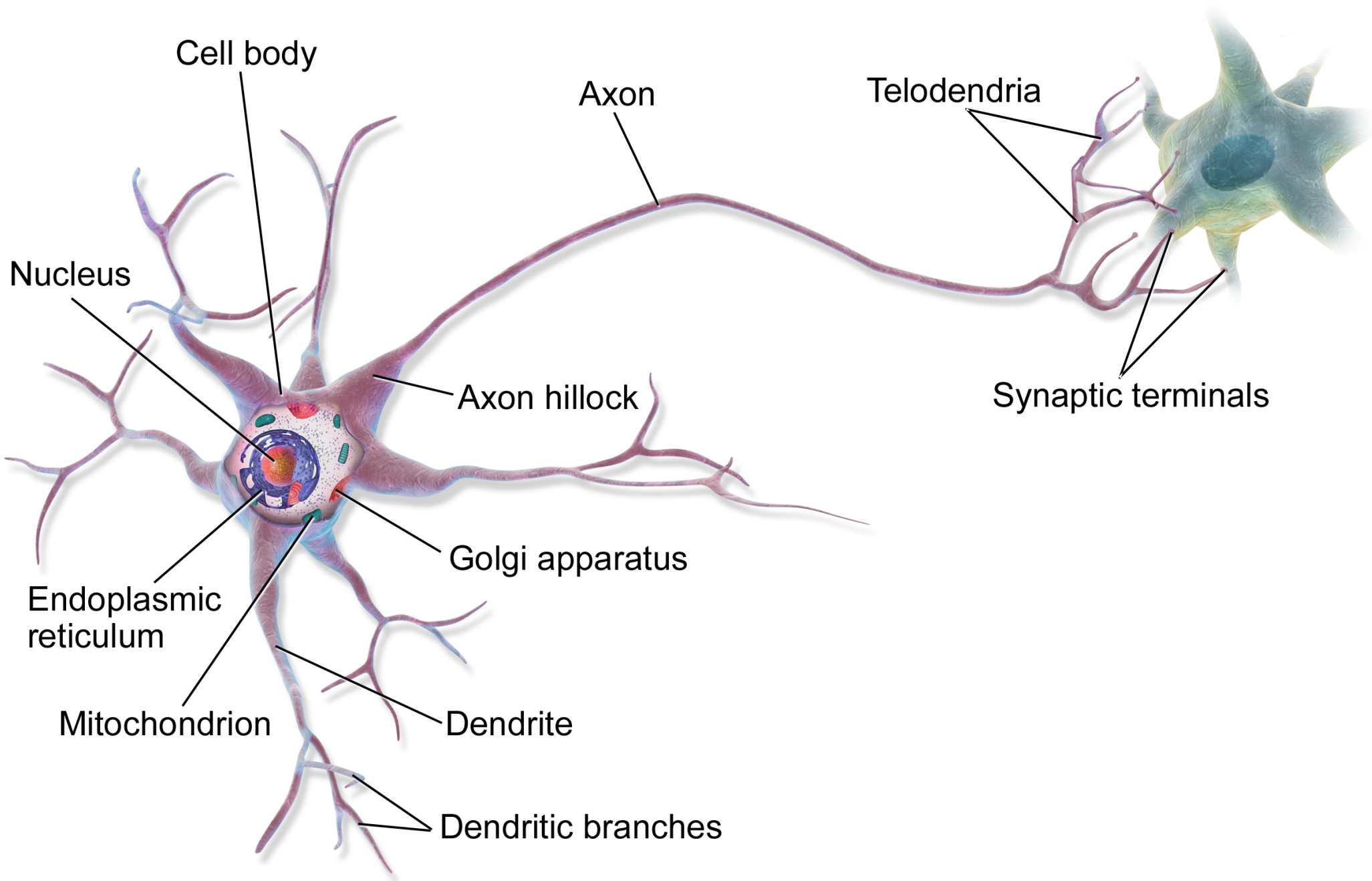
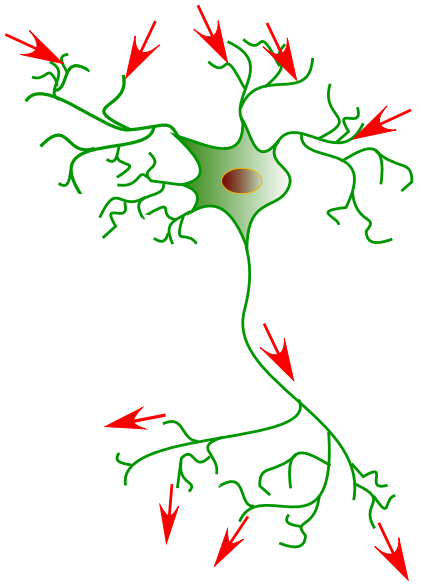
Deep Learning
History, Foundation and Applications



