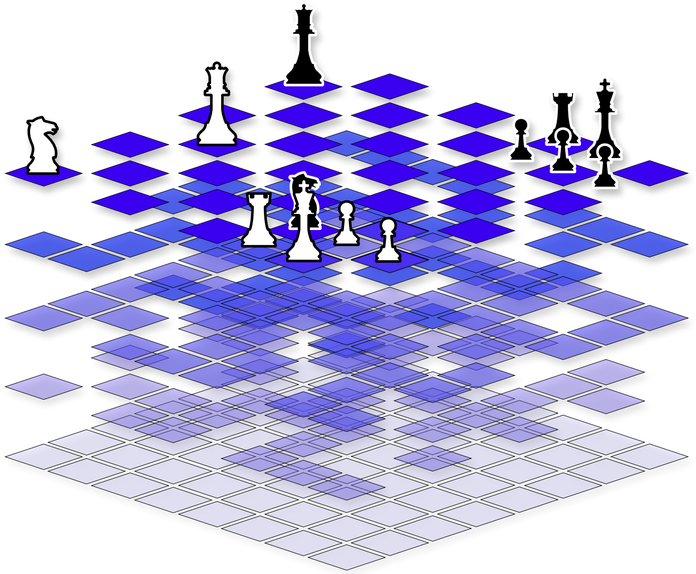
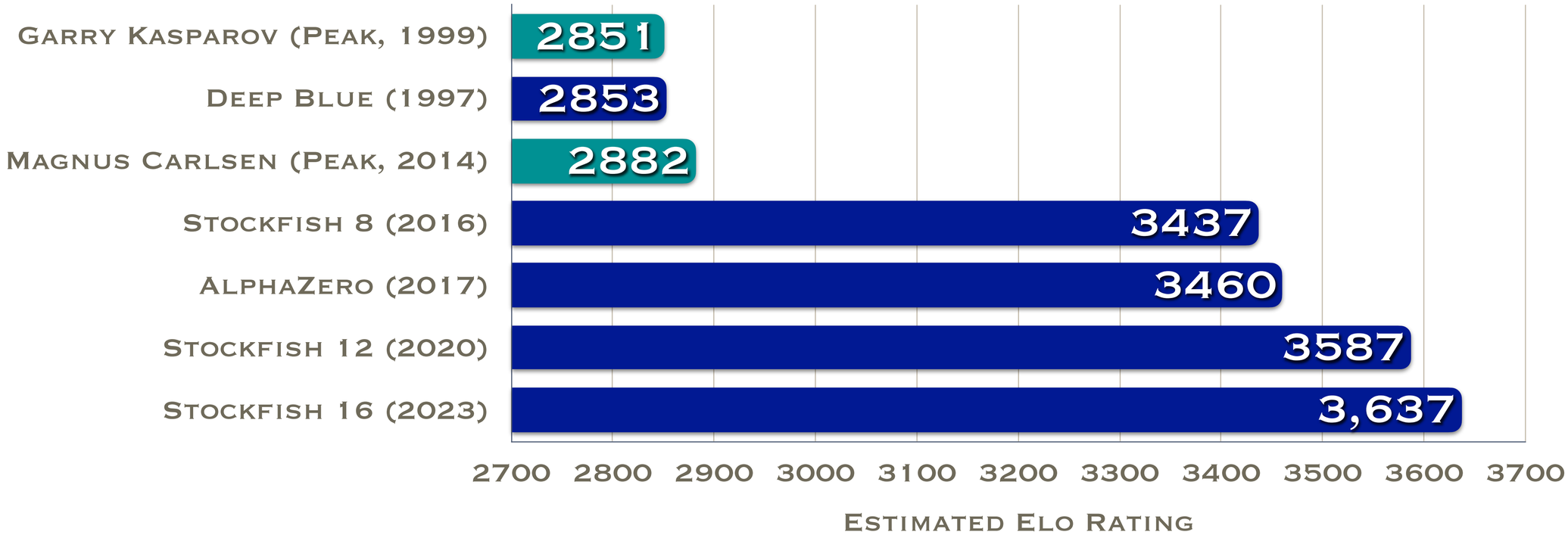
How Chess Engines Work



