EXPLORING CHESS VARIANTS WITH ALPHA ZERO

CONNER HETTINGER

THE STUDY

Assessing Game Balance with AlphaZero: Exploring Alternative Rule Sets in Chess

Authors:

- Nenad Tomašev
- Ulrich Paquet
- Demis Hassabis
  - DeepMind
- Vladimir Kramnik
  - World chess champion 2000 - 2007

Chess Engine:

- AlphaZero

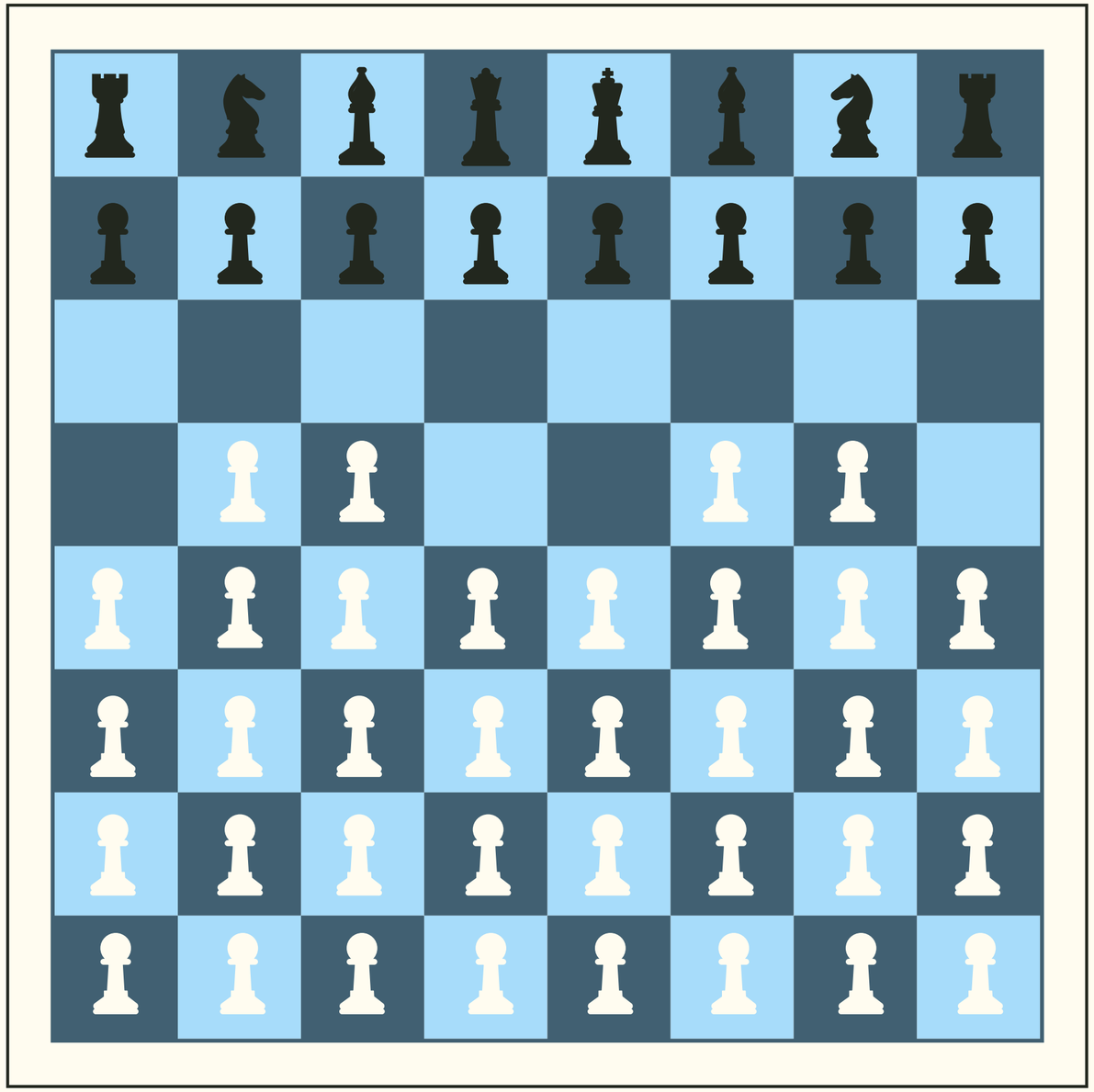
https://www.extremetech.com/extreme/260215-alphazero-new-chess-champion-harbinger-brave-new-world-ai

WHAT IS A VARIANT?

A chess variant is a version of chess where the original rules have been altered in some way.

In this study we will explore versions of chess with 1-2 rule changes. We don't consider changes that alter:

