

### Heuristic Analysis

Three different heuristics were implemented in order to evaluate the performance of each of them against the heuristic thought in class: the difference between the legal moves of player v.s. the opponent. This heuristic is referred to as 'ID\_Improved' throughout this analysis, where 'ID' means iterative deepening.

This paper describes the results achieved by comparing the custom heuristics described below against the 'ID\_Improved' heuristic.

**Heuristic 1:** The first heuristic implemented ('penalize\_corners\_heuristic') elaborates the idea of 'ID\_Improved' by penalizing the player when the current state of the board includes locations in corners. This is done because corners decrease the number of available moves, but even more important, corners truly decrease the opportunity of winning a game in the future (the player can easily be 'trapped' in a corner). Thus in addition to calculating the difference in legal moves of the player v.s. the opponent, the player is penalized harder when its current location in the board is a corner.

#### 'ID\_Improved' v.s. 'penalize\_corners\_heuristic' results:

ID_Improved Evaluation			Result	Student Evaluation			Result
ID_Improved	Random		17 to 3	Student	Random		19 to 1
ID_Improved	MM_Null		17 to 3	Student	MM_Null		15 to 5
ID_Improved	MM_Open		14 to 6	Student	MM_Open		15 to 5
ID_Improved	MM_Improved		13 to 7	Student	MM_Improved		13 to 7
ID_Improved	AB_Null		16 to 4	Student	AB_Null		15 to 5
ID_Improved	AB_Open		12 to 8	Student	AB_Open		13 to 7
ID_Improved	AB_Improved		9 to 11	Student	AB_Improved		14 to 6
ID_Improved			70.00%	Student			74.29%

**Heuristic 2:** The second heuristic implemented ('favor\_run\_away\_heuristic') also elaborates on 'ID\_Improved', but this time it favors player moves which are farther away from its opponent. This is done by adding the Euclidian distance from player to opponent to the number of legal moves of the player. As a result, player moves which have a greater distance from the opponent's location will have a higher score and thus be favored by this heuristic.

**'ID\_Improved' v.s. 'favor\_run\_away\_heuristic' results:**

ID_Improved Evaluation			Result	Student Evaluation			Result
ID_Improved	Random		19 to 1	Student	Random		17 to 3
ID_Improved	MM_Null		15 to 5	Student	MM_Null		15 to 5
ID_Improved	MM_Open		12 to 8	Student	MM_Open		13 to 7
ID_Improved	MM_Improved		13 to 7	Student	MM_Improved		14 to 6
ID_Improved	AB_Null		16 to 4	Student	AB_Null		17 to 3
ID_Improved	AB_Open		11 to 9	Student	AB_Open		12 to 8
ID_Improved	AB_Improved		13 to 7	Student	AB_Improved		13 to 7
ID_Improved			70.71%	Student			72.14%

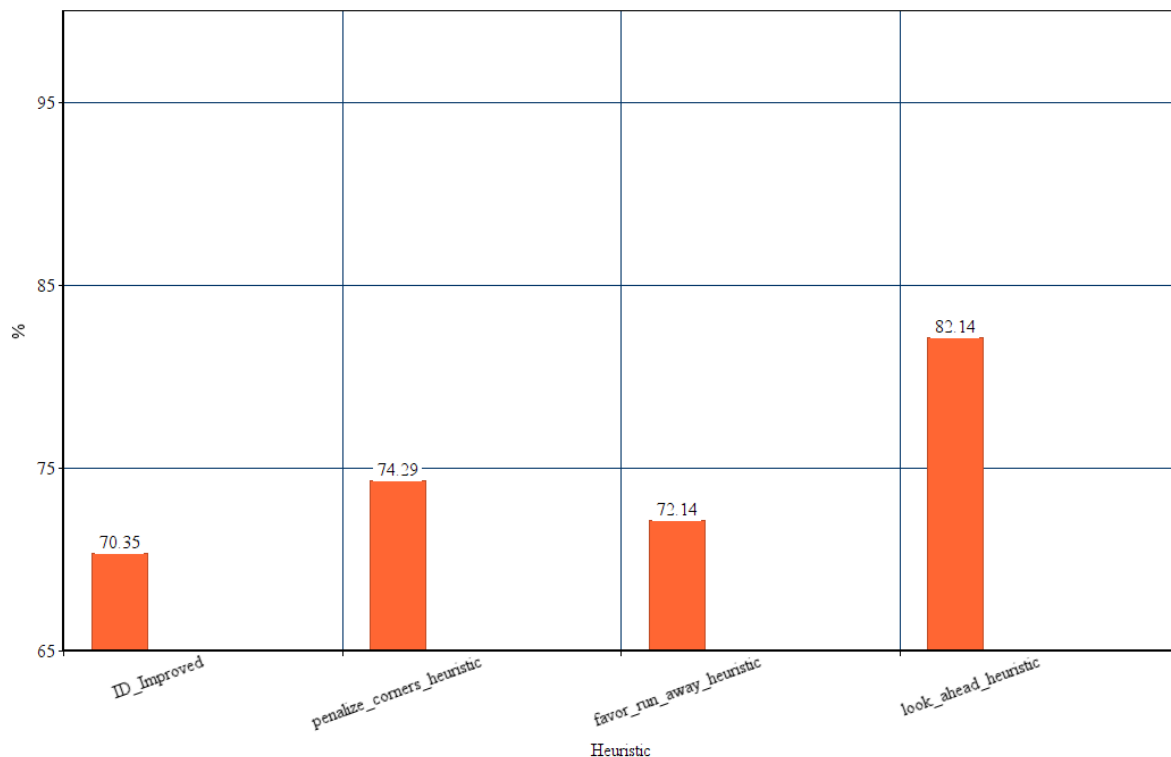
**Heuristic 3:** The last and best heuristic implemented ('look\_ahead\_heuristic') elaborates on the 'ID\_Improved' heuristic as well. The main difference between the 'ID\_Improved' and the 'look\_ahead\_heuristic' is that in addition to calculating the difference between legal moves of player v.s. the opponent, it calculates how many moves does each of those next legal moves have. As a result, this heuristic favors legal moves which have a larger number of moves in the future.

**'ID\_Improved' v.s. 'look\_ahead\_heuristic' results:**

ID_Improved Evaluation			Result	Student Evaluation			Result
ID_Improved	Random		18 to 2	Student	Random		19 to 1
ID_Improved	MM_Null		16 to 4	Student	MM_Null		18 to 2
ID_Improved	MM_Open		11 to 9	Student	MM_Open		12 to 8
ID_Improved	MM_Improved		14 to 6	Student	MM_Improved		18 to 2
ID_Improved	AB_Null		14 to 6	Student	AB_Null		17 to 3

ID_Improved	AB_Open	13 to 7	Student	AB_Open	15 to 5
ID_Improved	AB_Improved	13 to 7	Student	AB_Improved	16 to 4
ID_Improved		70.71%	Student		82.14%

### Heuristics Comparison



As a result of the previous experiments, the 'look\_ahead\_heuristic' was selected as the best heuristic implemented. Some of the reasons why the 'look\_ahead\_heuristic' performs consistently better than others are:

1. It builds on 'ID\_Improved', which is an already good and simple heuristic
2. It is still a very simple heuristic, and thus it does not affect the ability of the algorithm to search deep in the tree
3. It takes into consideration what the set of legal moves holds available for the upcoming play