Anvay Shah

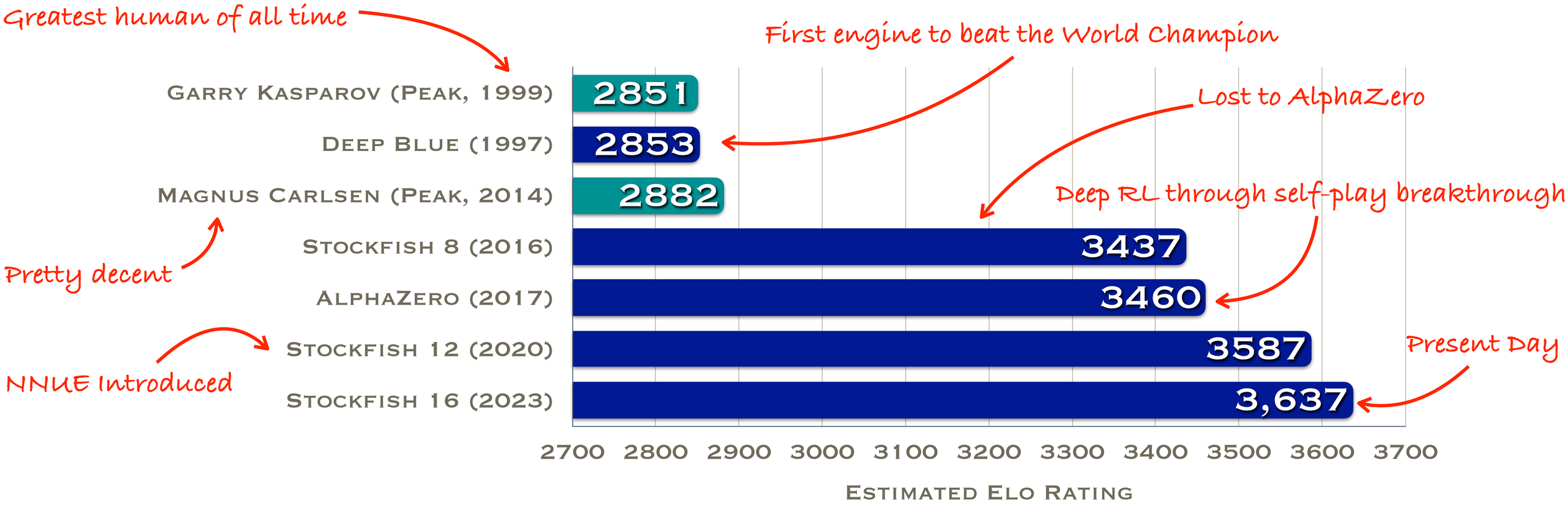
For Deep RL Workshop, Spring 2024 (Prof. Harshad Khadilkar)

History Of Engines (And Humans)



Source - CCRL 40/15 Rating List and Chess.com - The Strongest Computer Chess Engines Over Time

History Of Engines (And Humans)



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Chess Engines Before Neural Nets

Hand-Crafted Eval (HCE)

Question: (given a chess position) How do you know who is winning?

Source - Towards Data Science - Dissecting Stockfish Part 2

Chess Engines Before Neural Nets

Hand-Crafted Eval (HCE)

Question: (given a chess position) How do you know who is winning?

Heuristic-based HCE functions - $V(s)$

Weighted sum of domain specific quantities - linear function approximation

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Chess Engines Before Neural Nets

Hand-Crafted Eval (HCE)

Question: (given a chess position) How do you know who is winning?

Heuristic-based HCE functions - $V(s)$

Weighted sum of domain specific quantities - linear function approximation

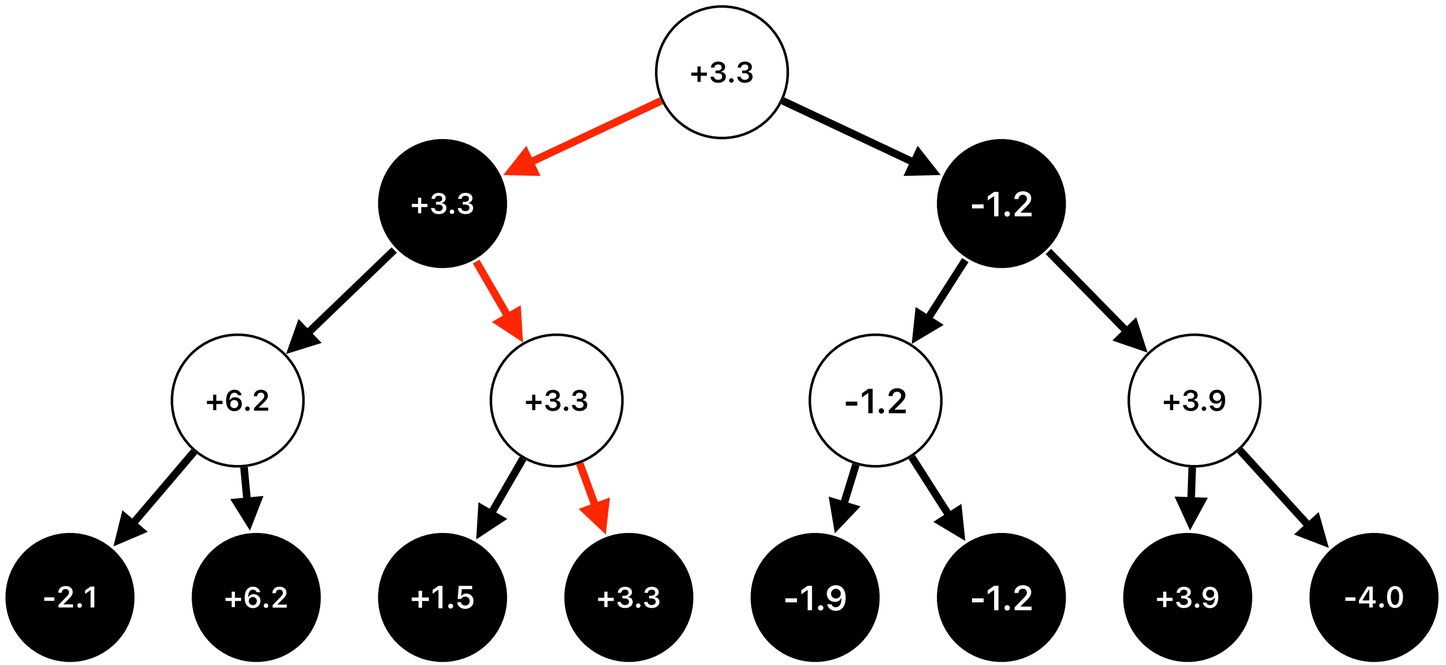
Material imbalance, positional advantage, material advantage, strategical advantage for pawns, strategical advantage for other pieces, incoming threats, passed pawns, space, king safety…

