

## Copenhagen Hnefatafl using Q-learning

### Introduction

Copenhagen Hnefatafl is a scandinavian board game belonging under the wider umbrella of tafl games. It is a perfect information, asymmetric, zero-sum game where the defender must get their king piece to one corner of the board, and the attacker must prevent them from doing so.

### Rules

The game rules are somewhat simple, though this doesn't make playing it easy. Each player can move any of their pieces along the vertical & horizontal axes (like a rook in chess). A piece can be captured (whereupon it is removed from play) by placing two opposing pieces adjacent to it, and opposite each other, additionally there are 5 "hostile tiles" (the four corners and center tile (if unoccupied), which count as hostile to any piece & may take part in a capture. The center tile may only be occupied by the king but other pieces may pass through it. The board edge doesn't count as hostile.

The win conditions for each player are as follows:

The defender must get their king (center piece) to one of the four corners of the board, alternatively, they may create an "exit fort". An exit fort is an arrangement of pieces that fulfils the following conditions:

1. The king must be on the edge of the board.
2. The king must be surrounded by defenders.
3. The surrounding defenders must be impossible to capture.

Conversly, the attacker must capture the king by placing four pieces adjacent to him. The king may not be captured on the edge of the board. If the king reaches the edge of the board, the attacker must capture every other defender piece in order to win.

This is not an exhaustive list of the rules of Copenhagen Hnefatafl, but it will suffice for the purposes of this report. A full list of rules may be found [here](#).

## The model

Since the game is played in a 11x11 board, using tabular qlearning with a state-board representation is impractical (if not impossible). Instead, we used a linear approximation function with the following features:

1. Bias
2. Own piece count
3. Opponent piece count
4. Own mobility (number of possible legal moves)
5. Opponent mobility
6. Opponent piece loss
7. Move distance
8. King progress (Manhattan distance to the nearest corner)
9. King threat (attacker pieces adjacent to the king)
10. Exit fort<sup>1</sup>
11. Winner

## Training

Because of the inherent asymmetry of the game two models are required, one for the attacker & one for the defender. The agents were trained against a random agent (an agent that plays random legal moves) for 30K games (defender) and 12K games (attacker)<sup>2</sup>.

After the original training phase, the two models were pitted against each-other for another 10K games using a “frozen” opponent. This means that the opponent model didn’t train during this process, instead, a random checkpoint was used for every game.

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1 Nonzero if the king is on the edge, and increases as more friendly pieces exist in a 2-tile radius of the king. Further increases if those pieces cannot be captured.

2 Because the attacker win condition is more complicated to achieve than that of the defender, training was substantially slowed, leading to time constraints.