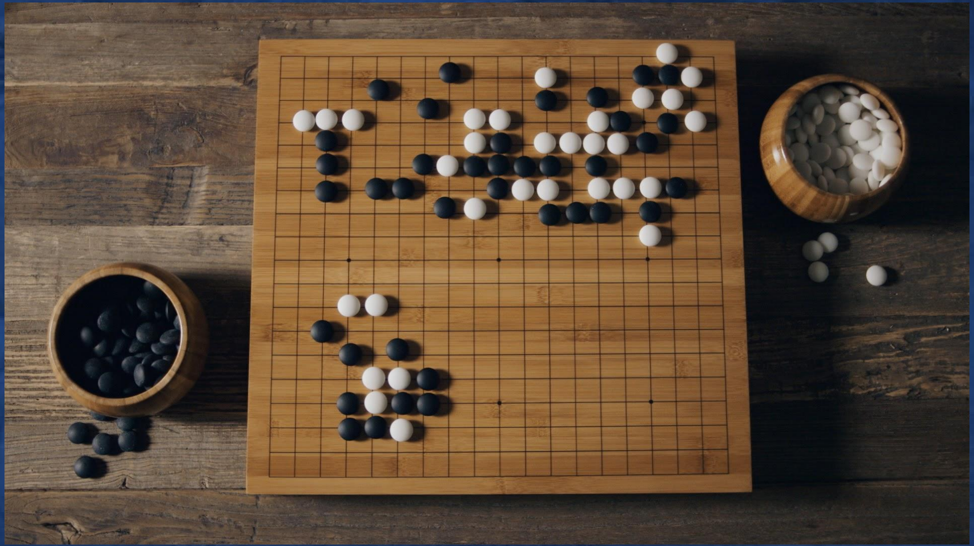
AlphaGo

Why is Go hard for computers to play?

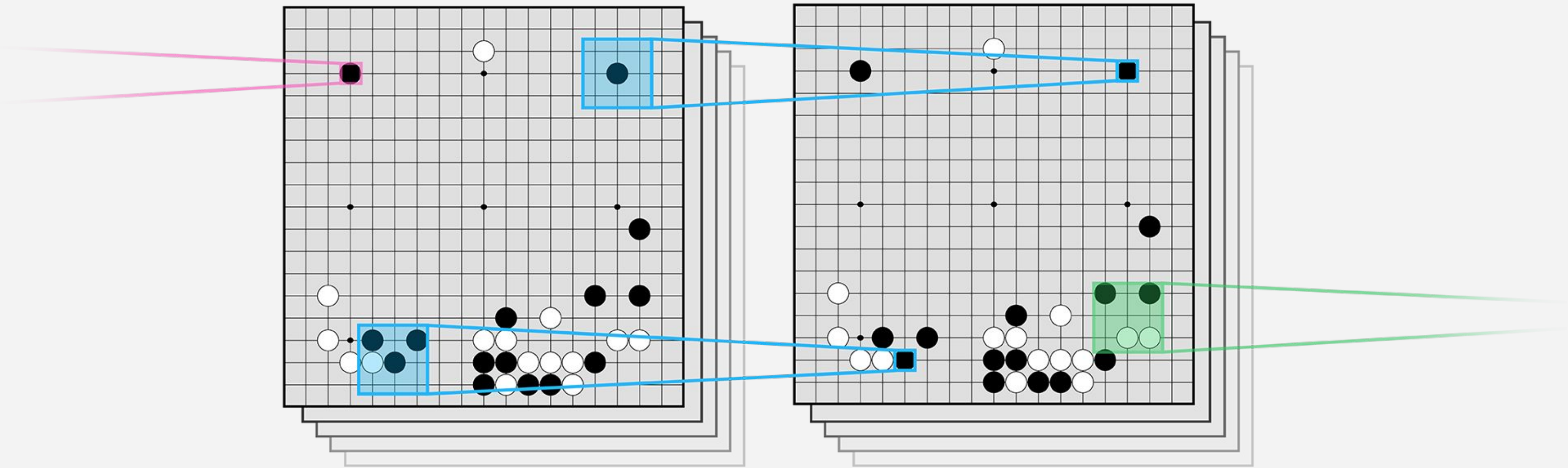
Game tree complexity = b^d

Brute force search intractable:

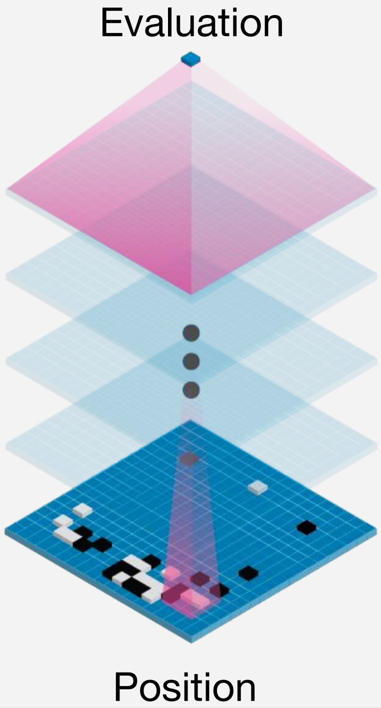
1. Search space is huge
2. "Impossible" for computers to evaluate who is winning

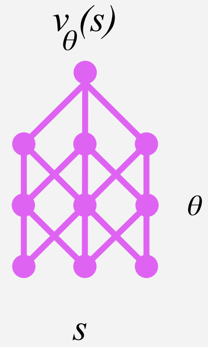


Convolutional neural network



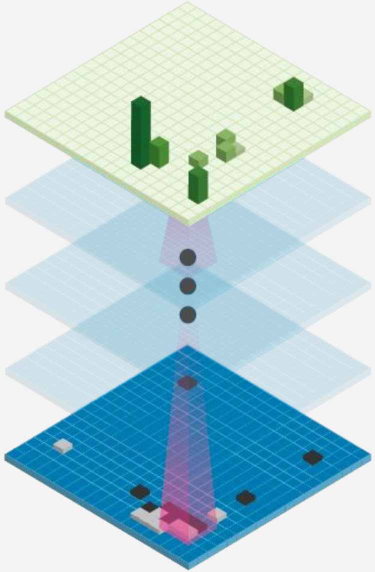
Value network





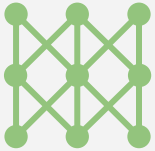
Policy network

Move probabilities



Position

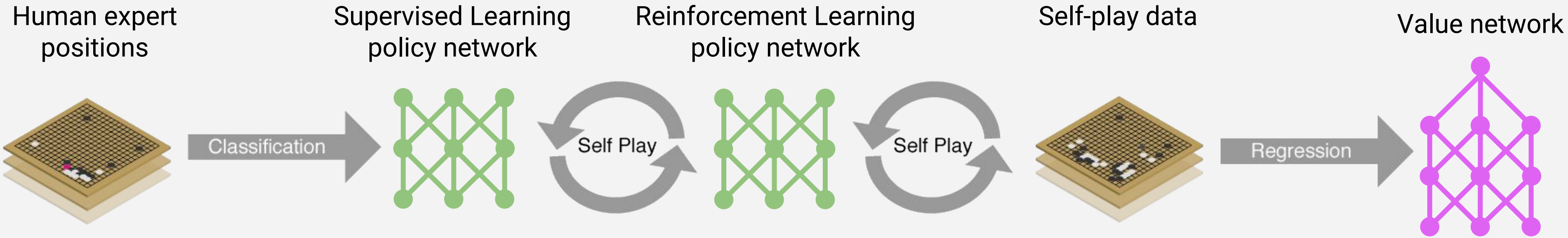
$p_\sigma(a|s)$



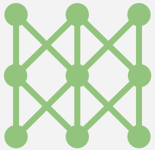
σ

s

Neural network training pipeline



Supervised learning of policy networks



Policy network: 12 layer convolutional neural network

Training data: 30M positions from human expert games (KGS 5+ dan)

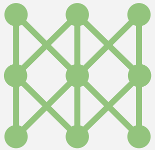
Training algorithm: maximise likelihood by stochastic gradient descent

$$\Delta\sigma \propto \frac{\partial \log p_\sigma(a|s)}{\partial \sigma}$$

Training time: 4 weeks on 50 GPUs using Google Cloud

Results: 57% accuracy on held out test data (state-of-the art was 44%)

Reinforcement learning of policy networks



Policy network: 12 layer convolutional neural network

Training data: games of self-play between policy network

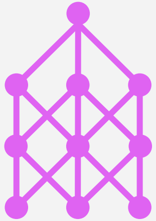
Training algorithm: maximise wins z by policy gradient reinforcement learning

$$\Delta\sigma \propto \frac{\partial \log p_\sigma(a|s)}{\partial \sigma} z$$

Training time: 1 week on 50 GPUs using Google Cloud

Results: 80% vs supervised learning. Raw network ~3 amateur dan.