Tapered Eval: Different set of weights for different stages of the game

Source - Towards Data Science - Dissecting Stockfish Part 2

Chess Engines Before Neural Nets

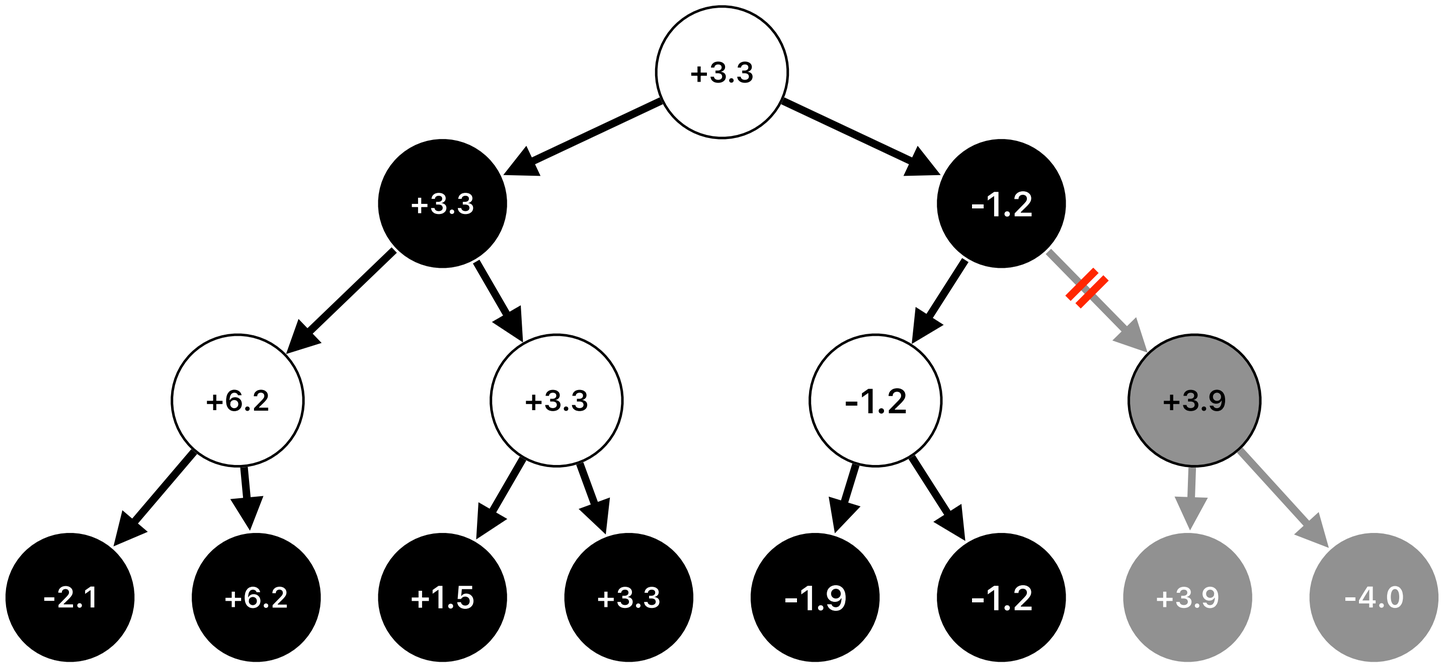
Minimax Search



Source - Towards Data Science - Dissecting Stockfish Part 2

Chess Engines Before Neural Nets

Alpha-Beta Pruning



Source - Towards Data Science - Dissecting Stockfish Part 2

AlphaZero Gives Stockfish a beating

Deep Reinforcement Learning, Self-Play

Learned to play Chess with zero domain knowledge through self-play

28 wins, 72 draws, 0 losses in 100 games vs Stockfish 8

Exhibited never seen before strategies and creative play in Chess

AlphaZero Gives Stockfish a beating

Deep Reinforcement Learning, Self-Play

Deep convolutional network with value and policy head - $V(s)$ and $\pi(s)$

Trained through self-play over 1000s of games - single net maintained

Source - AlphaGo Zero Explained In One Diagram - David Foster and AlphaZero paper - DeepMind

