv_stage          71.2%
```

From this, Adv_stages looks very promising. However, when we run two back-to-back comparisons to confirm this finding, we see this was just a fluke:

```
80 Matches each tournament
            First tournament   Second tournament
AB_Improved        68.0%              69.6%
Adv stages         65.2%              67.1%
```
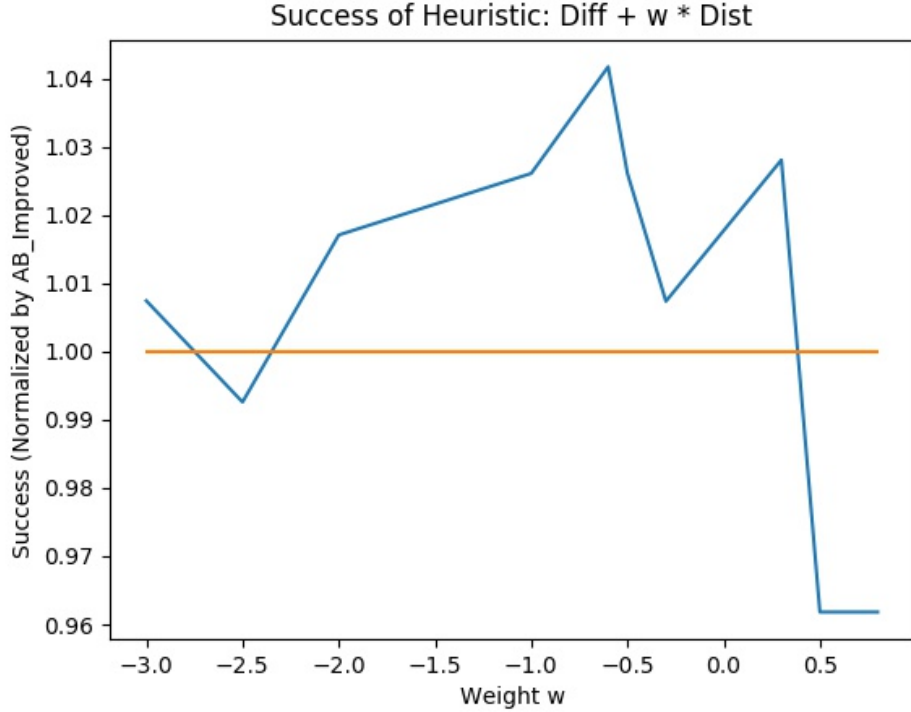
Figure 1: Normalized win rate for different combinations of Diff (difference between own legal moves and opponent legal moves) and Dist (steps from center square).

At this point, we return to a simple combination of Dist and Diff. It seems the added computational time from creating a more complicated look ahead is not worth it. Finally we decide to stay with a simple and fast heuristic. It remains only to determine the best weighting of Dist and Diff. We run one last set looking at a few other weights we haven't yet considered, and then chart average success vs the weight of Dist.

We graph results vs weighting of Dist in Figure 1. Each win rate is normalized by the AB_Improved win rate for that tournament. If the agent was run in multiple tournaments, we take an average win rate, weighted by number of games in that tournament.

2   Tournament Results

These are the full records for the results cited earlier.

```
                    ************************
                         Playing Matches
                    ************************

Match #    Opponent    AB_Improved     Custom      Custom_2      Diff_Dist      Dist
                       Won | Lost    Won | Lost   Won | Lost    Won | Lost     Won
   1        Random     97  |   3     95  |   5    92  |   8     83  |  17      93
   2        MM_Open    73  |  27     70  |  30    74  |  26     64  |  36      73
   3        MM_Center  72  |  28     78  |  22    77  |  23     67  |  33      68
   4        MM_Improved 77 |  23     74  |  26    74  |  26     66  |  34      71
   5        AB_Open    50  |  50     53  |  47    48  |  52     47  |  53      53
   6        AB_Center  53  |  47     55  |  45    53  |  47     42  |  58      60
   7        AB_Improved 45 |  55     51  |  49    52  |  48     39  |  61      48
------------------------------------------------------------------------------
           Win Rate:     66.7%        68.0%        67.1%         58.3%         66



