

Problem 1: Develop a custom heuristic

I picked the heuristic $\#my_moves - \#opponent_moves$ to be the baseline to compare its performance with the ones that I tested on top of a custom player with minimax, AB pruning and iterative deepening.

For each of the table entries, the custom player was playing 50 rounds with the fair matches flag enabled (200 games).

The heuristics that I implemented are:

- Weighted attacking ($\#my_moves - weight * \#opponent_moves$)
- Weighted defensive ($weight * \#my_moves - \#opponent_moves$)
- Weighted increasingly attacking ($\#my_moves - weight * \#opponent_moves * game_progress$)
- Weighted increasingly defensive ($weight * \#my_moves * game_progress - \#opponent_moves$)
- Defensive to attacking (when $game_progress \leq 0.5$ use “Weighted defensive”, otherwise use “Weighted attacking”)
- Attacking to defensive (when $game_progress \leq 0.5$ use “Weighted attacking”, otherwise use “Weighted defensive”)

Where:

- weight is an integer number equal or greater than 1.
- game_progress is a value from 0 to 1 that measures how far we are into the game, and is calculated by the formula $state.ply_count / board_size$

Custom Player Heuristic	Weight	Wins against Random Player	Wins against Greedy Player	Wins against Minimax Player	Wins
Baseline ($\#my_moves - \#opp_moves$)		90.5%	63.0%	65.5%	73.0%
Weighted attacking	2	92.5%	93.0%	75.5%	87.0%
Weighted attacking	3	94.5%	67.0%	73.5%	78.3%
Weighted defensive	2	92.5%	86.0%	72.5%	83.7%
Weighted defensive	3	92.5%	87.5%	71.5%	83.8%
Weighted increasingly attacking	2	94.5%	86.5%	75.5%	85.5%
Weighted increasingly attacking	3	94.5%	90.0%	78.0%	87.5%
Weighted increasingly defensive	2	93.5%	85.5%	76.5%	85.2%
Weighted increasingly defensive	3	92.5%	90.0%	81.5%	88.0%
Defensive to attacking	2	93.5%	90.0%	77.0%	86.8%
Defensive to attacking	3	94.5%	89.5%	77.5%	87.2%
Attacking to defensive	2	93.0%	95.5%	65.5%	84.7%
Attacking to defensive	3	92.5%	95.5%	76.5%	88.2%

Best and worst performing heuristics are highlighted for each opponent.

Different weight values seem to influence the performance of the custom player, and it seems that the heuristics that change as the game advances tend to do better as well.

Problem 2: Develop an opening book

The opening book I created played 10 million rounds, keeping the ratio of wins versus tries for each of the picked actions, with a depth of 4 plies.

In this case, the performance baseline was measured using the $\#my_moves - \#opponent_moves$ heuristic, with a random opening for the first 4 plies.

This way we are able to see that the book opening, using the same heuristic, gets a noticeable performance improvement.

Both openings were tested along 50 rounds with the fair matches flag disabled (100 games).

Custom Player Heuristic	Book or random opening	Wins against Random Player	Wins against Greedy Player	Wins against Minimax Player	Wins
Baseline ($\#my_moves - \#opp_moves$)	Random	95.0%	89.0%	68.0%	84.0%
Baseline ($\#my_moves - \#opp_moves$)	Book	98.0%	100.0%	76.0%	91.3%

Questions

- **Advanced Heuristic**

- **What features of the game does your heuristic incorporate, and why do you think those features matter in evaluating states during search?**

This is addressed above in the description of the heuristics. I think that making the custom player more aggressive (with the introduction of weight) and the evolution during the game, when considering game progress gives a better chance.

- **Analyze the search depth your agent achieves using your custom heuristic. Does search speed matter more or less than accuracy to the performance of your heuristic?**

For most of the plies, my custom player returns an action within a depth of 6 to 10. The maximum depth that I imposed to it was 100. While making improvements such as AB pruning and iterative deepening I noticed that both speed and accuracy were important for the performance of any of the heuristics tested.

- **Opening book**

- **Describe your process for collecting statistics to build your opening book. How did you choose states to sample? And how did you perform rollouts to determine a winner?**

As it is stated above, the opening book was created by playing 10 million rounds randomly, and keeping the actions with the biggest ratio of wins versus tries, with a depth of 4 plies.

- **What opening moves does your book suggest are most effective on an empty board for player 1 and what is player 2's best reply?**

Player 1 is suggested to move to 58 (which was a bit surprising to me, I expected to be suggested to move to center, i.e. 57).

Player's 2 best reply is move to 95.