Neural Networks and CNNs

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Introduction

Classical vs Deep machine learning

Classical ML

Everything excluding Neural Networks (SVMs, trees, forests, boosting, linear models)

Deep Learning

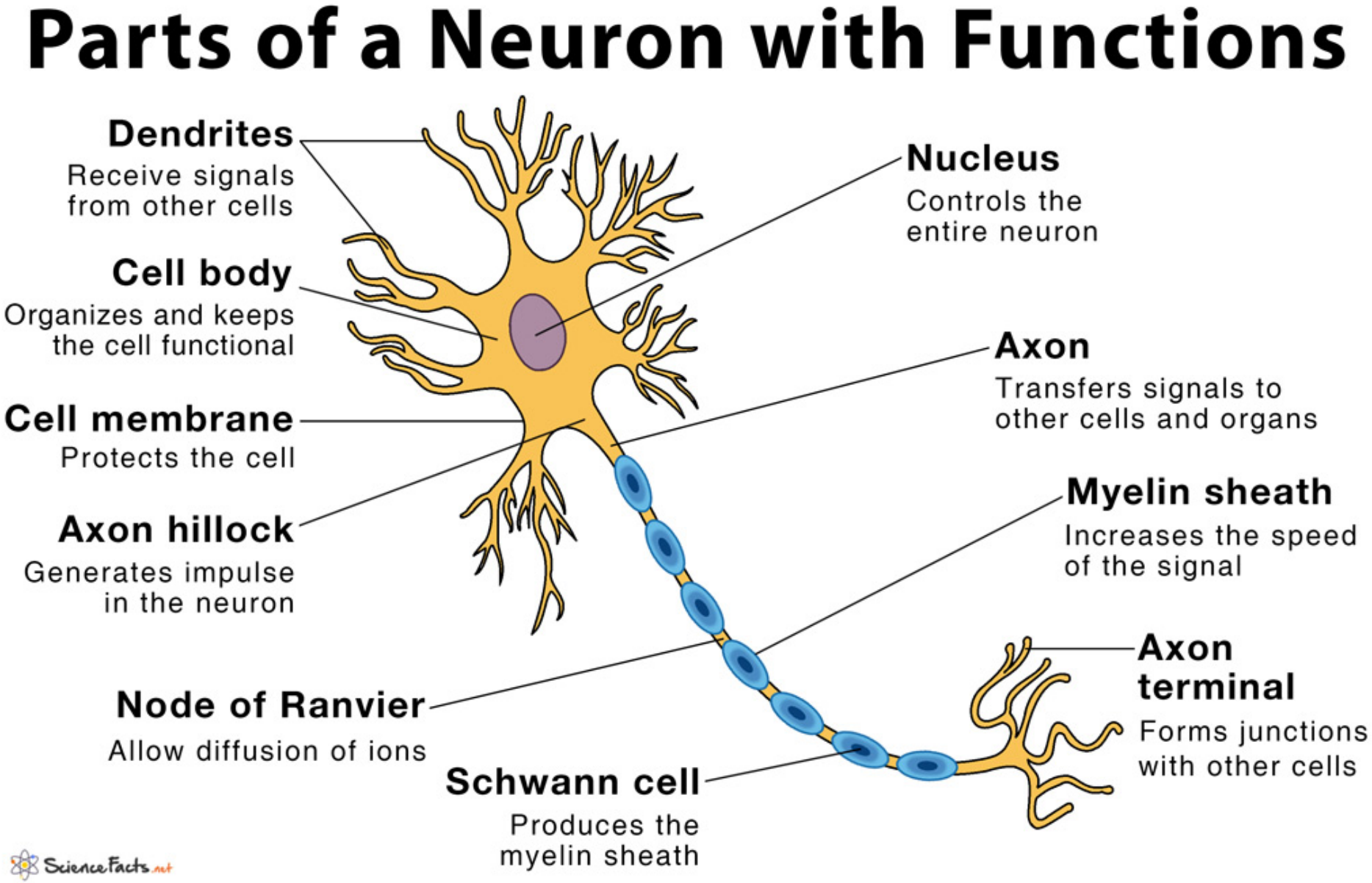
Neural Networks (regardless of complexity)