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Question: How does AlphaZero choose a move?

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Deep Reinforcement Learning, Self-Play

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Question: How does AlphaZero choose a move?

Monte Carlo Tree Search (MCTS) + Predictor Upper Confidence Tree Search (PUCT)

Choose action that maximises $Q(s, a)$ (exploitation) + U (exploration)

Source - AlphaGo Zero Explained In One Diagram - David Foster and AlphaZero paper - DeepMind

AlphaZero Gives Stockfish a beating

Where is AlphaZero Today?

Leela Chess Zero - AlphaZero framework with different model architectures

Top Chess Engine Championship (TCEC) - LCZero usually 2nd behind Stockfish in the last 5 years, occasionally 1st or 3rd

Stockfish 12 (And Above)

NNUE (Efficiently Updatable Neural Network)

Idea: Use a small (4 layers) Neural Network for state evaluation in search

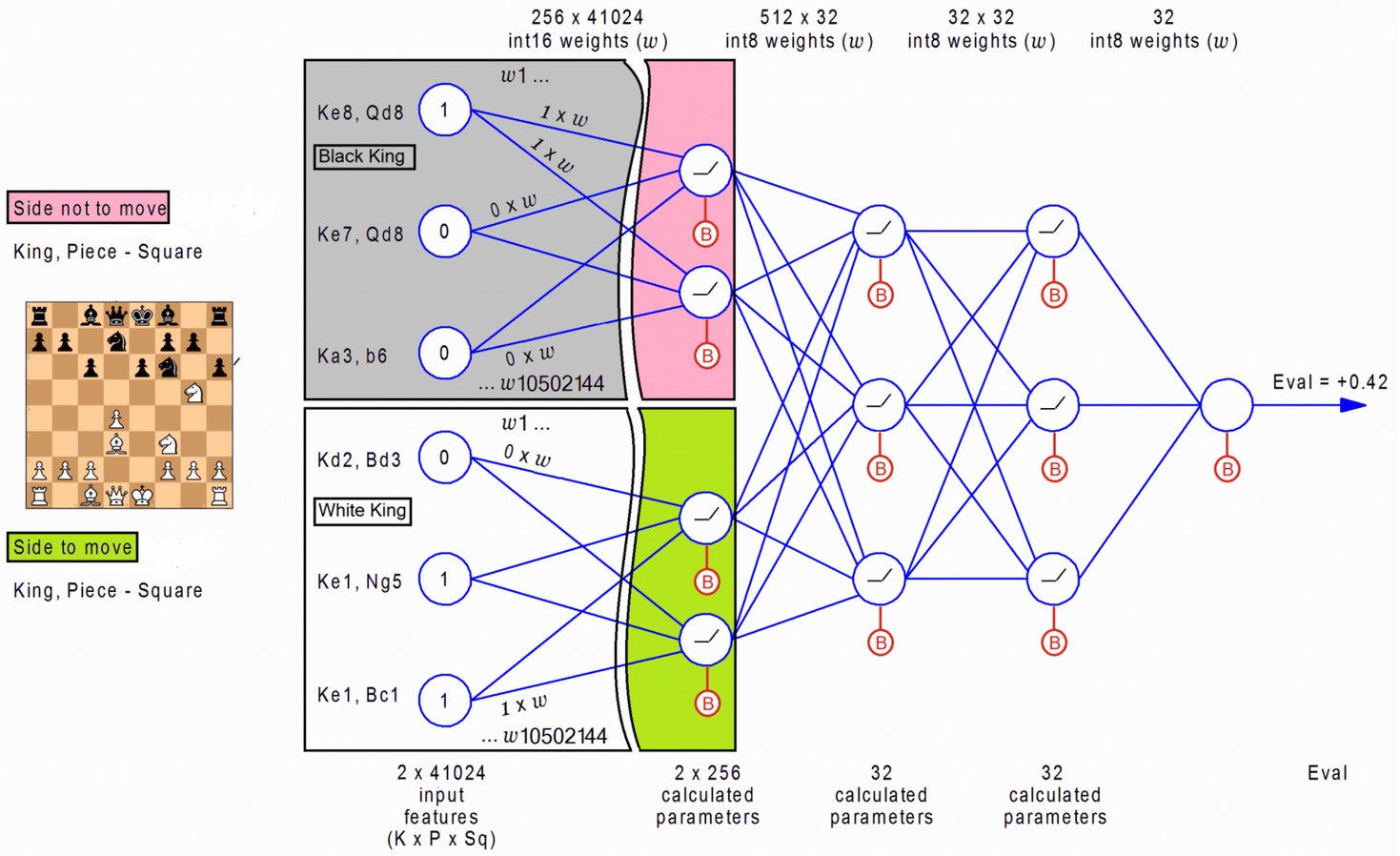
Earlier used successfully in Shogi, introduced in chess since Stockfish 12

