Heuristic Analysis

The best, most basic and easy to understand definition of heuristics is that they are a "rule of thumb" that we should go by under certain circumstances. With that in mind, intuitively it would make sense to find the best "rules of thumb" and combine then into a single evaluation function in order to leverage the best approach under a number of different circumstances. With that in mind, the approach taken for this project has been to identify individual heuristics that are successful on their own and use them to create a single evaluation function; concomitantly, the downside of increasing the complexity of the evaluation function is that the agent will have less time to go "deeper" in the search.

In the interest of "full disclosure" I have not, despite implementing and testing several different heuristics, been able to find one or a combination of heuristic s that has a significant impact on the percentage of wins achieved by the agent in the test. At best, perhaps a 5% improvement has been achieved but not consistently.

The heuristics attempted and their results are:

1. **Custom_score**: Identify if there are any "can't reflect" positions returning the difference between the agent's and opponent's quantity of these moves; per the lessons, "can't reflect" positions are positions on the board that can't be easily countered/negated by the opponent; *see Figure 1*
2. **Custom_score2**: Legal moves for agent contains center position – the availability of the center position has a significant impact on the likelihood of winning especially as part of an "opening book"; *see Figure 2*
3. **Custom_score3**: Combining logic to of 1 and 2 above; determines if available moves contain the center position and if they contains "can't reflect" positions; the value is more positively or negatively weighted depending on whether the agent or the opponent has the center position in their list of available moves, respectively; *see Figure 3*

Based on my findings using heuristics alone has a relatively small impact on the overall "winning" performance of the agent; ideally, these "heuristics" would be implemented in the "get_move" function and select either the center position or a "can't reflect" position before resorting to using minimax as we know, per the lectures, that these moves significantly affect the agent's ability to win. However, **if only heuristics can be used, I would recommend using the "Custom_score3" heuristic** (discussed above) due to the fact that it produced the highest percentage of wins and the function takes the center position's "opening book" move into consideration as well as the "can't reflect" moves. All of this takes place while the execution time of this function grows, at worst, geometrically with the size of the board which means the agent will not be spending "too much" time executing this heuristic instead of traversing deeper into the graph of moves

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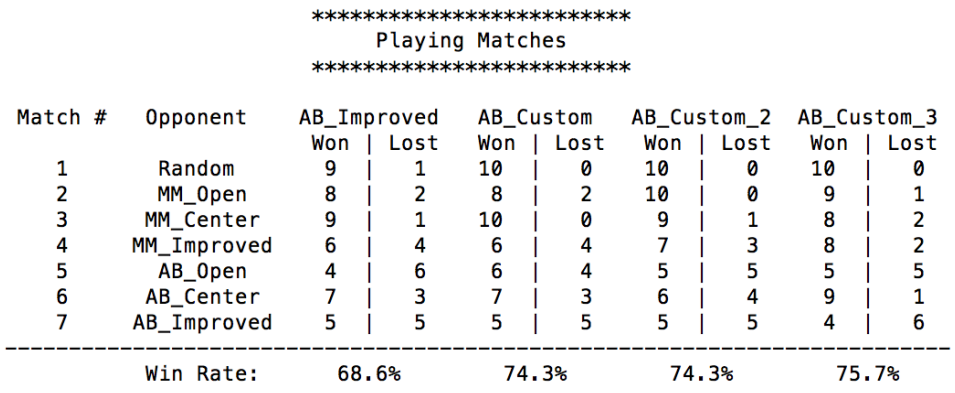
Figure 1 – AB_Custom produces at best 74.3% wins for heuristic #1



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                    *************************
                        Playing Matches
                    *************************

