Introduction to New Heuristics

In this section, we will present three new heuristics for the isolation game with knights:

1. Centrality Weighted Open Moves Score (Central)
2. Increasing Pressure Score (Pressure)
3. Increasing Pressure Centrality Weighted Open Moves Score (Central Pressure)

Centrality Weighted Open Moves Score

In traditional chess, the knight is the most effective when placed in the center of the board, where it can move to eight distinct squared (Expert Chess Strategies, 2018). Consequently, open moves to the center should be of higher value, as they potentially allow more moves in subsequent plays. We used the following centrality measure to determine the value of a square:

$$c_{loc} = c_x + c_y$$
$$c_x = x_{central}^2 - (x_{central} - x)^2 = x * (2 * x_{central} - x)$$
$$c_y = y_{central}^2 - (y_{central} - y)^2 = y * (2 * y_{central} - y)$$

$$c_{loc}: Centrality\ of\ location, expressed\ as\ tuple(x, y)$$
$$c_x: Centrality\ of\ x\ coordinate$$
$$c_y: Centrality\ of\ y\ coordinate$$
$$x_{central}: Central\ column\ index\ on\ board$$
$$y_{central}: Central\ row\ index\ on\ board$$

This creates a polynomial kernel, peaking in the center of the board and falling to the edges.

	0	1	2	3	4	5	6
0	0	5	8	9	8	5	0
1	5	10	13	14	13	10	5
2	8	13	16	17	16	13	8
3	9	14	17	18	17	14	9
4	8	13	16	17	16	13	8
5	5	10	13	14	13	10	5
6	0	5	8	9	8	5	0

Figure 1: Centrality value of every square on a 7x7 board

Consequently, the value of a cutoff-state can be computed as follows:

$$score(state, player) = \sum_{move \in legal\ moves(player)} c_{move} - \sum_{move \in legal\ moves(opponent)} c_{move}$$

Increasing Pressure Score

At the beginning of the game, the agent should focus on establishing a preferable layout for itself, rather than chasing after the opponent. With increasing plays, the agent should get more aggressive and increase pressure on the opponent.

$$pressure(state) = 0.25 + \frac{n_{occupied}}{49 * 2}$$

$$n_{occupied}: Number\ of\ occupied\ cells\ at\ state$$

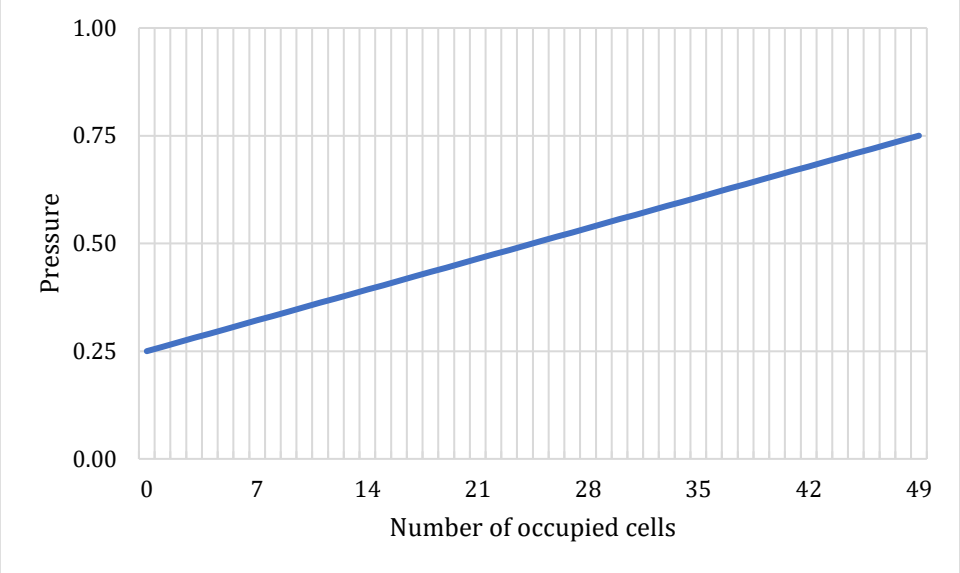

Figure 2: Pressure by number of occupied cells

The higher the pressure, the more the agent focuses on reducing the options for the opponent, instead of extending its own options:

$$score(state, player) = (1 - p) * n_{player} - p * n_{opponent}$$

$$p: Pressure\ at\ state$$
$$n_{player}: Number\ of\ legal\ moves\ for\ player$$
$$n_{opponent}: Number\ of\ legal\ moves\ for\ opponent$$

Increasing Pressure Centrality Weighted Open Moves Score

Bringing together the two aforementioned heuristics, we obtain an agent that plays with increasing pressure, while being aware of the centrality value of each square:

$$score(state, player) = (1 - p) * \sum_{move \in legal\ moves(player)} c_{move} - p * \sum_{move \in legal\ moves(opponent)} c_{move}$$

Experiment

This chapter introduces the reader to the experimental setup for the benchmark study and summarizes the results.