Slower but 80 Elo stronger than HCE

Source - Chess Programming Wiki - Stockfish NNUE

NNUE Architecture

HalfKP Structure



Question: How to encode a chess position into features for a NN?

Source - Chess Programming Wiki - Stockfish NNUE and Re: NNUE Question - King Placements

NNUE Architecture

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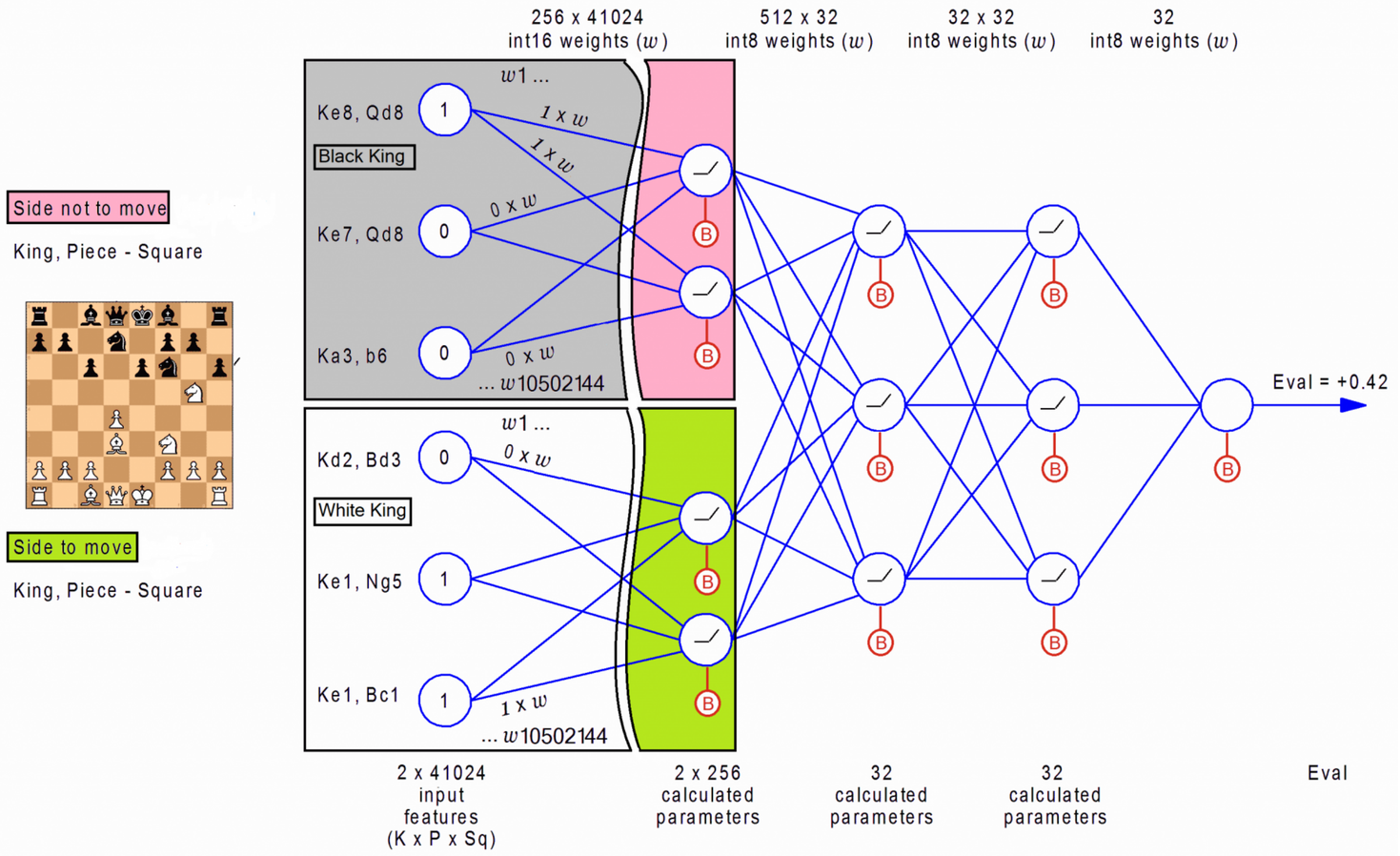


Question: How to encode a chess position into features for a NN?

