

Heuristic Analysis

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Heuristic descriptions

All of the custom scores were heuristics designed to track the relative number of moves left for the player (N_p) versus the opponent (N_o). However, “relative” was determined differently. The three heuristics are described below:

Heuristic 1:

$$\text{custom_score} = N_p - 3N_o$$

The motivation for this heuristic was to weight N_o more than N_p , so that the agent will strive towards reducing N_o more quickly than increasing N_p . This is a more aggressive approach to playing the game.

Heuristic 2:

$$\text{custom_score} = \text{exclusive}(N_p) - 3 \text{ exclusive}(N_o)$$

Especially in the early stages of the game, N_p and N_o are large, but in many of these cases, the moves are not exclusive to player or opponent. The exclusive function searches for moves that are available only to the player (or opponent). As before, a more aggressive playing strategy is incorporated by penalizing N_o more heavily than rewarding N_p .

Heuristic 3:

$$\text{custom_score} = N_p / (3N_o + 0.1)$$

Rather than looking at absolute difference between the scores, heuristic 3 looks at the ratio between the scores. This helps to more heavily weight moves which keeps N_o small, and the custom score does not scale linearly with N_o , unlike heuristics 1 and 2. (The addition of 0.1 in the denominator helps to prevent numerical errors when $N_o = 0$.)

Win rates

Against default tournament opponents

From Table 1, against default tournament opponents (Random, MM_Open, MM_Center, MM_Improved, AB_Open, AB_Center, AB_Improved), all three heuristics with alpha-beta pruning performed with >50% overall win rate. However, it is clear that the AB_Open, AB_Center are more formidable opponents. Using heuristic 2 and 3 is sometimes insufficient to beat these tougher opponents. Heuristic 1 is however always able to beat all tournament opponents at least 60% of the time.

Opponent	AB_Improved	AB_Custom	AB_Custom_2	AB_Custom_3
Random	100%	100%	100%	100%
MM_Open	70%	80%	80%	70%

MM_Center	90%	100%	80%	90%
MM_Improved	60%	60%	70%	60%
AB_Open	50%	60%	60%	50%
AB_Center	60%	80%	40%	50%
AB_Improved	30%	70%	50%	50%
Overall win rate	65.7%	78.6%	68.6%	67.1%

Table 1: Win ratio between different agents. The win ratio of the agent (color-coded blue) are shown in the table.

Against each other

Next, I also explicitly compared the three heuristics by running a tournament of them against each other (Table 2). None of the heuristics is able to dominate ($\geq 70\%$ win ratio) over the others.

Opponent	AB_Custom	AB_Custom_2	AB_Custom_3
AB_Custom	-	60%	45%
AB_Custom_2	40%	-	55%
AB_Custom_3	55%	45%	-
Overall win rate	47.5%	52.5%	50%

Table 2: Win ratio between agents using the custom heuristics. The win ratio of the agent (color-coded blue) are shown in the table. Due to the tight matchups, a total of 40 games were played between any two agents for better statistics.

Best evaluation heuristic

Heuristic 1 is the best heuristic, because:

- On average, it is able to beat Random, MM_Open, MM_Center, MM_Improved, AB_Open, AB_Center and AB_Improved more than 50% of the time (Table 1), and with overall better win ratio than when the custom heuristic 2 or 3 is used.
- It is able to dominate ($\geq 70\%$ win ratio) over more opponents than when using heuristic 2 or 3.
- On average, it outperforms heuristic 3, and loses to heuristic 2 about 60% of the time. Nonetheless, none of the heuristics is able to dominate over each other.