Neural Networks

History

- The first ideas were proposed mid XX century trying to mimic how brain works, but weren't really successful
- Backpropagation - way to teach neural networks introduced in 1986 - beginning of neural networks as we know
- CNN introduced in 1990
- "Attention Is All You Need" - transformers introduced in 2017
- ChatGPT and recent boom

Obligatory biological neuron slide



Multi Layer Perceptron

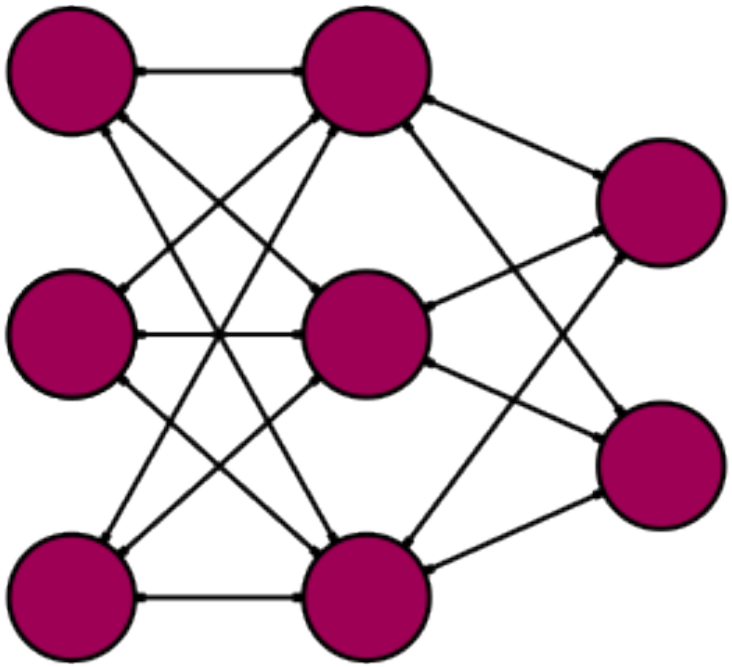


Figure: Our club logo - representation of a simple neural network

Activation Functions

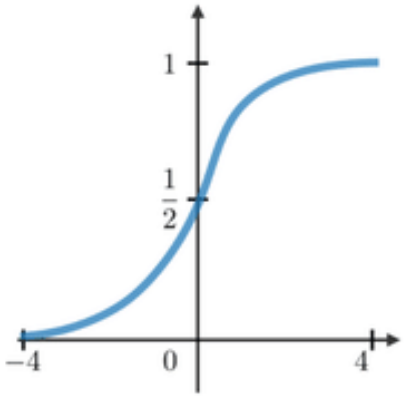
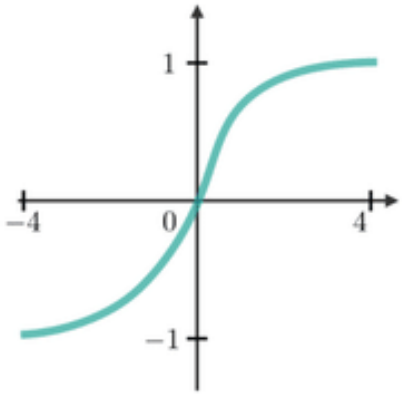
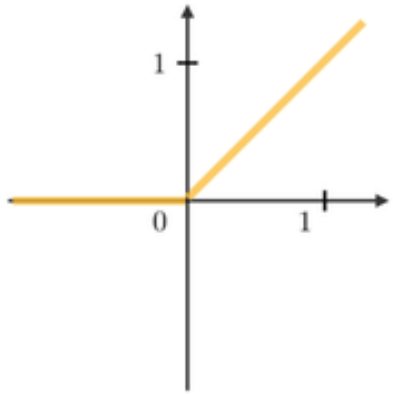
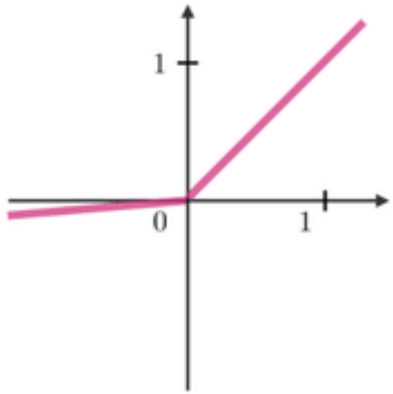
Sigmoid	Tanh	ReLU	Leaky ReLU
$g(z) = \frac{1}{1+e^{-z}}$	$g(z) = \frac{e^{z}-e^{-z}}{e^{z}+e^{-z}}$	$g(z) = \max(0, z)$	$g(z) = \max(\epsilon z, z)$ with $\epsilon \ll 1$
			