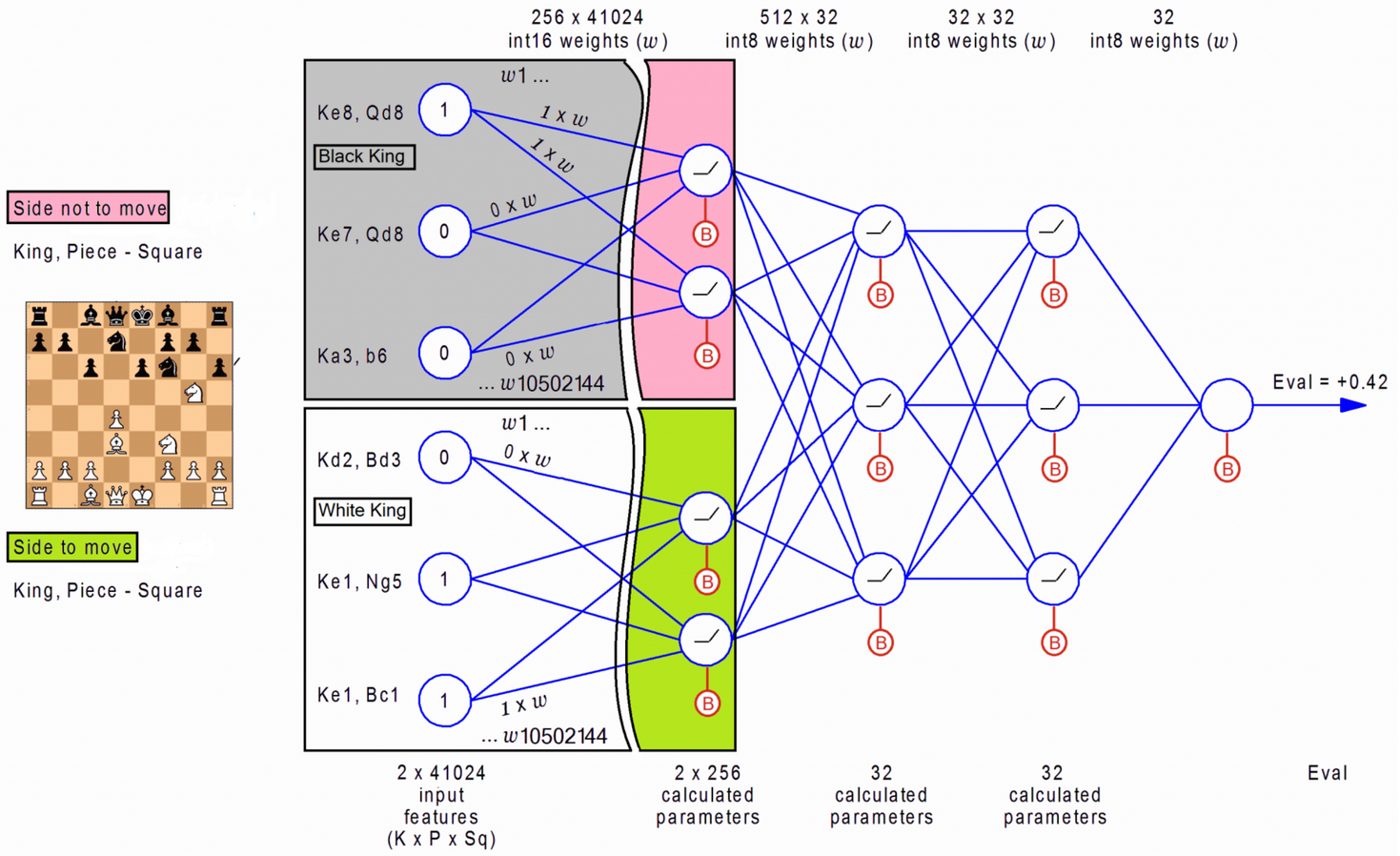
Naive way - A feature for each tuple - `(square, piece, colour)`

Number of features = 64 x 6 x 2 = 768

Source - Chess Programming Wiki - Stockfish NNUE and Re: NNUE Question - King Placements