Experimental Setup

To validate the performance of the new heuristics ("AB Central", "AB Pressure", "AB Central Pressure"), we conducted a large benchmark tournament, where they played against the following agents:

1. A random player ("Random");
2. A minimax player with open move score (""MM Open");
3. A minimax player with center score ("MM Center");
4. A minimax player with improved score ("MM Improved");
5. An alphabeta player with open move score ("AB Open");
6. An alphabeta player with center score ("AB Center");
7. An alphabeta player with improved score ("AB Improved")

Every agent played 25 matches against each opponent with a time limit of 150 milliseconds. We repeated the experiment 30 times. Finally, we analyzed the results graphically with boxplots and statistically with an one-sided Wilcox test.

Benchmark Results

In median terms, the baseline (AB Improved) result can be improved by all three of the new agents:

Table 1: Performance per Agent

	AB Improved	AB Central	AB Pressure	AB Central Pressure
Median	67	69.71	67.43	69.71
Standard Deviation	2.15	2.50	1.75	1.98

AB Central and AB Central Pressure show equal performance in terms on median wins rate. However, AB Central Pressure seems to be more consistent, indicated by a lower standard deviation:

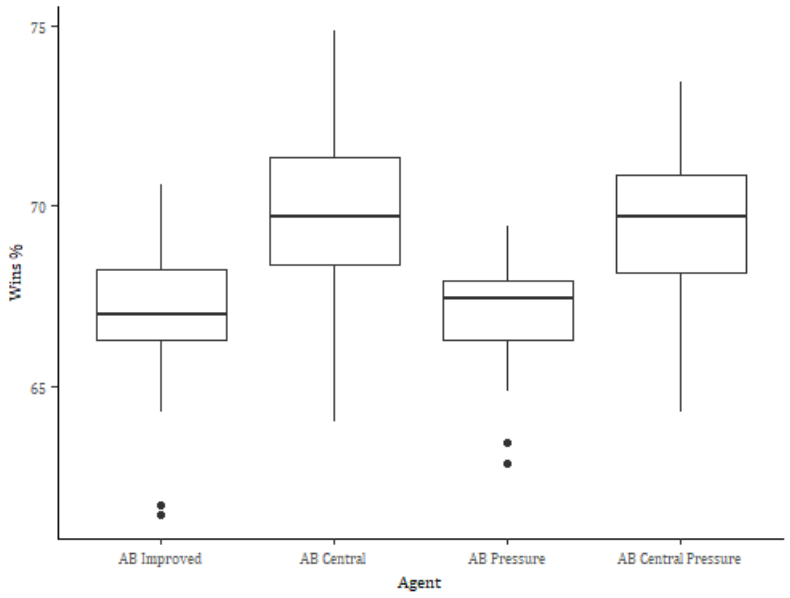

Figure 3: Wins % per Agent

Finally, we compared the median win rates of the three custom agents against AB Improved in a one-sided Wilcox test with H_0: "The wins rate of the customer agent is less or equal to the wins rate of AB Improved".

Table 2: P-Values for Wilcox Test

	AB Central	AB Pressure	AB Central Pressure
P-Value	6.57e-06	5.09e-01	1.49e-05

As stated by the p-values, we can reject H_0 for AB Central and AB Central Pressure with statistical significance, based on an α of 0.05.

Conclusion

In this report, we introduced three new heuristics: Central, Pressure and Central Pressure. The heuristics are inspired from chess strategies. Combined with a minimax tree with alphabeta pruning, Central and Central Pressure can outperform AB Improved with statistical significance. Given the more consistent results of AB Central Pressure, we recommend to choose this heuristic for future matches.

Future studies can focus on the parameter tuning of the agent. For the pressure component, the minimum and maximum pressure can certainly be optimized, as well as the slope and the shape of the curve. With regards to the central component, the density of the kernel can be tuned.

References

Expert Chess Strategies (2018). Chess Knight Moves. [online] www.expert-chess-strategies.com. Available at: https://www.expert-chess-strategies.com/chess-knight.html [Accessed 6 Feb. 2018].