Figure: Common Activation functions

Forward Pass

Example

https://playground.tensorflow.org

Mathematical formulation

$$y = f(X, \theta) \tag{1}$$

$$\min_{\theta} \mathcal{L}(f(X, \theta)) \tag{2}$$

$\mathcal{L}$ - loss function

$$\theta_{n+1} = \theta_n + \frac{\partial \mathcal{L}(\theta_n)}{\partial \theta} \tag{3}$$

Calculating derivatives

Chain Rule

$$\frac{d}{dx}f(g(x)) = \frac{d}{dg(x)}f(g(x)) \times \frac{d}{dx}g(x) \tag{4}$$

Automatic Differentiation (Backward pass)

Example on the blackboard:

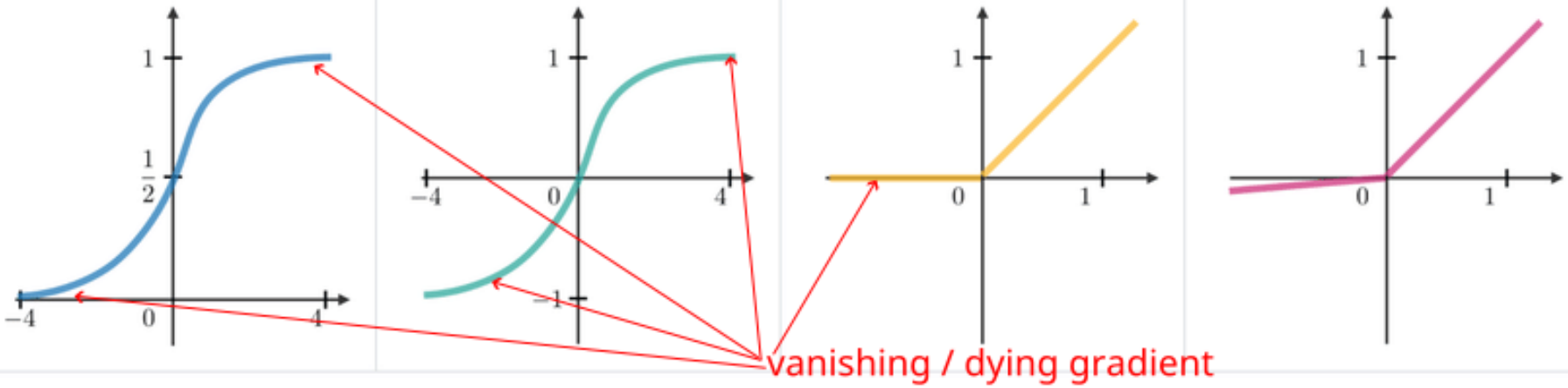
$f(\mathbf{x}) = (x_1 x_2 sin(x_3) + e^{x_1 x_2})/x_3$

$\mathbf{x} = [1, 2, \pi/2]^T$

$\nabla f(\mathbf{x}) = [(4 + 4e^2)/\pi, (2 + 2e^2)/\pi, (-8 - 4e^2)\pi^2]^T$

Back to activations

Sigmoid	Tanh	ReLU	Leaky ReLU
$g(z) = \frac{1}{1+e^{-z}}$	$g(z) = \frac{e^z - e^{-z}}{e^z + e^{-z}}$	$g(z) = \max(0, z)$	$g(z) = \max(\epsilon z, z)$ with $\epsilon \ll 1$