A neuron in the brain

- Neurons collects inputs from other neurons
- Strength of an input is controlled by synaptic weight of that connection
- If the input signal exceeds a threshold,
  post synaptic neuron fires spike
- Neurons adapt weights to learn



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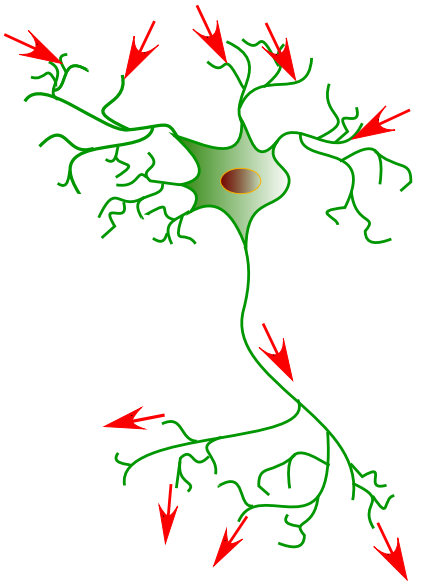
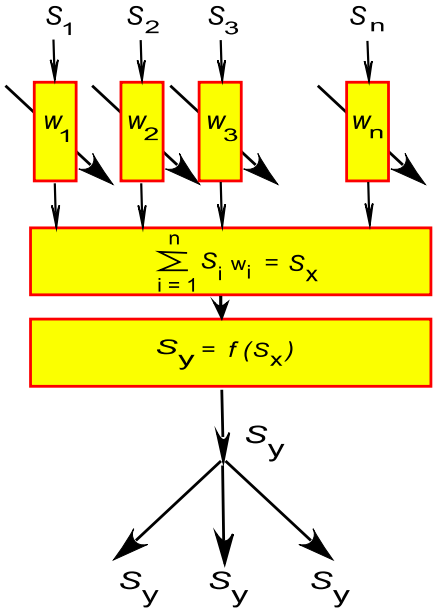
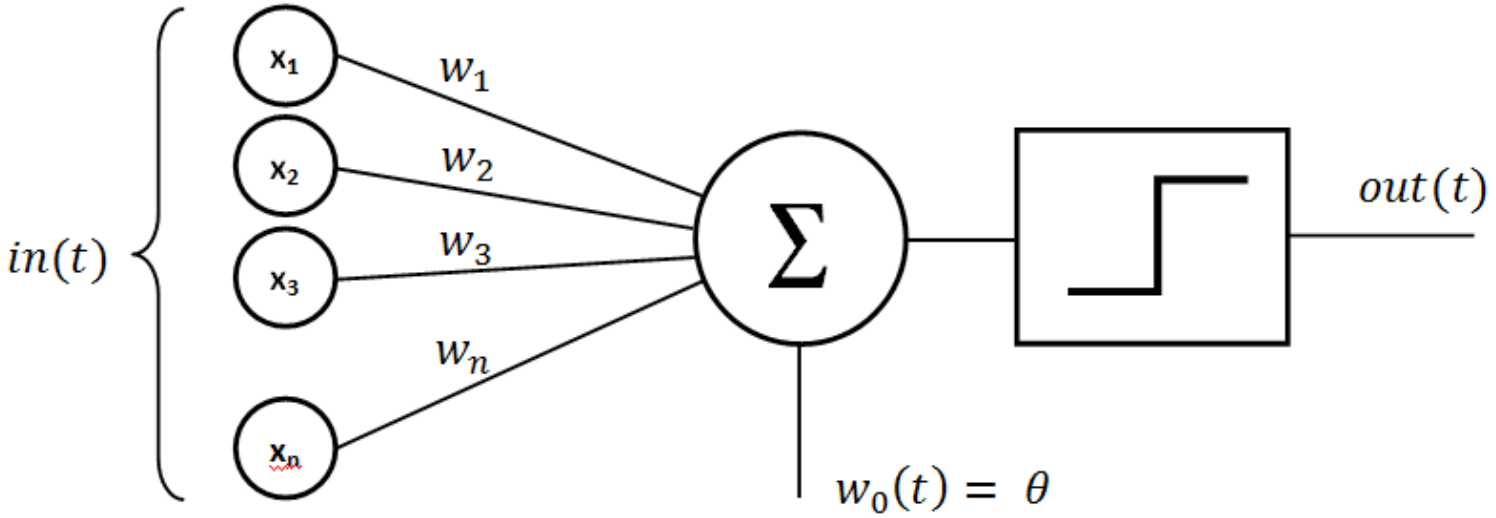