                    ************************
                         Playing Matches
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Match #    Opponent    AB_Improved     Custom      Custom_2      Diff_Dist      Dist
                       Won | Lost    Won | Lost   Won | Lost    Won | Lost     Won
   1        Random     94  |   6     94  |   6    95  |   5     88  |  12      92
   2        MM_Open    74  |  26     74  |  26    77  |  23     72  |  28      70
   3        MM_Center  77  |  23     78  |  22    66  |  34     63  |  37      71
   4        MM_Improved 70 |  30     66  |  34    69  |  31     67  |  33      70
   5        AB_Open    47  |  53     54  |  46    50  |  50     47  |  53      48
   6        AB_Center  60  |  40     56  |  44    55  |  45     42  |  58      54
   7        AB_Improved 49 |  51     50  |  50    46  |  54     38  |  62      48
------------------------------------------------------------------------------
           Win Rate:     67.3%        67.4%        65.4%         59.6%         64



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```

```
                         Playing Matches
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Match #    Opponent    AB_Improved    Custom    Diff_dist_sum Mod Stages
                       Won | Lost   Won | Lost   Won | Lost   Won | Lost
   1        Random     89  |  11    93  |  7     92  |  8     91  |  9
   2        MM_Open    76  |  24    66  |  34    68  |  32    73  |  27
   3       MM_Center   72  |  28    65  |  35    74  |  26    71  |  29
   4      MM_Improved  67  |  33    69  |  31    77  |  23    69  |  31
   5        AB_Open    49  |  51    50  |  50    55  |  45    52  |  48
   6       AB_Center   54  |  46    57  |  43    50  |  50    57  |  43
   7      AB_Improved  46  |  54    49  |  51    53  |  47    51  |  49
--------------------------------------------------------------------------
          Win Rate:      64.7%        64.1%        67.0%        66.3%



                    ************************
                         Playing Matches
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Match #    Opponent    AB_Improved Diff_dist_sum   Stage
                       Won | Lost   Won | Lost   Won | Lost
   1        Random     53  |  7     58  |  2     56  |  4
   2        MM_Open    44  |  16    43  |  17    44  |  16
   3       MM_Center   46  |  14    47  |  13    46  |  14
   4      MM_Improved  39  |  21    47  |  13    41  |  19
   5        AB_Open    33  |  27    31  |  29    29  |  31
   6       AB_Center   32  |  28    33  |  27    33  |  27
   7      AB_Improved  27  |  33    28  |  32    27  |  33
--------------------------------------------------------------------------
          Win Rate:      65.2%        68.3%        65.7%



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                         Playing Matches
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Match #    Opponent    AB_Improved Diff_dist_sum Diff_SqDist
```

Match #	Opponent	Won	Lost	Won	Lost	Won	Lost
1	Random	55	5	59	1	52	8
2	MM_Open	43	17	45	15	44	16
3	MM_Center	48	12	47	13	43	17
4	MM_Improved	46	14	43	17	45	15
5	AB_Open	29	31	31	29	29	31
6	AB_Center	33	27	36	24	27	33
7	AB_Improved	27	33	34	26	26	34

Win Rate: 66.9%   70.2%   63.3%

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Playing Matches
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Match #	Opponent	AB_Improved		Diff_dist_sum		DD_half		DD_subt	
		Won	Lost	Won	Lost	Won	Lost	Won	Lost
1	Random	58	2	58	2	57	3	58	2
2	MM_Open	43	17	44	16	44	16	46	14
3	MM_Center	41	19	44	16	47	13	43	17
4	MM_Improved	44	16	45	15	47	13	48	12
5	AB_Open	28	32	34	26	32	28	32	28
6	AB_Center	38	22	32	28	33	27	35	25
7	AB_Improved	28	32	28	32	32	28	25	35