Reinforcement learning of value networks



Value network: 12 layer convolutional neural network

Training data: 30 million games of self-play

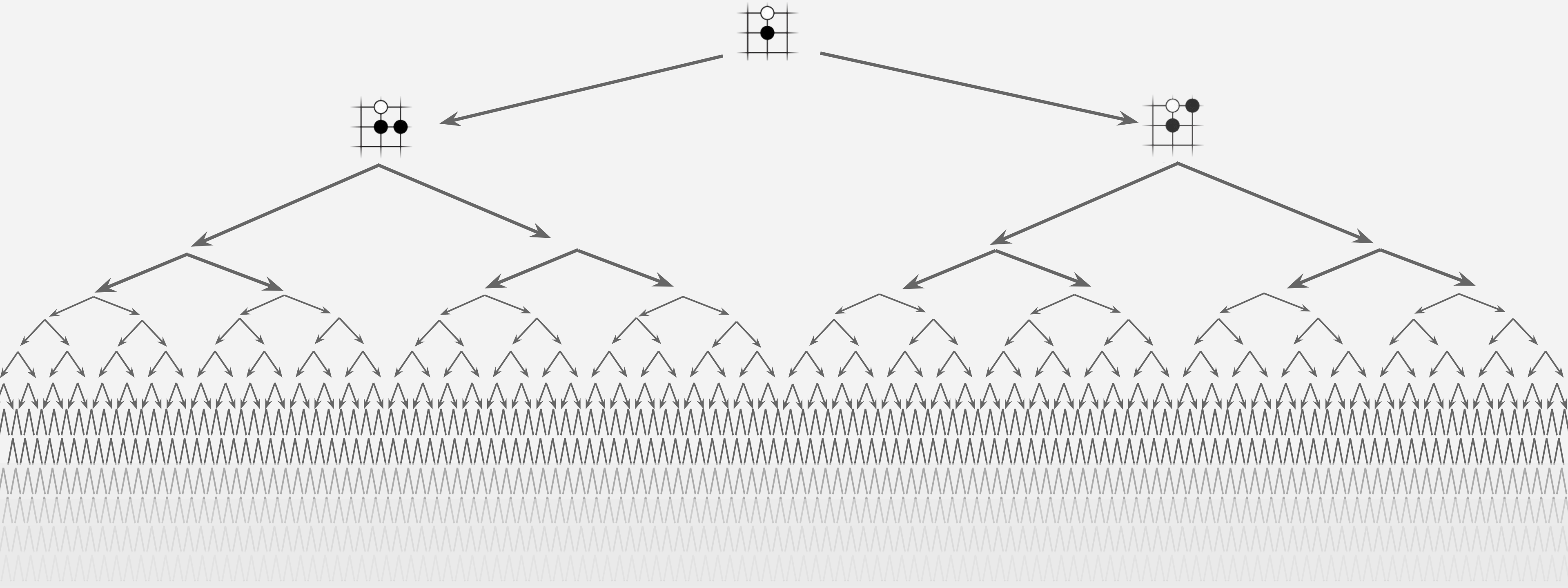
Training algorithm: minimise MSE by stochastic gradient descent

$$\Delta\theta \propto \frac{\partial v_\theta(s)}{\partial\theta}\left(z - v_\theta(s)\right)$$