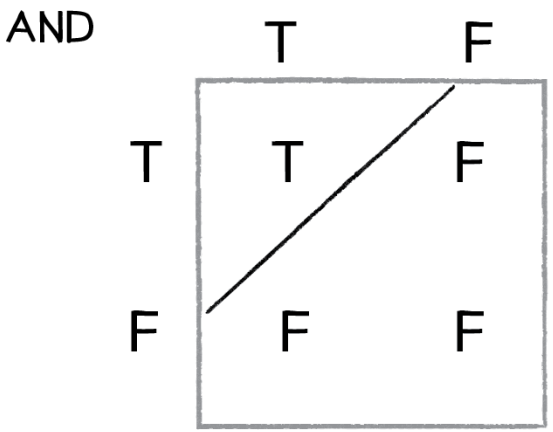
Perceptron

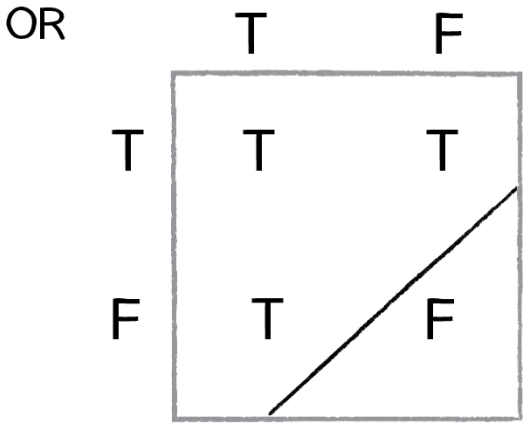


- Binary threshold neuron → Binary classifier
- One layer
- There exists a very simple learning algorithm
- Need good (hand crafted) input features

Perceptron

- Became popular in the 60s
- Big claims were made
- In 1969 Minsky and Paperts published a book and showed limitations of perceptron





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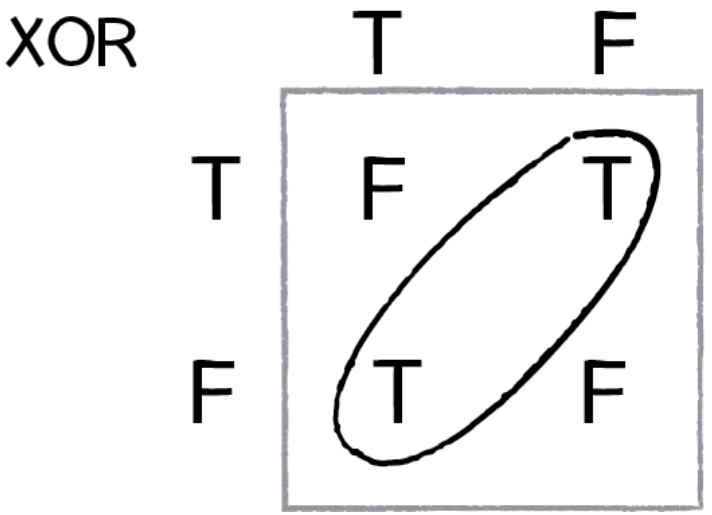