- Starting position
- The pieces
- The board

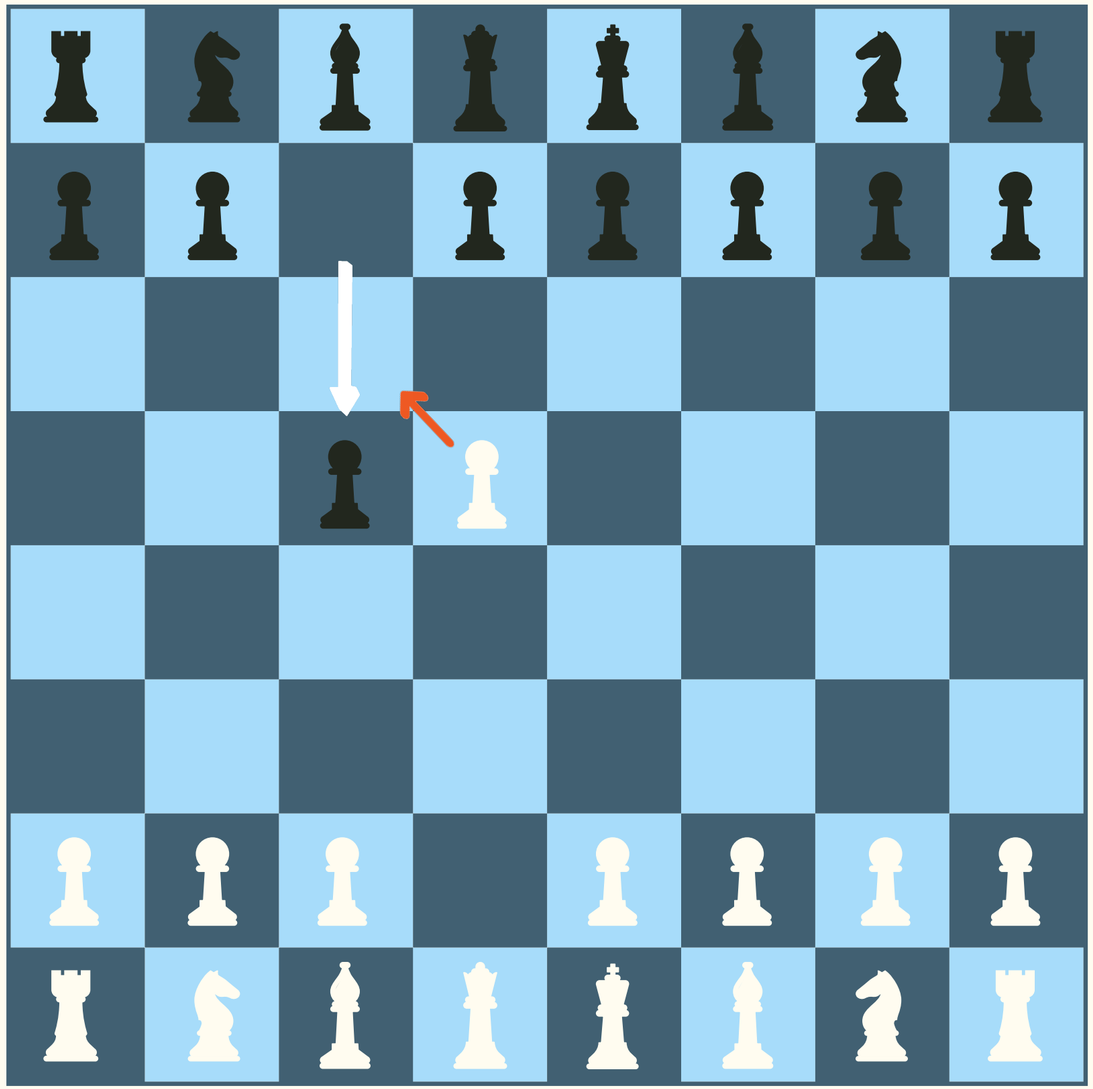


IN THIS TALK

- Chess Ideas
- Alpha Zero
  - Monte Carlo Tree Search
  - Deep Neural Networks

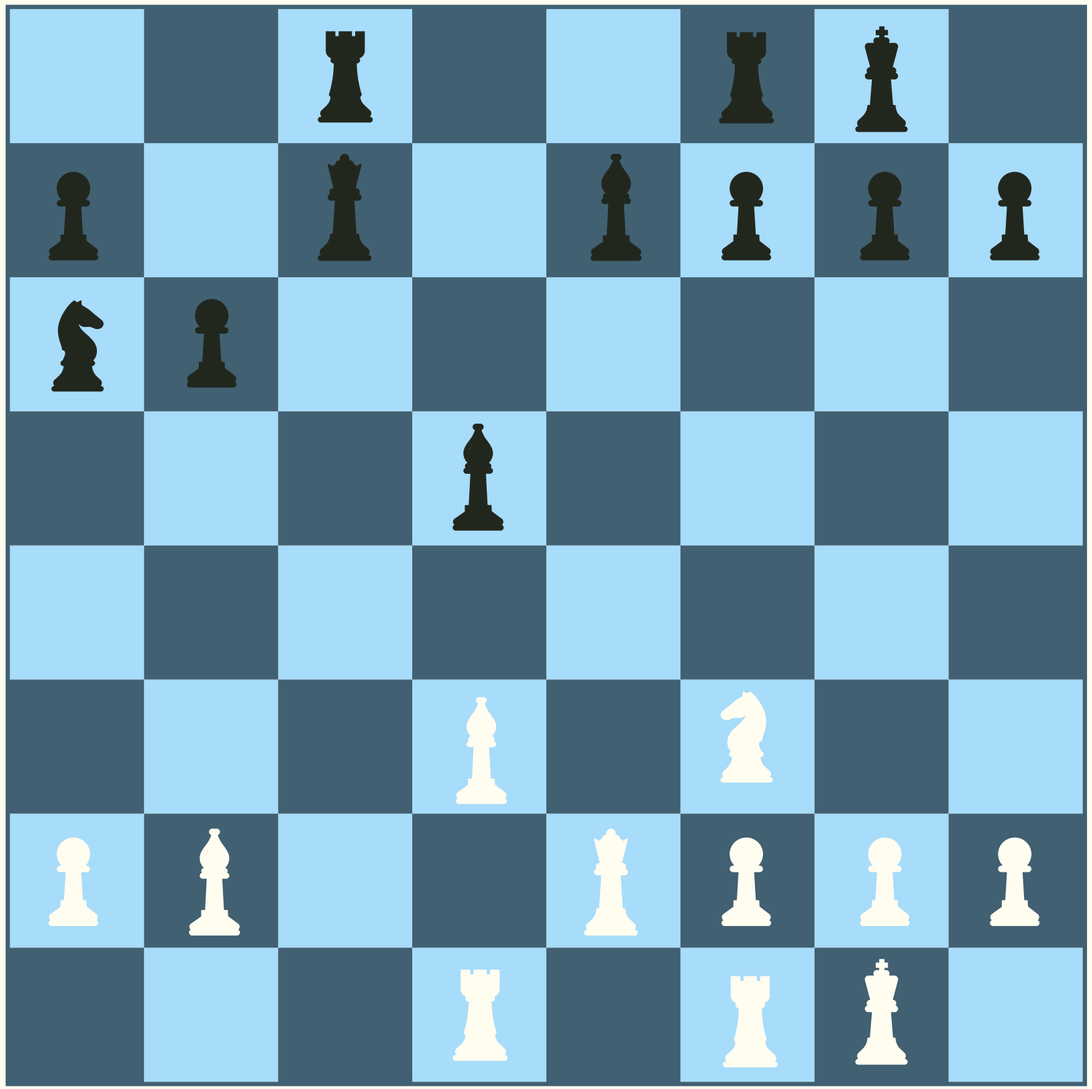
Special Chess Move