NNUE Architecture

HalfKP Structure



HalfKP input is overparametrized

(king, square, piece, colour) x 2

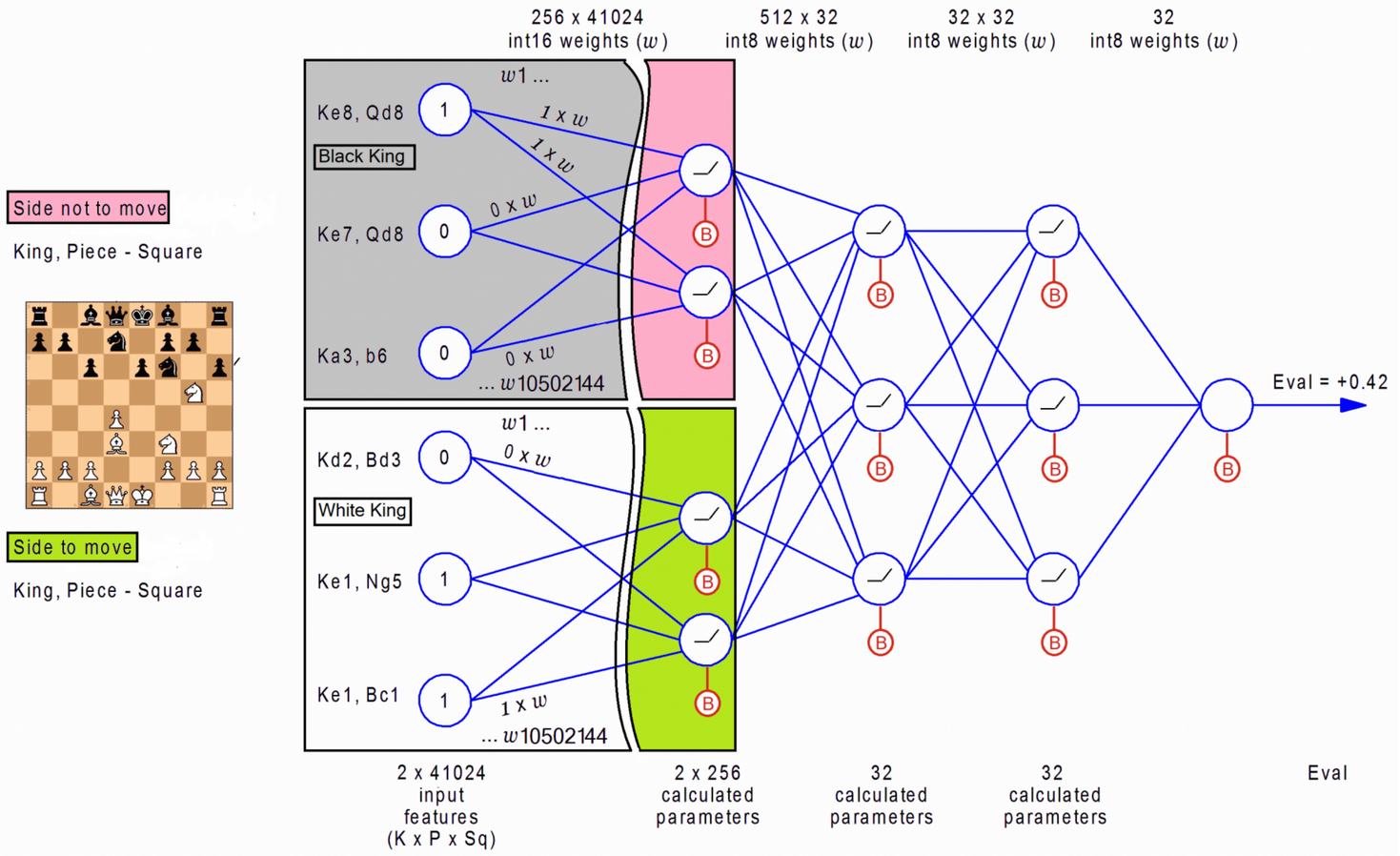
Number of features = 64 x 64 x 5 x 2 x 2

= 40960 x 2

Source - Chess Programming Wiki - Stockfish NNUE and Re: NNUE Question - King Placements

NNUE Architecture

HalfKP Structure



Incremental updates: fast forward pass as you only need to perform matrix multiplications for the features which have changed

Training: Supervised learning on Stockfish 11 evaluations

Source - Chess Programming Wiki - Stockfish NNUE and Re: NNUE Question - King Placements

Stockfish 12 (And Above)

NNUE (Efficiently Updatable Neural Network)