 Match #    Opponent    AB_Improved    AB_Custom    AB_Custom_2   AB_Custom_3
                         Won | Lost    Won | Lost    Won | Lost    Won | Lost
    1         Random      9  |   1     10  |   0     10  |   0     10  |   0
    2         MM_Open     8  |   2      8  |   2     10  |   0      9  |   1
    3       MM_Center     9  |   1     10  |   0      9  |   1      8  |   2
    4     MM_Improved     6  |   4      6  |   4      7  |   3      8  |   2
    5         AB_Open     4  |   6      6  |   4      5  |   5      5  |   5
    6       AB_Center     7  |   3      7  |   3      6  |   4      9  |   1
    7      AB_Improved    5  |   5      5  |   5      5  |   5      4  |   6
--------------------------------------------------------------------------------
            Win Rate:      68.6%        74.3%        74.3%        75.7%
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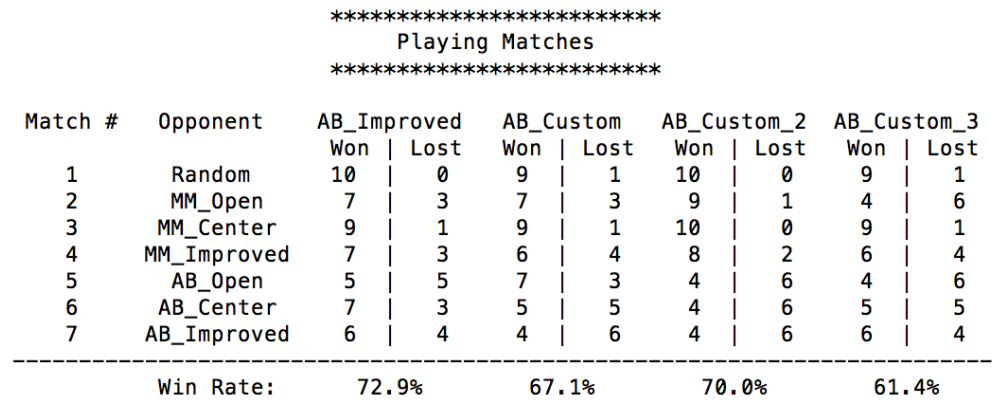
Figure 2 – AB_Custom_2 produces at best 70% wins for heuristic #2



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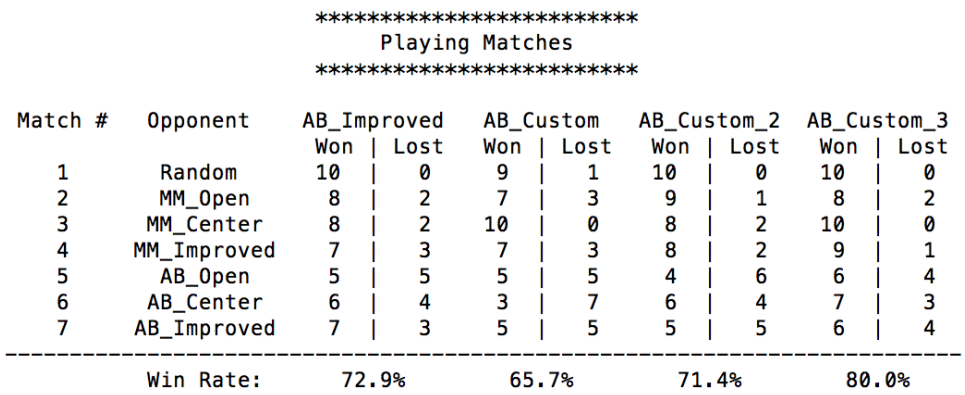
                    *************************
                        Playing Matches
                    *************************

 Match #    Opponent    AB_Improved    AB_Custom    AB_Custom_2   AB_Custom_3
                         Won | Lost    Won | Lost    Won | Lost    Won | Lost
    1         Random     10  |   0      9  |   1     10  |   0      9  |   1
    2         MM_Open     7  |   3      7  |   3      9  |   1      4  |   6
    3       MM_Center     9  |   1      9  |   1     10  |   0      9  |   1
    4     MM_Improved     7  |   3      6  |   4      8  |   2      6  |   4
    5         AB_Open     5  |   5      7  |   3      4  |   6      4  |   6
    6       AB_Center     7  |   3      5  |   5      4  |   6      5  |   5
    7      AB_Improved    6  |   4      4  |   6      4  |   6      6  |   4
--------------------------------------------------------------------------------
            Win Rate:      72.9%        67.1%        70.0%        61.4%
```

Figure 3 AB_Custom_3 produces at best 80% for heuristic #3



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                    *************************
                        Playing Matches
                    *************************

 Match #    Opponent    AB_Improved    AB_Custom    AB_Custom_2   AB_Custom_3
                         Won | Lost    Won | Lost    Won | Lost    Won | Lost
    1         Random     10  |   0      9  |   1     10  |   0     10  |   0
    2         MM_Open     8  |   2      7  |   3      9  |   1      8  |   2
    3       MM_Center     8  |   2     10  |   0      8  |   2     10  |   0
    4     MM_Improved     7  |   3      7  |   3      8  |   2      9  |   1
    5         AB_Open     5  |   5      5  |   5      4  |   6      6  |   4
    6       AB_Center     6  |   4      3  |   7      6  |   4      7  |   3
    7      AB_Improved    7  |   3      5  |   5      5  |   5      6  |   4
--------------------------------------------------------------------------------
            Win Rate:      72.9%        65.7%        71.4%        80.0%
```