Perceptron

- Minsky and Paperts only showed limitation for some types of neural networks, but people were disappointed
- Multilayer Perceptron (aka deep network) do not have this problem
- While the learning algorithm “back propagation” was already known, training was very unreliable and so deeper networks did not work in most application
- “AI Winter”

Recent success of Deep Learning

- Since around 2012 neural networks have made a big come back
- Much more data available
- Much faster processors for training
- Learned lots of tricks how to train them
  - new activation functions (ReLU)
  - Better weight initialization
  - Improved optimization
  - Tricks to accelerate learning (e.g. batch normalization)
  - Methods to prevent overfitting

Current state

- Many cases where neural networks replace other custom solutions
- Often custom solutions work well too, but require huge amount of engineering and manual work to get going
- Replacing domain knowledge

Example Speech recognition (e.g. Amazon Alexa)

- Previously:
  - model for how the vocal chords and mouth create sounds (phonemes)
  - model for sound travelling through room
  - model for microphone characteristic
  - signal processing components developed for analyzing samples
- Today: most components replaced by one big neural network
- Reasons:
  - Can optimize the entire stack (not only individual components)
  - Easy to improve model: get more data
  - Less domain knowledge and model assumptions necessary

Applications

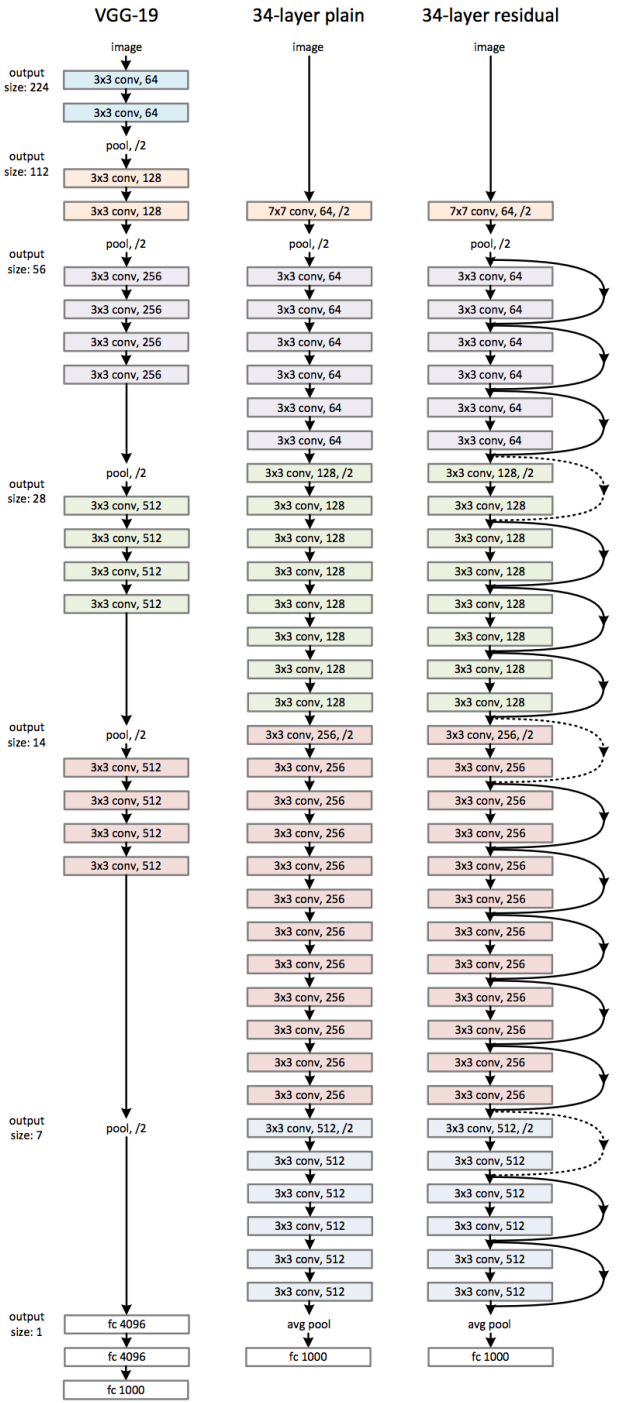
Computer vision

Deep Residual Learning for Image Recognition

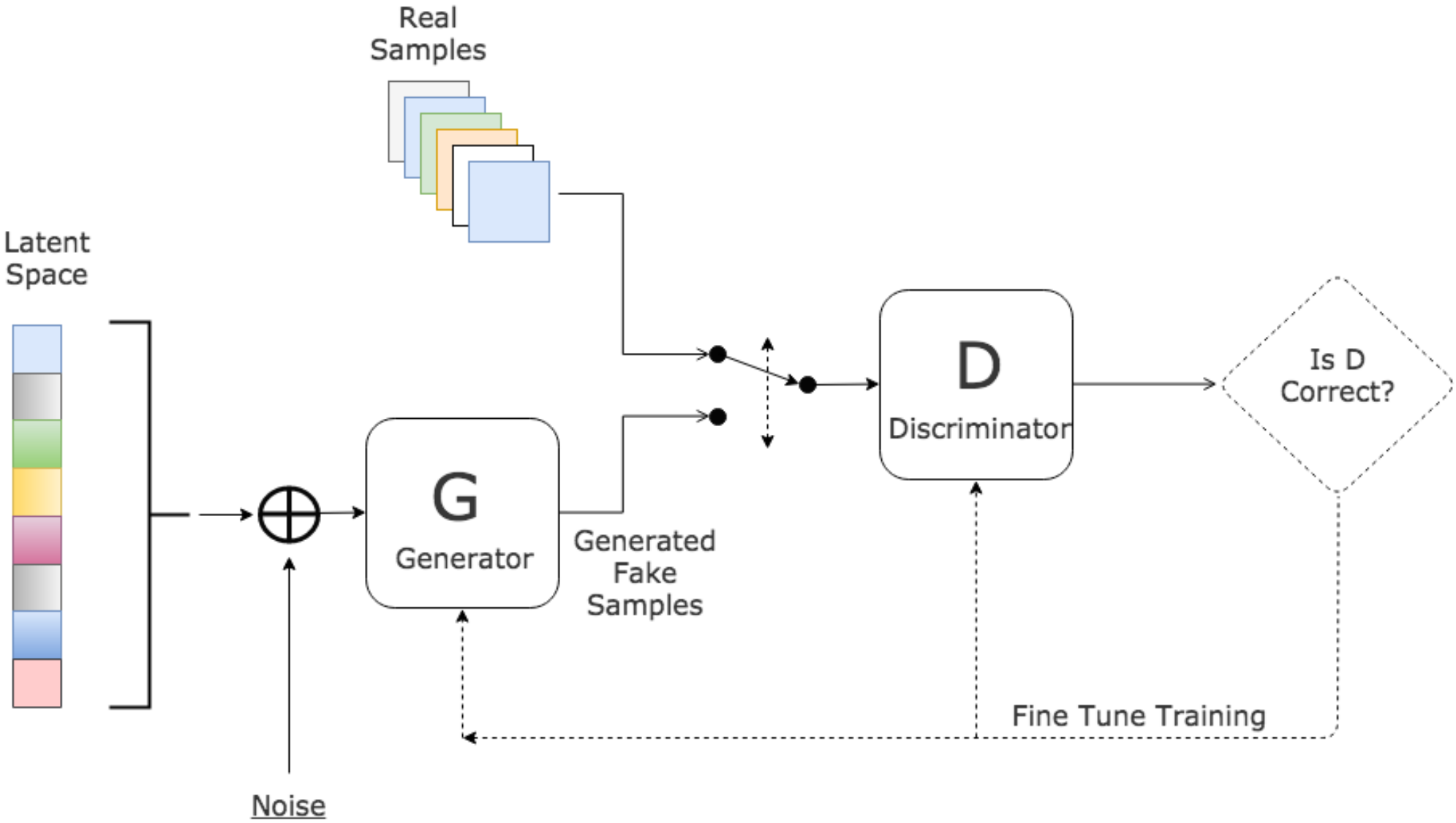
- Train very deep neural networks 100 – 1000 Layers!
- Exceed human-level performance on recognizing images
- Approach has been applied to other computer vision tasks:

  Video: Image Segmentation

https://arxiv.org/pdf/1512.03385.pdf

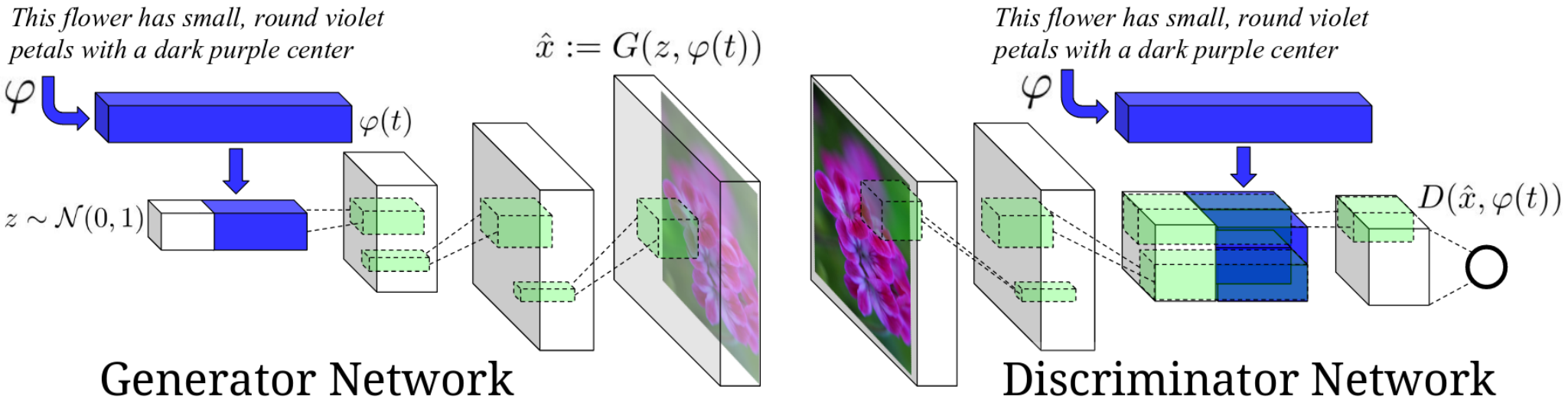


Generative Adversarial Network



https://arxiv.org/abs/1406.2661

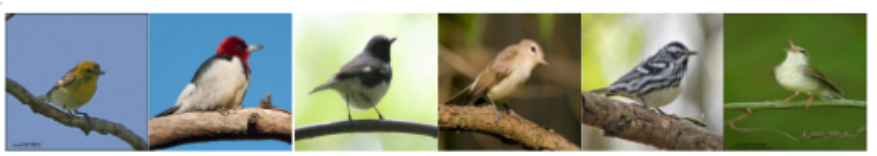
GAN - Application



https://arxiv.org/pdf/1605.05396.pdf

Text descriptions (content)

Images (style)



The bird has a **yellow breast** with **grey** features and a small beak.

This is a large **white** bird with **black wings** and a **red head**.

A small bird with a **black head and wings** and features grey wings.

This bird has a **white breast**, brown and white coloring on its head and wings, and a thin pointy beak.

A small bird with **white base** and **black stripes** throughout its belly, head, and feathers.

A small sized bird that has a cream belly and a short pointed bill.

This bird is **completely red**.

This bird is **completely white**.

This is a **yellow** bird. The **wings are bright blue**.

Reinforcement Learning

- Supervised learning:
  You provide the true target e.g. Label to the network for learning
- In many situations this is not possible e.g. learning to drive a car
- Reinforcement Learning: Network outputs sequence of actions and receives a reward at some point
- Network has to learn what actions will lead to a high reward (potentially much later) → learn a strategy

Video: Atari