EN PASSANT

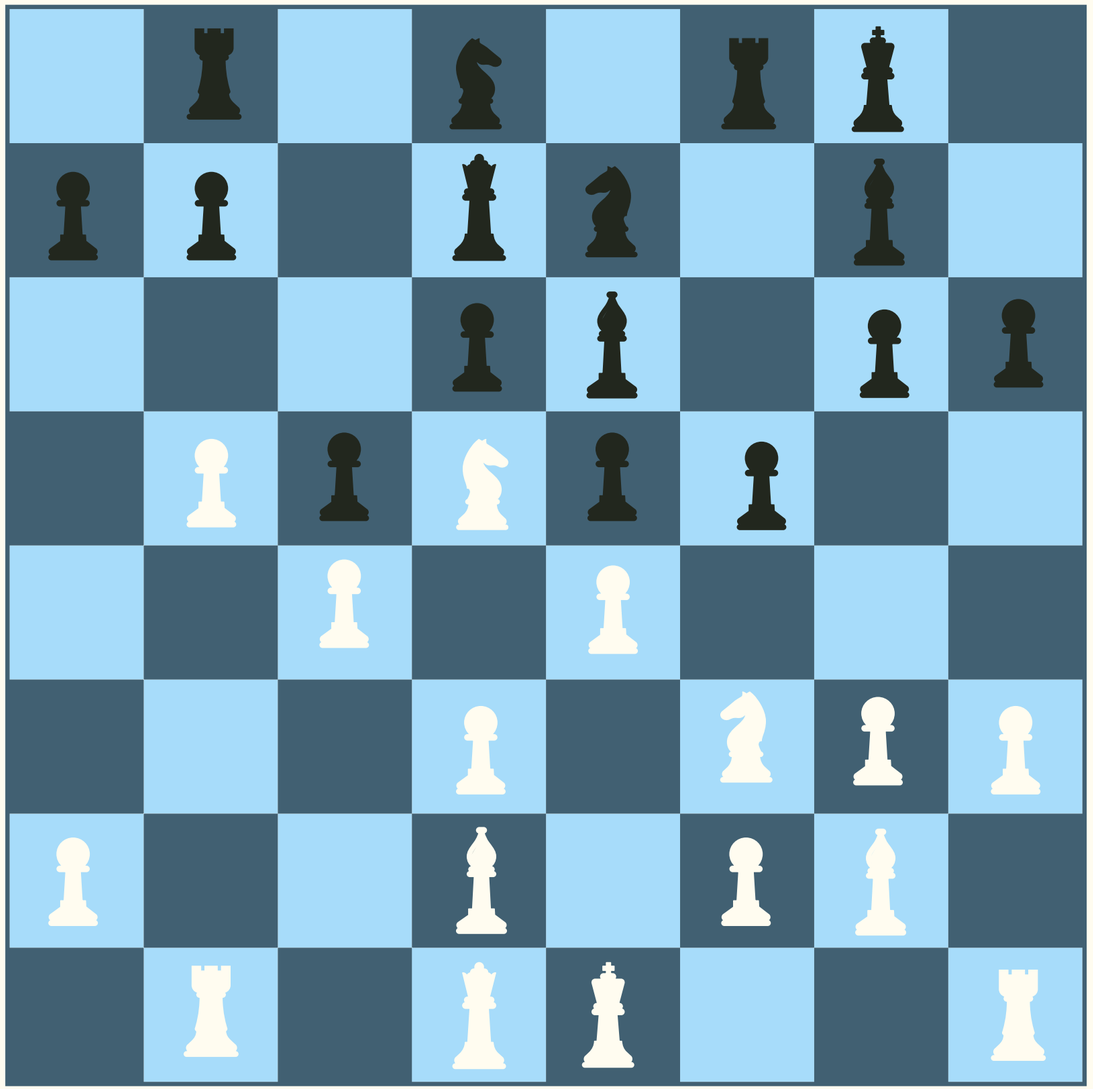


Pawn Structure

OPEN



CLOSED



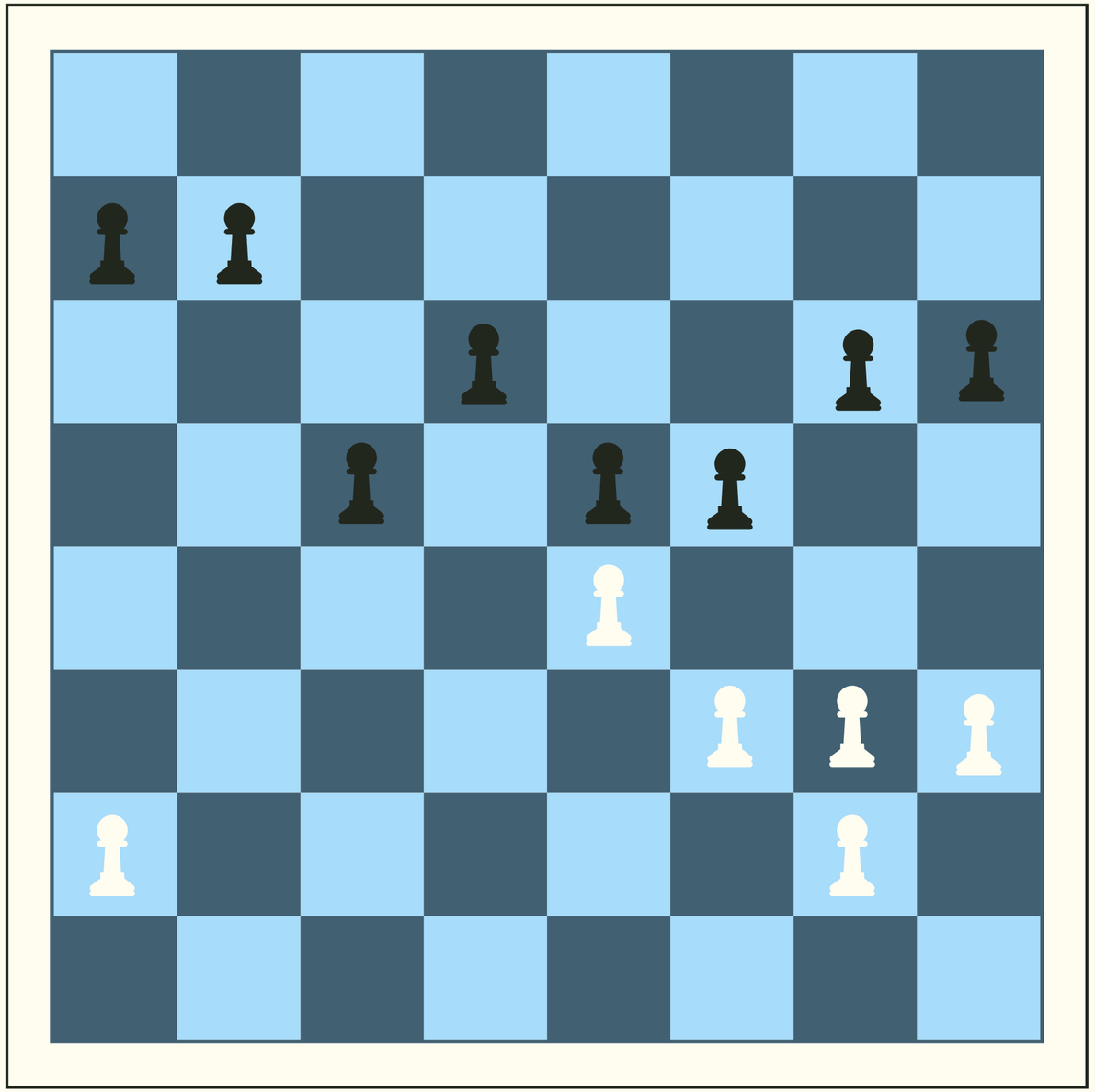
PAWN WEAKNESSES

Types of weaknesses

- Isolated pawn
- Holes
- Backwards pawn
- Doubled pawn

Strength:

- Passed pawn



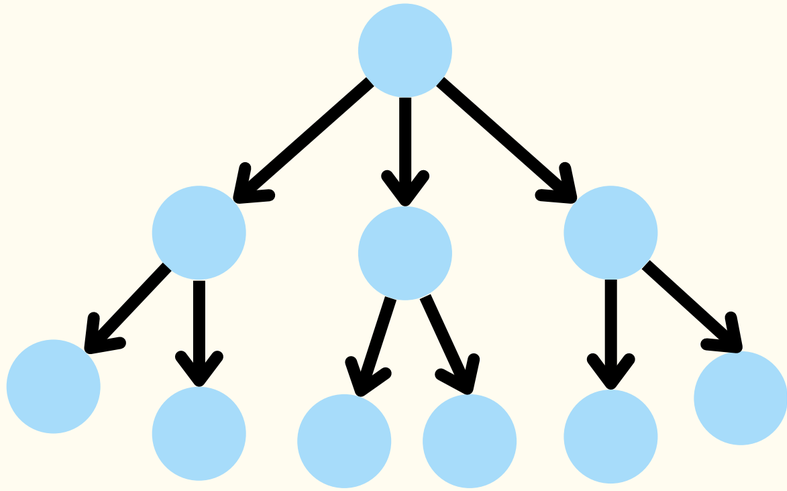
MONTE CARLO TREE SEARCH (MCTS)

MCTS

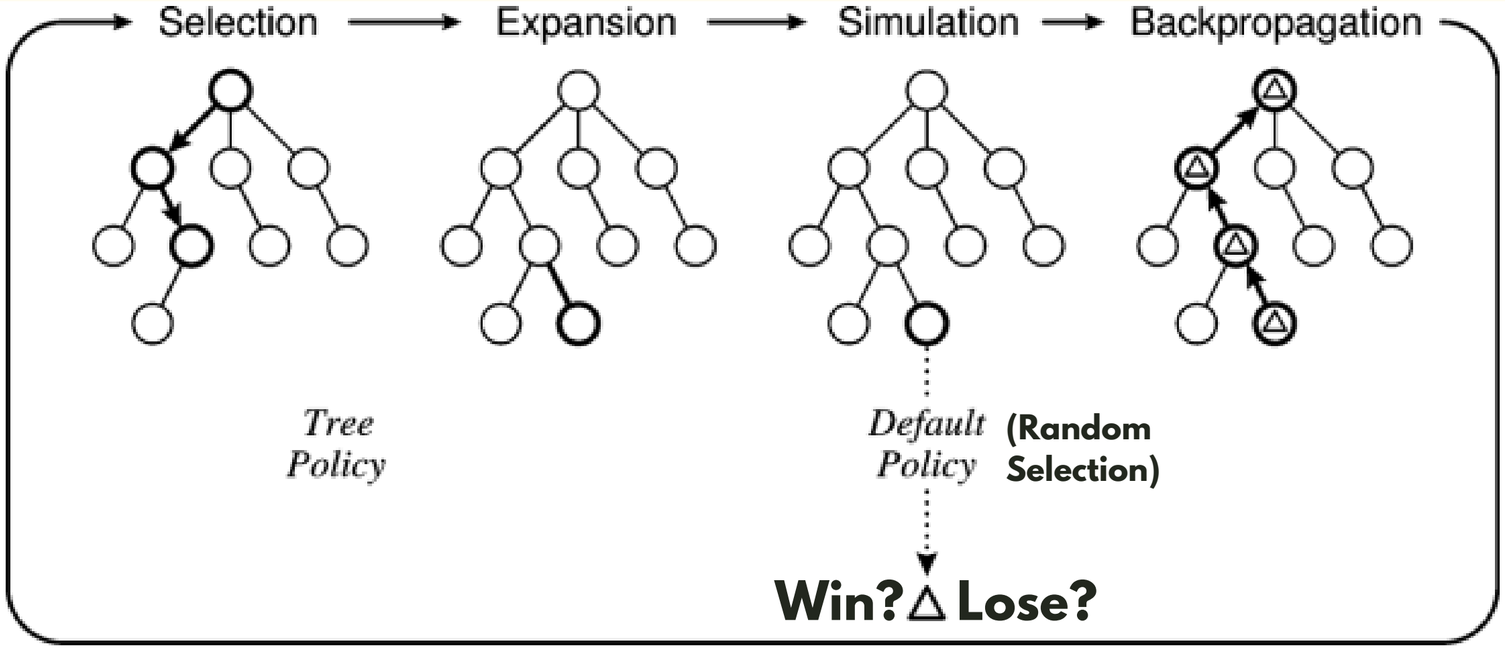
Two principles:

- The value of an action can be approximated using random simulation
- These values can be used to adjust some policy to choose the best action in a given state.

Procedurally generates a tree based on these two principles



FOUR MAIN STEPS



http://www.incompleteideas.net/609%20dropbox/other%20readings%20and%20resources/MCTS-survey.pdf

- **Selection: Choosing some "best" move based on some strategy**
- **Expansion: Expanding on the chosen move**
- **Simulation: Playing random moves, giving value**
- **Backpropagation: Spread value**

DEEP NEURAL NETWORKS

- Feedforward
- Convolutional
- Residual

Feed Forward

FEED FORWARD NETWORK

Three sections:

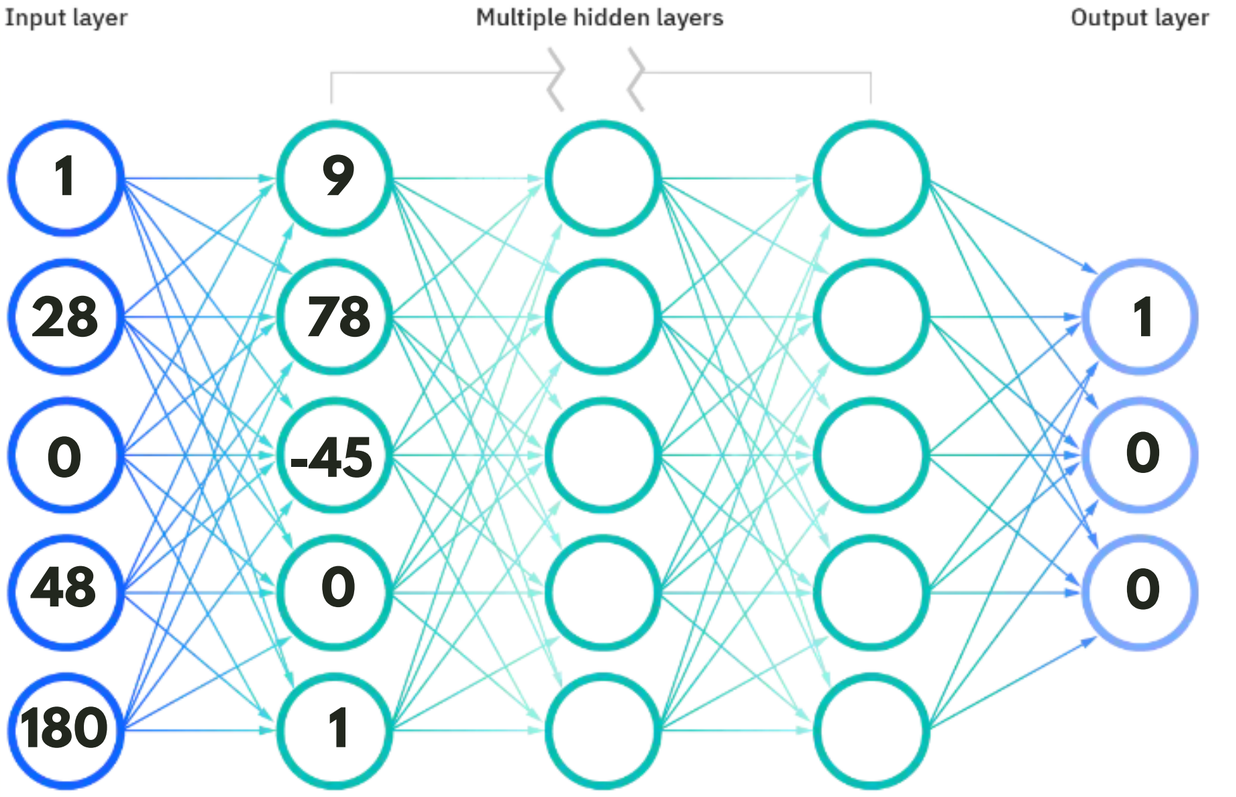
- Input layer
- Hidden layers
- Output layer

Node parts:

- Input/Output edges (with weights)
- Activation function
  - ReLu:
    - Maps negatives to 0

How does it learn?

- Training
- Loss function
- Changing weights

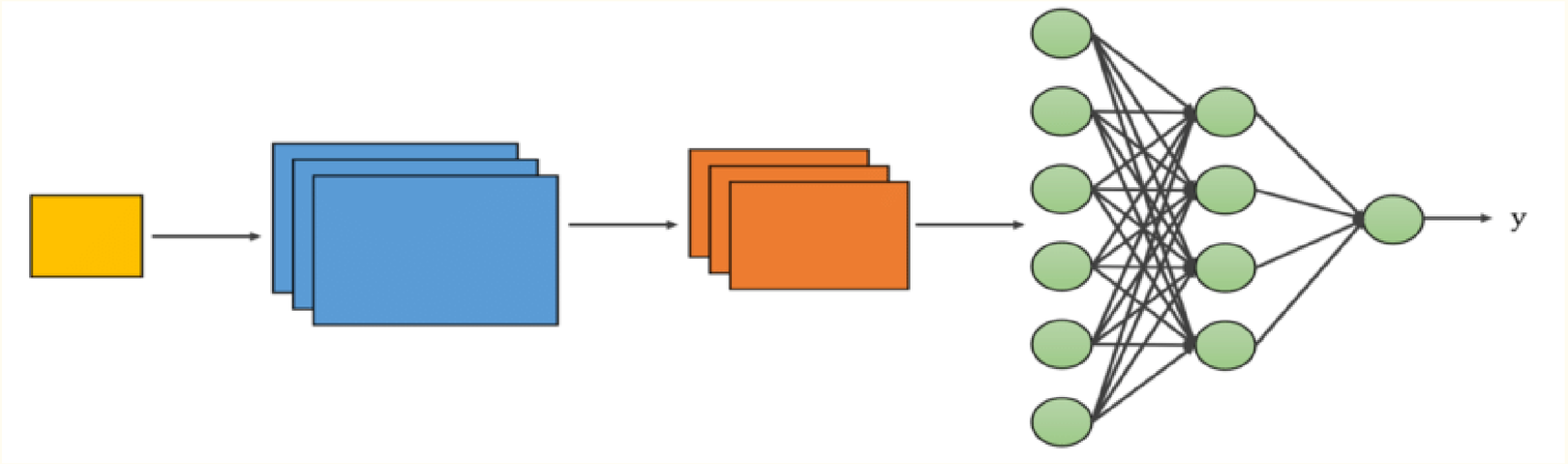


https://www.ibm.com/cloud/learn/neural-networks

Convolutional

CONVOLUTIONAL NETWORK

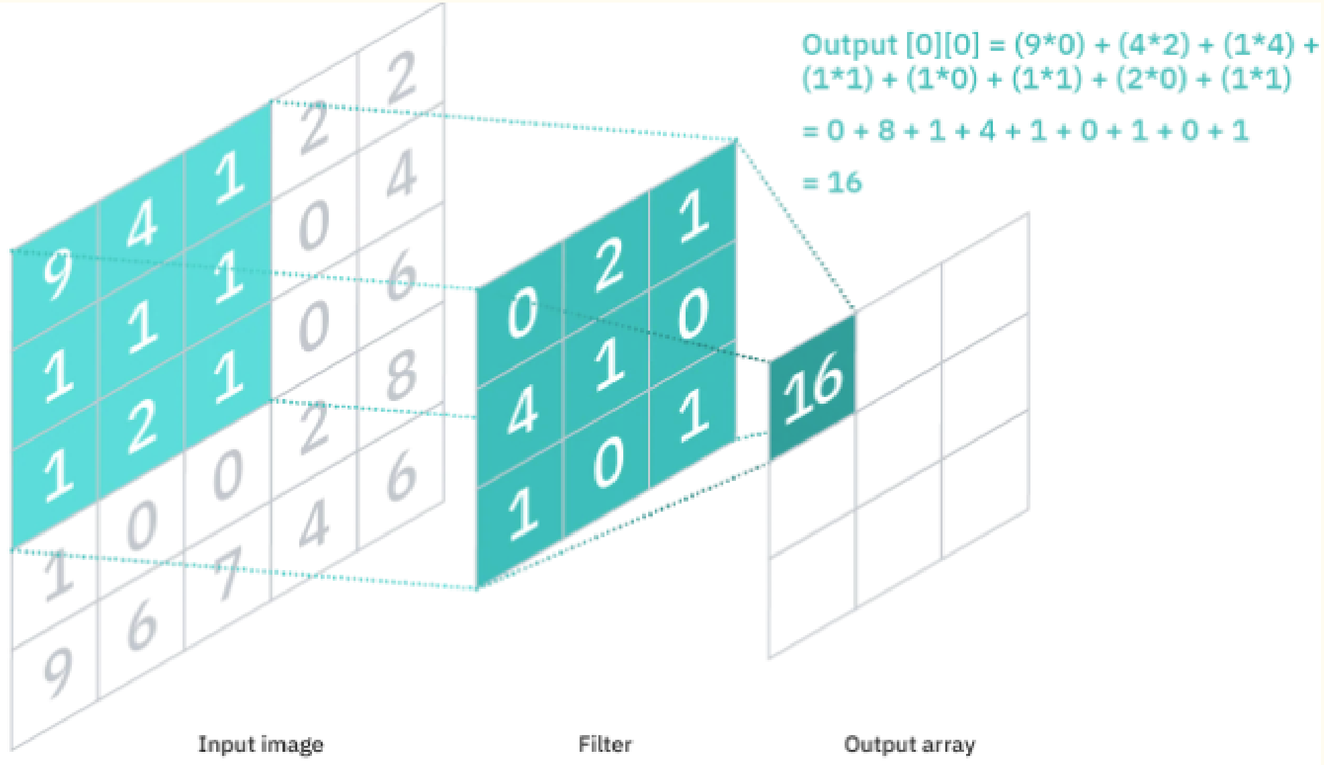
https://medium.com/swlh/an-overview-on-convolutional-neural-networks-ea48e76fb186