Stockfish 14 - HalfKAv2 architecture used instead of HalfKP

Stockfish 16 - HCE removed entirely and replaced with NNUE

Source - Chess Programming Wiki - Stockfish NNUE

Leela Chess Zero

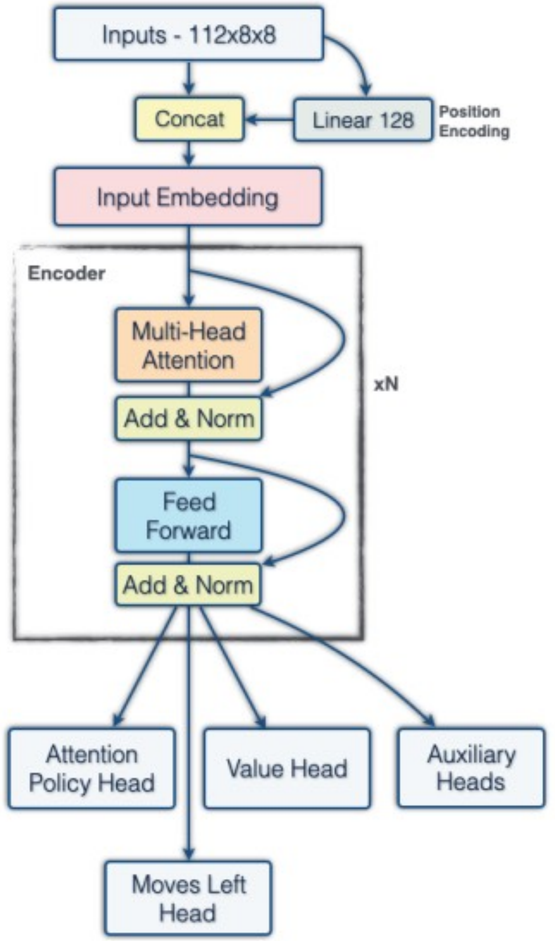
Transformers and Beyond...?

LCZero convolutional models weak at finding long-range ideas on the chessboard

BT4 Transformer architecture —

64 tokens, 15 encoder layers, Embedding size 1024, FFN size 1536

— 191.3 million parameters (slightly smaller than convolutional models)



Source - Lczero Blog - Transformer Progress

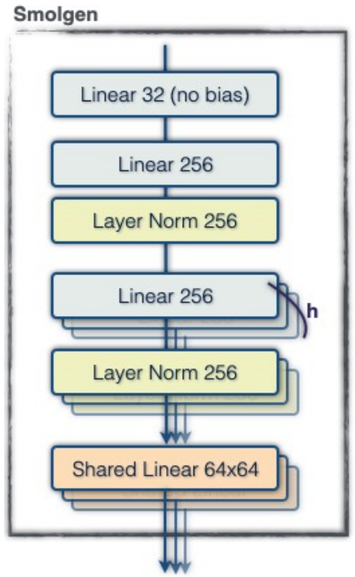
Leela Chess Zero

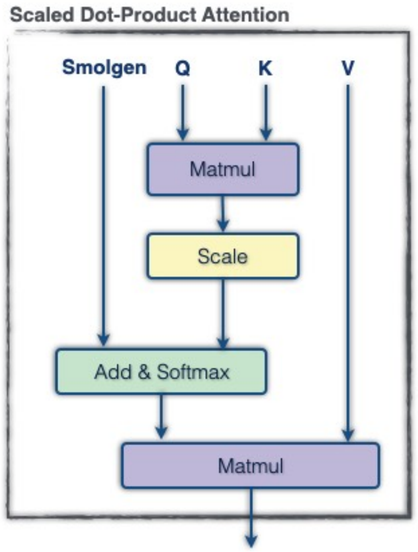
Transformers and Beyond...?

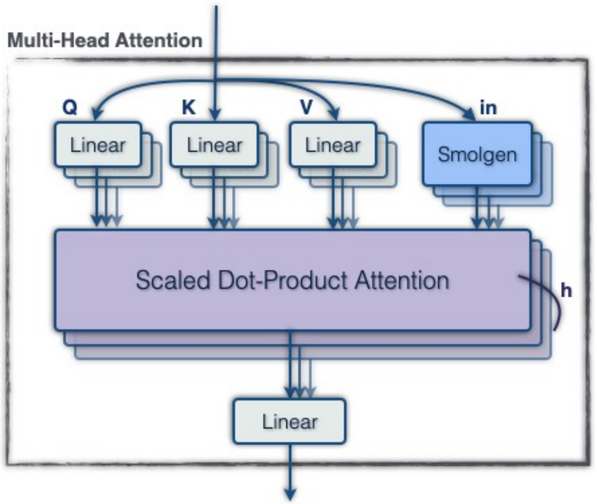
Chess-specific distance metrics used in positional encoding (instead of euclidean distance)

Dynamic positional information based on nature of position - smolgen model

Policy net for BT4 model 270 Elo stronger than that of T78 - strongest convolutional model







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