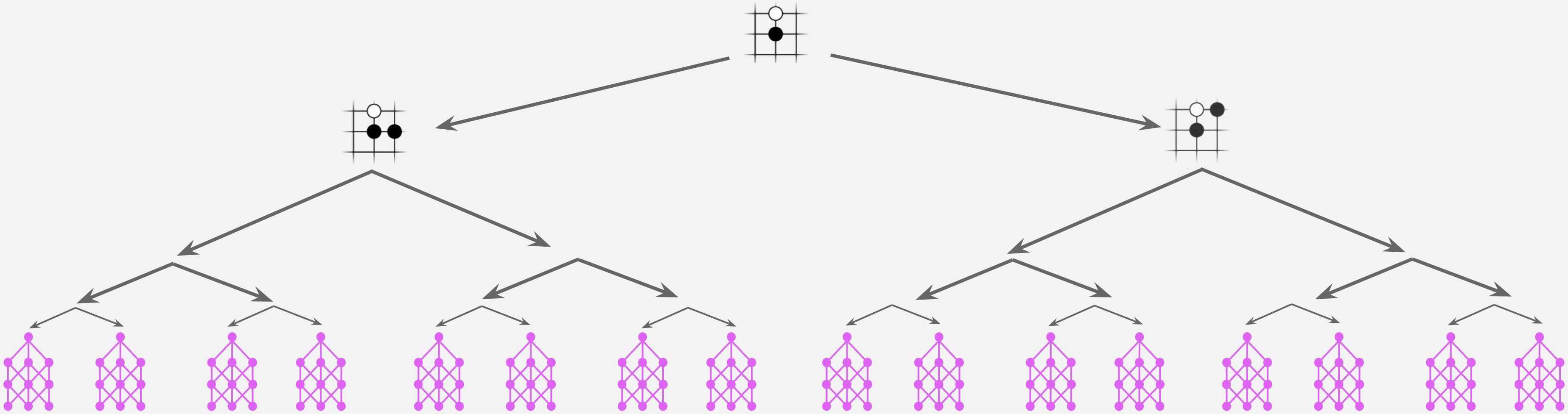
Training time: 1 week on 50 GPUs using Google Cloud

Results: First strong position evaluation function - previously thought impossible