Five kinds of layers:

Input **Convolutional** **Pooling** **Fully Connected** **Output**

CONVOLUTIONAL LAYER



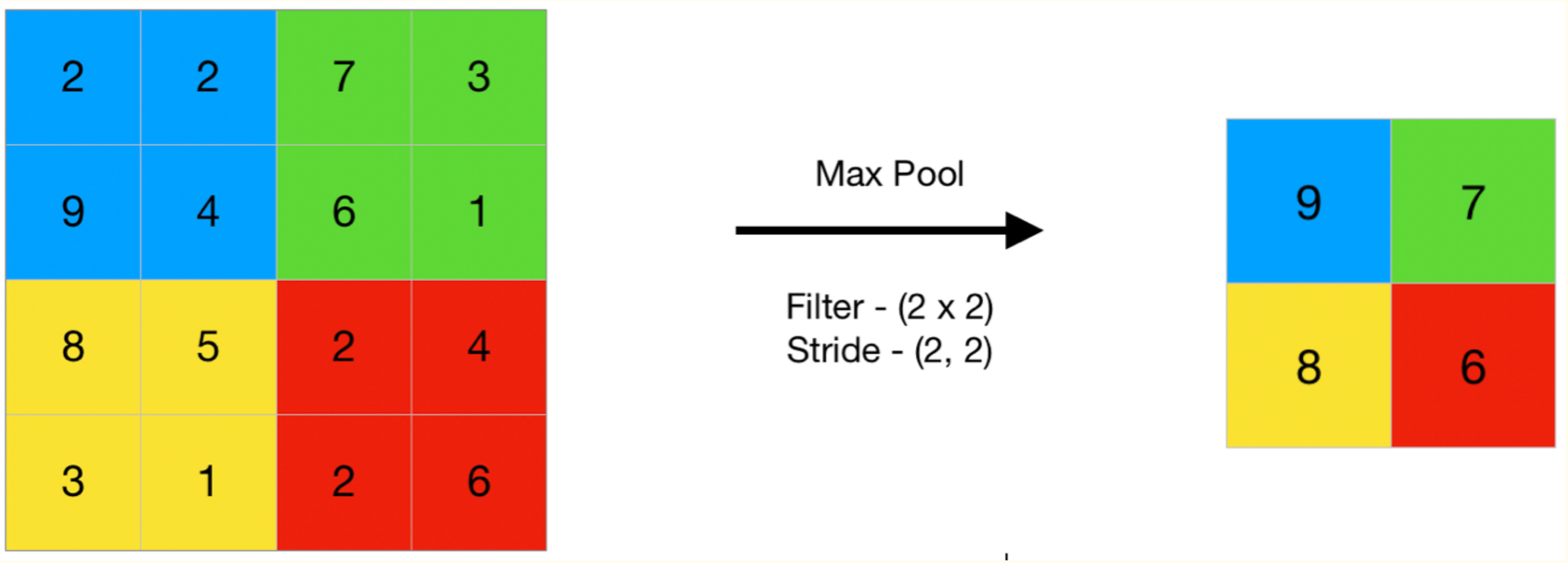
https://www.ibm.com/cloud/learn/convolutional-neural-networks

Three sections:

- **Input image**
- **Filter**
- **Output array**

The filter scans the image looking for some pattern or feature using the same concept as a feedforward network.

POOLING LAYER

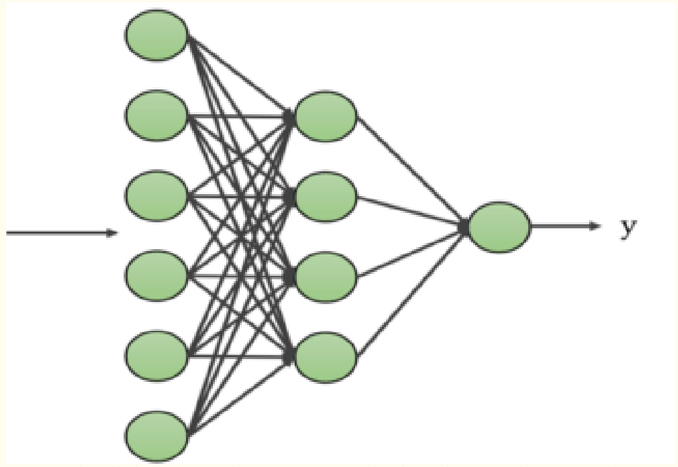


https://www.geeksforgeeks.org/cnn-introduction-to-pooling-layer/

Three parts:

- **Input (output from conv. layer)**
- **Aggregation function**
- **Output layer**

FULLY CONNECTED LAYER



https://medium.com/swlh/an-overview-on-convolutional-neural-networks-ea48e76fb186