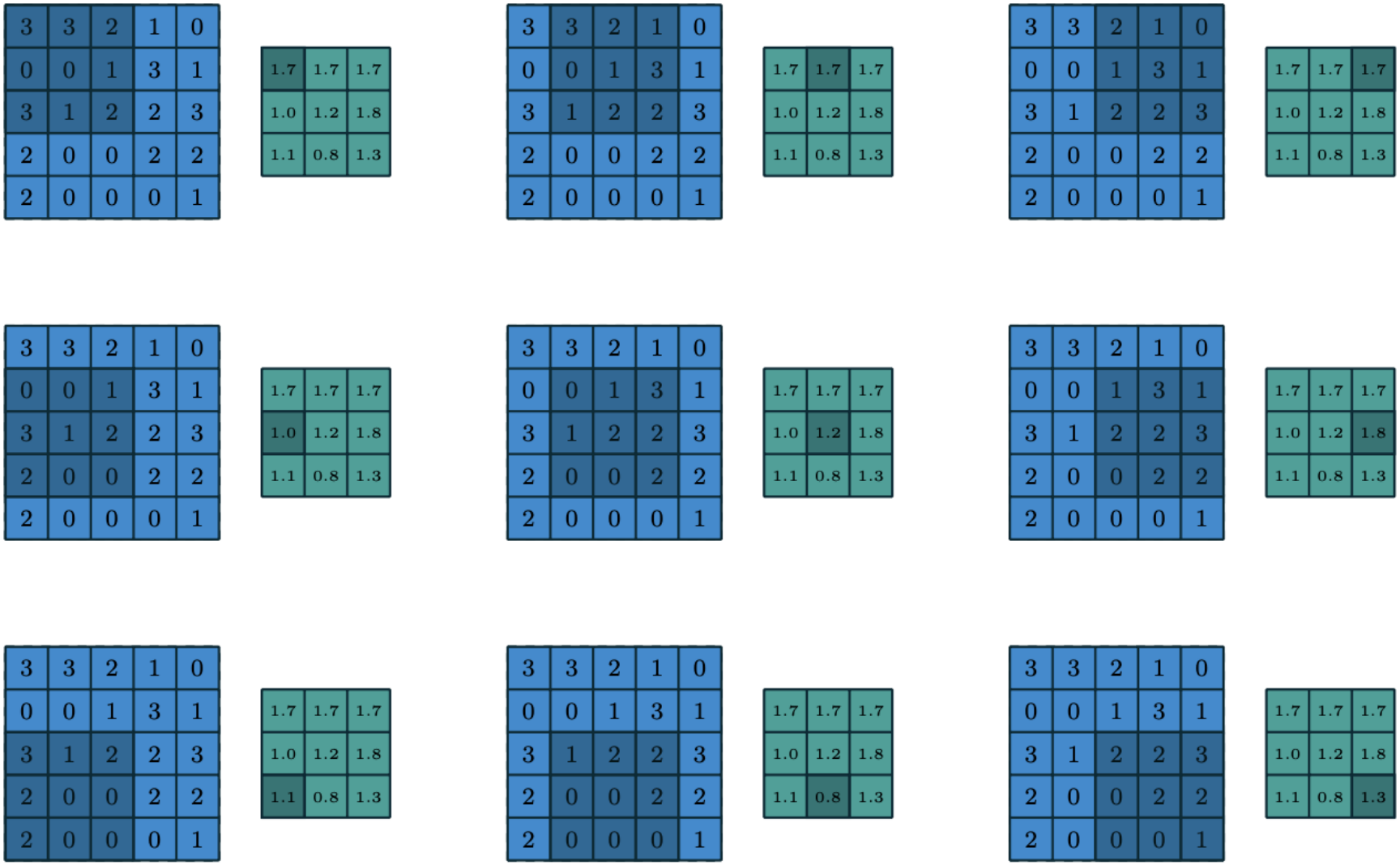


Pros Cons

- Computation heavy
- **A LOT** of parameters (10^{12} for GPT-4)
- Easily overfited
- Can approximate any function*
- Very versatile
- Sequential Learning

Convolutional Neural Networks (CNNs)

Convolution



Some Convolution Kernels

Example

https://setosa.io/ev/image-kernels/

How to choose the right kernels?