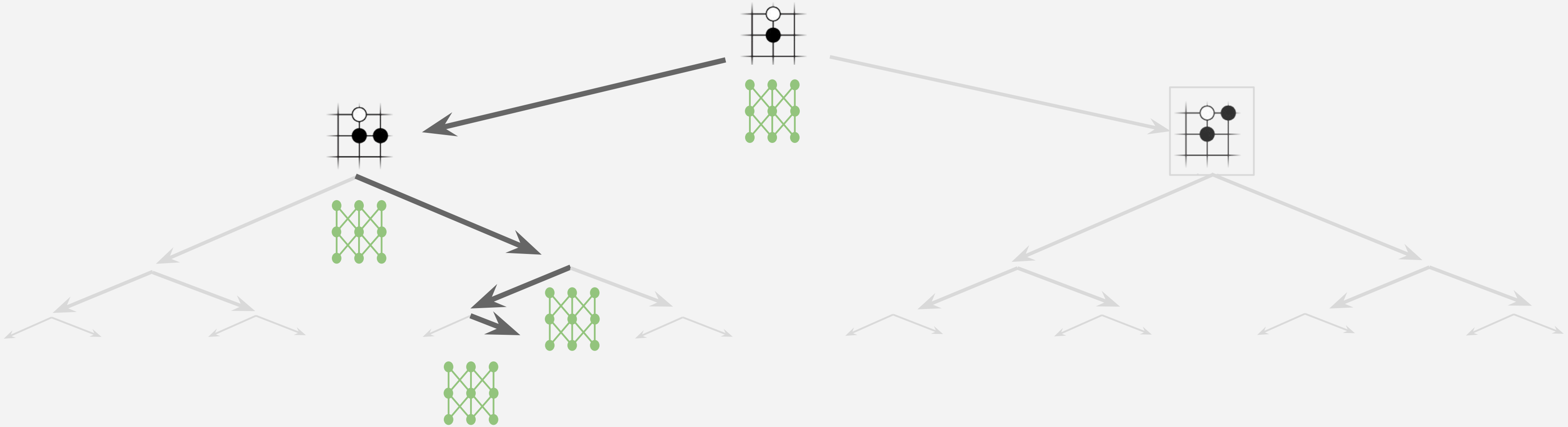
Exhaustive search



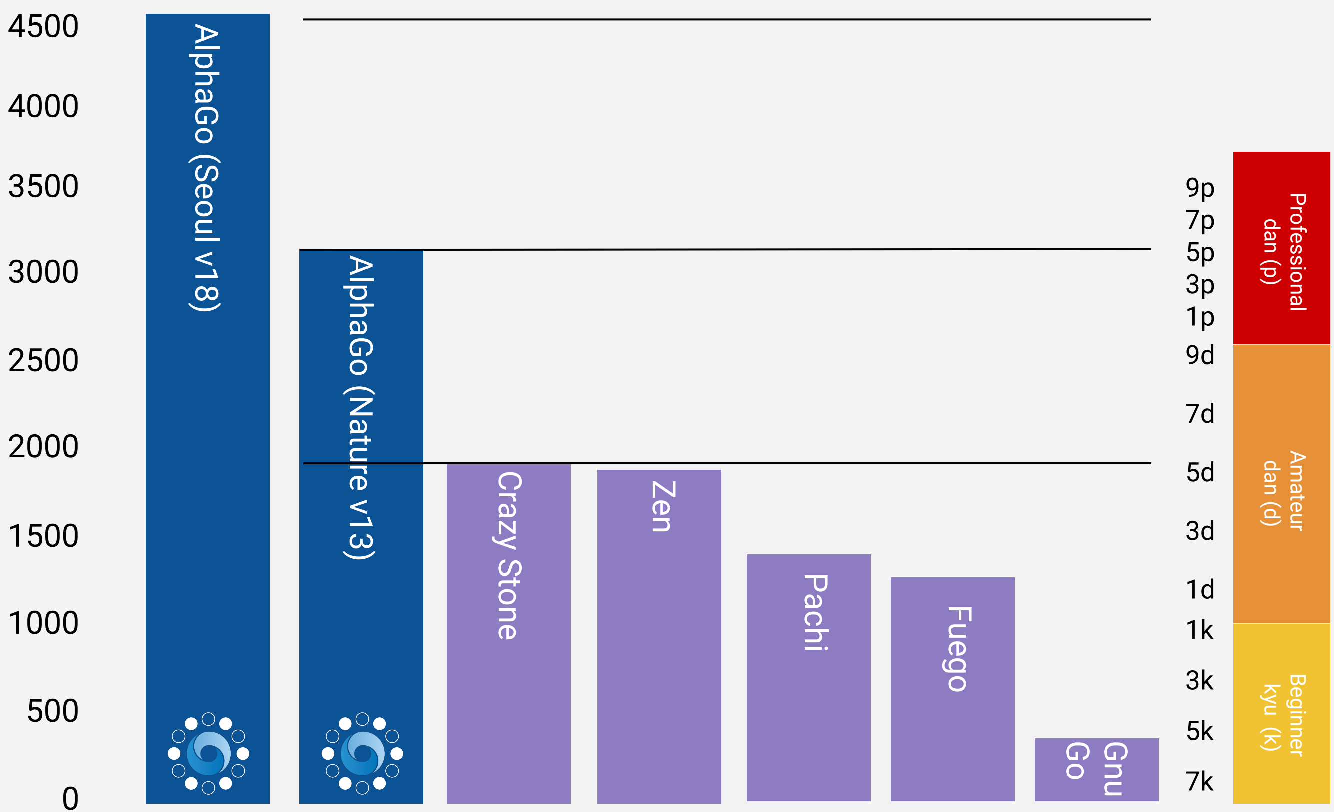
Reducing depth with value network

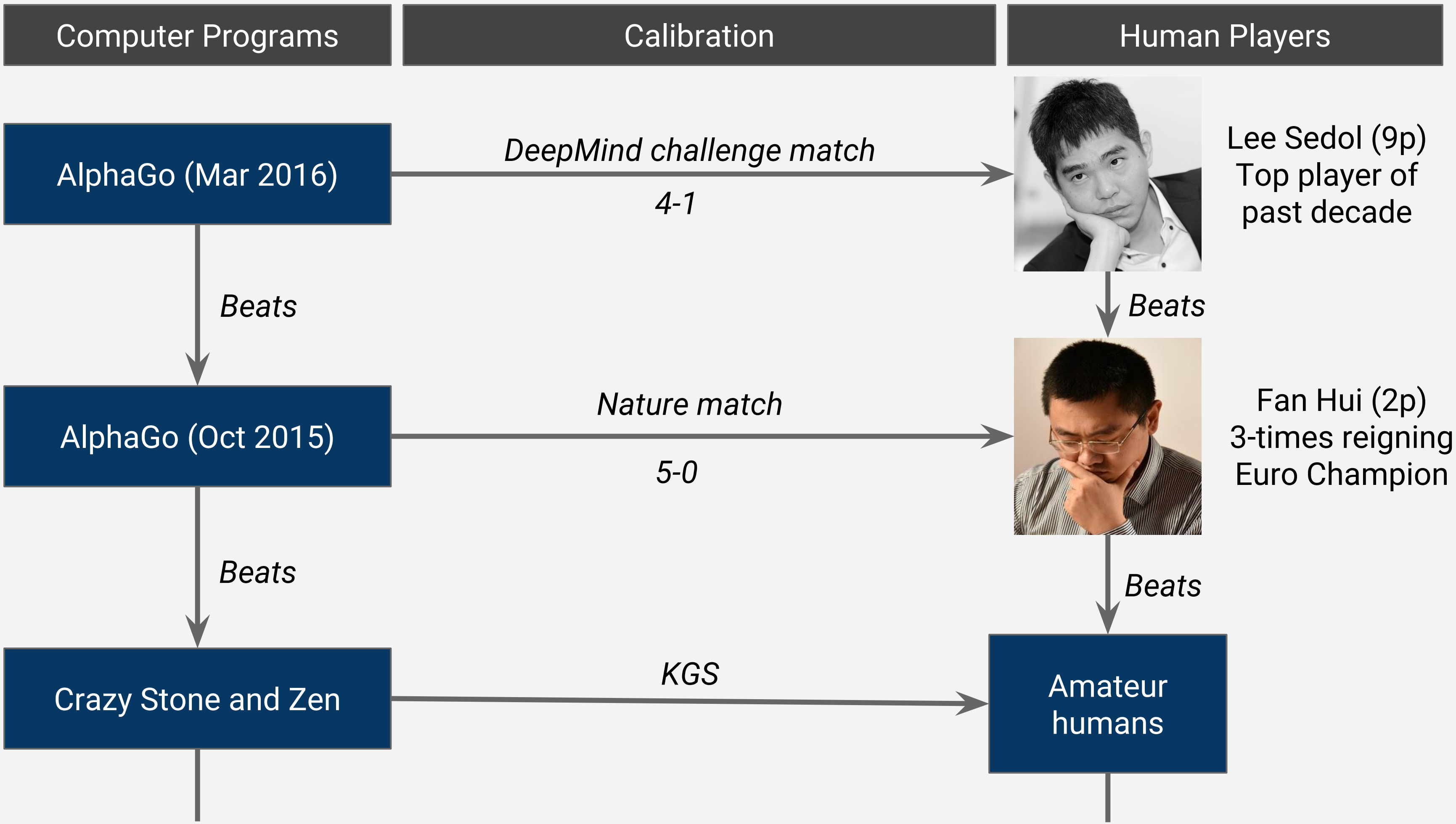


Reducing breadth with policy network

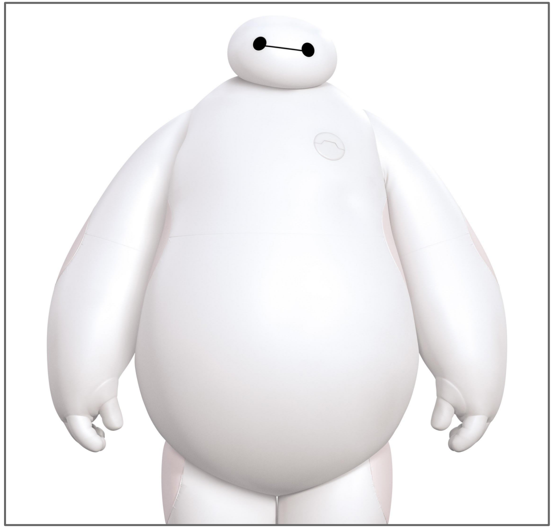


Evaluating AlphaGo against computers




Computer Programs
Calibration
Human Players
AlphaGo (Mar 2016)
DeepMind challenge match
4-1
Lee Sedol (9p)
Top player of
past decade
Beats
Beats
AlphaGo (Oct 2015)
Nature match
5-0
Fan Hui (2p)
3-times reigning
Euro Champion
Beats
Beats
Crazy Stone and Zen
KGS
Amateur
humans

What's Next?




Google DeepMind