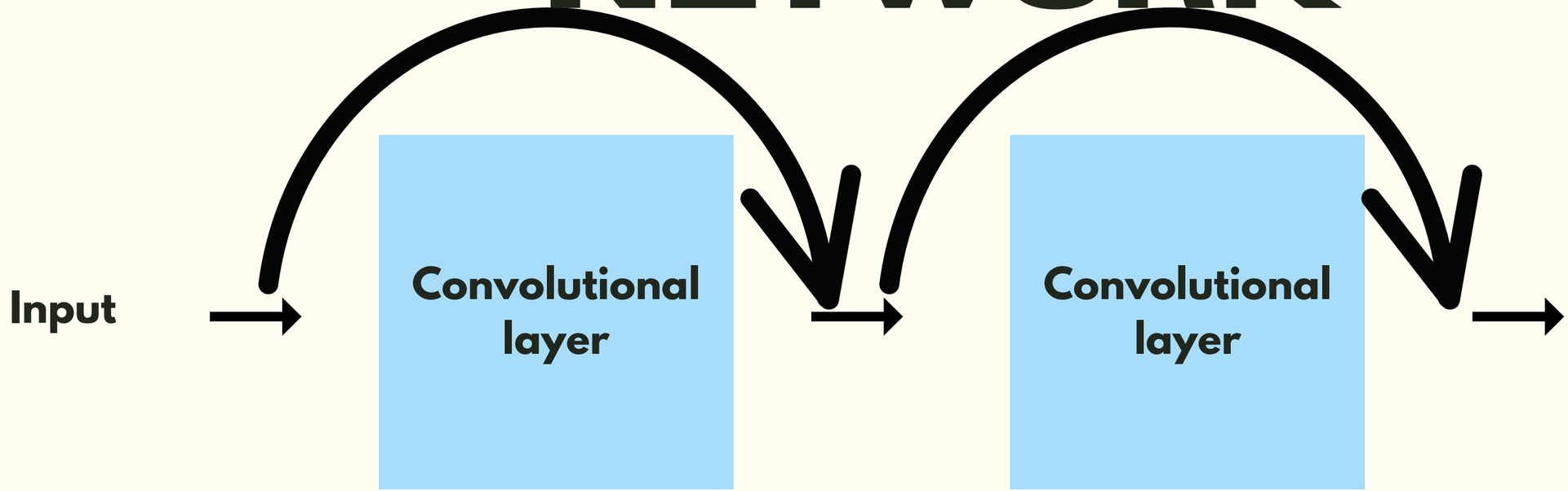
Like a feedforward network:

- **Every node connected to next layer**
- **Activation functions**
- **Output has some classification for each node**

All other layers are partially connected to the output

Residual

RESIDUAL NETWORK



- Adds complexity
- Doesn't increase computation as much

ALPHA ZERO

ALPHA ZERO

AlphaZero:

- **MCTS**
- **Residual Network**

Residual Network:

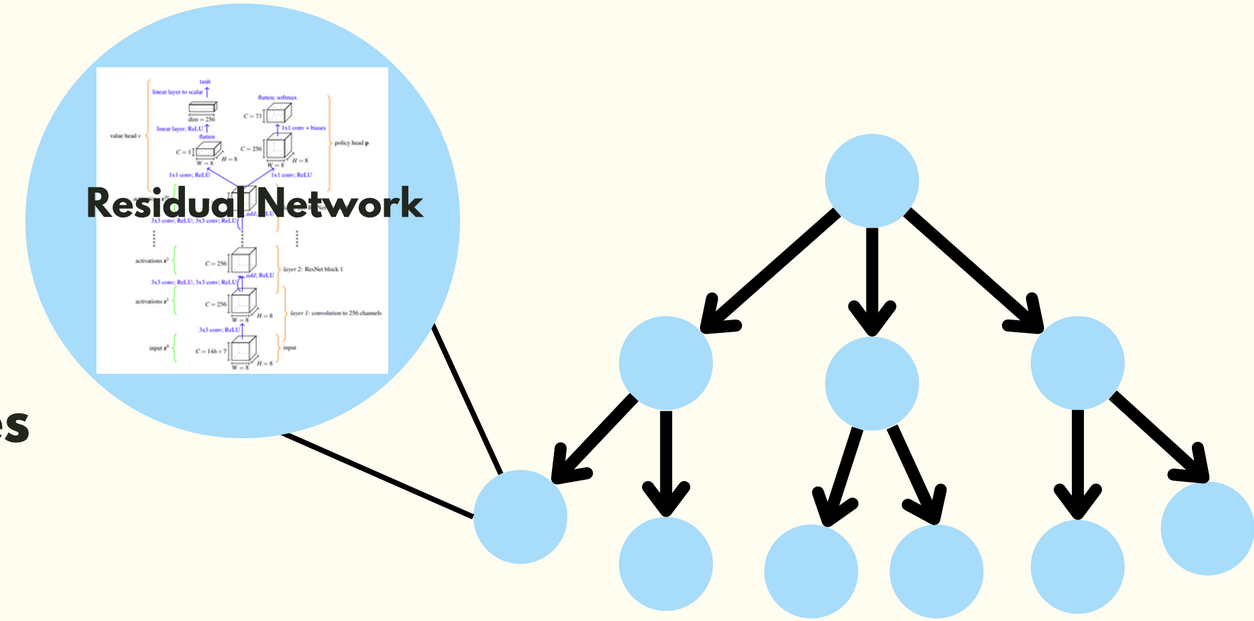
- **Outputs:**
  - **Vector of move probabilities**
  - **Expected outcome**

MCTS:

- **Uses vector for selection**
- **Uses expected outcome for simulation**

Training:

- **Self play**
- **Doesn't change weights till the end**



METHODS

- Variants
- Training

VARIANTS

This is a list of all the variants used in the study.

For this presentation I will cover Pawn-sideways and self-capture chess.

Variant	Primary rule change	Secondary rule change
No-castling	Castling is disallowed throughout the game	-
No-castling (10)	Castling is disallowed for the first 10 moves (20 plies)	-
Pawn one square	Pawns can only move by one square	-
Stalemate=win	Forcing stalemate is a win rather than a draw	-
Torpedo	Pawns can move by 1 or 2 squares anywhere on the board. En passant can consequently happen anywhere on the board.	-
Semi-torpedo	Pawns can move by two square both from the 2nd and the 3rd rank	-
Pawn-back	Pawns can move backwards by one square, but only back to the 2nd/7th rank for White/Black	Pawn moves do not count towards the 50 move rule
Pawn-sideways	Pawns can also move laterally by one square. Captures are unchanged, diagonally upwards	Sideway pawn moves do not count towards the 50 move rule
Self-capture	It is possible to capture one's own pieces	-