Win Rate: 66.7%   67.9%   69.5%   68.3%

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Playing Matches
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Match #	Opponent	AB_Improved		Diff_dist_sum		DD_half		DD_subt		DD_ful
		Won	Lost	Won	Lost	Won	Lost	Won	Lost	Won
1	Random	57	3	52	8	58	2	58	2	60
2	MM_Open	46	14	44	16	40	20	43	17	50
3	MM_Center	44	16	42	18	42	18	46	14	45
4	MM_Improved	41	19	45	15	42	18	49	11	46
5	AB_Open	29	31	29	31	28	32	28	32	35

| 6 | AB_Center | 36 | 24 | 37 | 23 | 32 | 28 | 32 | 28 | 37 |
| 7 | AB_Improved | 33 | 27 | 31 | 29 | 33 | 27 | 32 | 28 | 31 |

```
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        Win Rate:    68.1%      66.7%      65.5%      68.6%        72
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                          Playing Matches
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Match #	Opponent	AB_Improved		DD_full_subt		DD_dbl_sub		Adv stages	
		Won	Lost	Won	Lost	Won	Lost	Won	Lost
1	Random	52	8	55	5	56	4	57	3
2	MM_Open	38	22	43	17	48	12	48	12
3	MM_Center	44	16	39	21	43	17	55	5
4	MM_Improved	42	18	43	17	42	18	44	16
5	AB_Open	30	30	37	23	32	28	29	31
6	AB_Center	34	26	30	30	32	28	36	24
7	AB_Improved	31	29	31	29	27	33	30	30

```
----------------------------------------------------------------------
        Win Rate:    64.5%      66.2%      66.7%      71.2%
```

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                    **************************
                          Playing Matches
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```

Match #	Opponent	AB_Improved		Adv stages	
		Won	Lost	Won	Lost
1	Random	74	6	74	6
2	MM_Open	58	22	55	25
3	MM_Center	58	22	52	28
4	MM_Improved	62	18	59	21
5	AB_Open	45	35	39	41
6	AB_Center	46	34	46	34
7	AB_Improved	38	42	40	40

```
----------------------------------------------------------------------
        Win Rate:    68.0%      65.2%
```

```
                    **************************
```

```
                        Playing Matches
                        ************************

 Match #    Opponent    AB_Improved  Adv stages
                        Won | Lost   Won | Lost
    1         Random     77 |   3     76 |   4
    2         MM_Open    59 |  21     55 |  25
    3         MM_Center  62 |  18     57 |  23
    4        MM_Improved 52 |  28     56 |  24
    5         AB_Open    49 |  31     45 |  35
    6         AB_Center  47 |  33     48 |  32
    7        AB_Improved 44 |  36     39 |  41
------------------------------------------------------------------------
           Win Rate:     69.6%        67.1%


 Match #    Opponent    AB_Improved Diff Late GameDD_full_subt  DD_dbl_sub   DD_2
                        Won | Lost   Won | Lost   Won | Lost   Won | Lost   Won
    1         Random     55 |   5     56 |   4     58 |   2     58 |   2     56
    2         MM_Open    43 |  17     41 |  19     41 |  19     50 |  10     45
    3         MM_Center  48 |  12     45 |  15     51 |   9     41 |  19     44
    4        MM_Improved 41 |  19     48 |  12     43 |  17     45 |  15     43
    5         AB_Open    37 |  23     29 |  31     33 |  27     25 |  35     29
    6         AB_Center  30 |  30     37 |  23     35 |  25     32 |  28     35
    7        AB_Improved 29 |  31     25 |  35     32 |  28     32 |  28     29
------------------------------------------------------------------------
           Win Rate:     67.4%        66.9%        69.8%        67.4%        66


                        ************************
                        Playing Matches
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 Match #    Opponent    AB_Improved DD_half_subt  DD_eq_subt
                        Won | Lost   Won | Lost   Won | Lost
    1         Random     53 |   7     58 |   2     55 |   5
    2         MM_Open    47 |  13     43 |  17     49 |  11
    3         MM_Center  38 |  22     45 |  15     45 |  15
    4        MM_Improved 40 |  20     43 |  17     39 |  21
    5         AB_Open    30 |  30     29 |  31     31 |  29
    6         AB_Center  35 |  25     34 |  26     32 |  28
    7        AB_Improved 31 |  29     29 |  31     30 |  30
```

       Win Rate: 65.2%   66.9%   66.9%