Use learnable parameters

Example of CNN

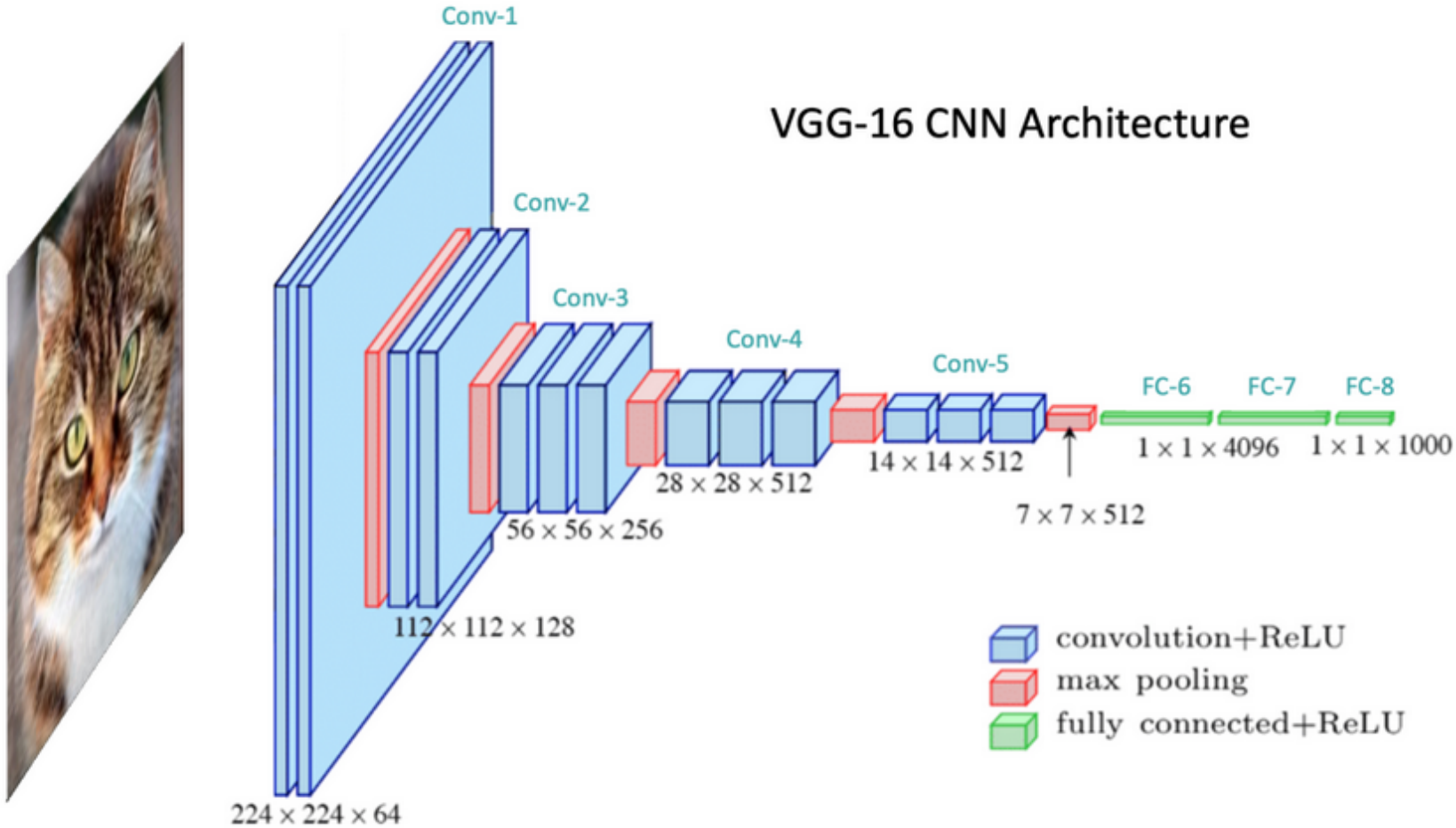


Figure: VGG-16 Architecture

Concepts

Concepts in Neural Networks

- Classification
- Transfer Learning
- Encoder-Decoder Architecture
- Siamese Nets
- Generational Networks
- Auxiliary task

Thanks for your attention

Additional sources

- https://pytorch.org/tutorials/
- https://youtu.be/aircAruvnKk
- https://developers.google.com/machine-learning/crash-course
- https://playground.tensorflow.org
- https://github.com/PawelGlr/MIOwAD_labs (self promotion ^^)