TRAINING

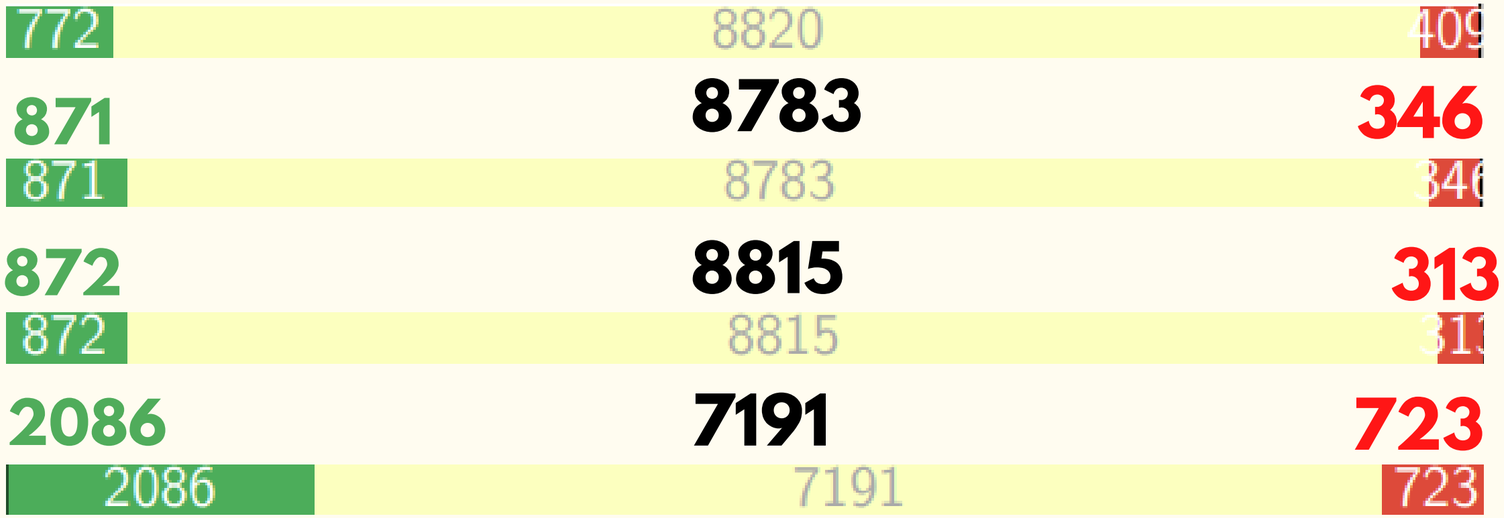
- For each variation AlphaZero starts with the same set of hyperparameters each time
- The models were trained for 1 million training steps
- To encourage exploration, during training noise is injected into the prior move probabilities.

RESULTS

- 10,000 games at 1 second per move
- 1,000 games played at 1 minute per move

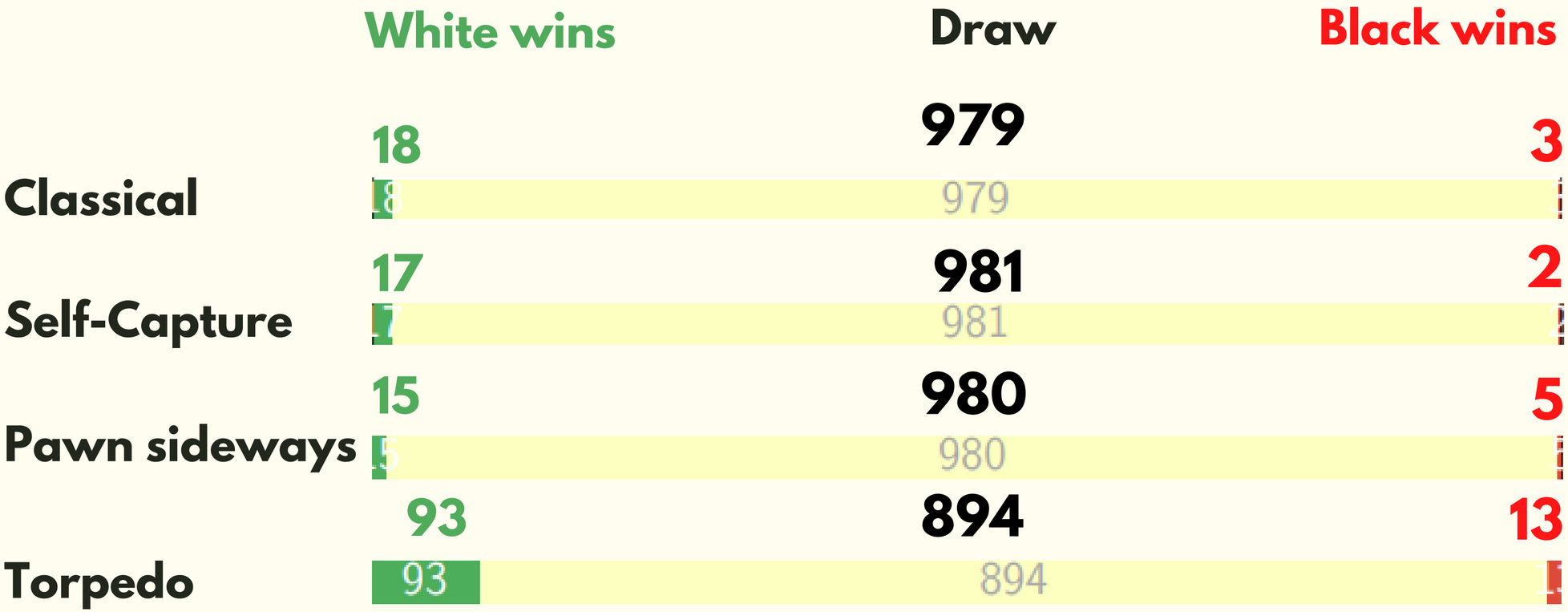
TEST WITH 10,000 GAMES WITH 1 SECOND MOVES

	White wins	Draw	Black wins
Classical	772	8820	409
Self-Capture	871	8783	346
Pawn sideways	872	8815	313
Torpedo	2086	7191	723



- Draw rates are always fairly high in high-level chess
- White typically has an advantage
- The 1 second time limit on moves makes each game more decisive which showcases the white side advantage more.

TEST WITH 1,000 GAMES WITH 1 MINUTE MOVES



- With 1 minute moves the games become a lot less decisive
- White side advantage still exists, but becomes more subtle
- Draw rates increase

ANALYSIS

ANALYSIS

BY VLADIMIR KRAMNIK

Torpedo Chess:

- Aggressive
- More decisive
- Passed pawns are valuable
- En passant becomes more common

Pawn-sideways chess:

- Complex
- New strategies
- Hard to analyze
- Open vs Closed pawn structures

Self-capture chess:

- Not much changed
- Rare for self-captures to happen
- Some self-captures are for exploration

CONCLUSION

QUESTIONS

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Nenad Tomasev, Ulrich Paquet, Demis Hassabis, Vladimir Kramnik: Assessing Game Balance with AlphaZero: Exploring Alternative Rule Sets in Chess. https://arxiv.org/abs/2009.04374 (2020)

McGrath, Thomas et al. “Acquisition of Chess Knowledge in AlphaZero.” ArXiv abs/2111.09259 (2021): n. Pag

Michael C. Fu. 2018. Monte Carlo tree search: a tutorial. In Proceedings of the 2018 Winter Simulation Conference (WSC '18). IEEE Press, 222–236.

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