

# Deep learning basics

G. Châtel

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# Machine learning

## Supervised learning

Machine learning is a subfield of artificial intelligence.

**Intuitively** We want to *learn from* and *make predictions on* data.

**Technically** We want to build a model that approximate well (e.g. minimize a loss function) an unknown function.

# Application examples

## Supervised learning

- Regression

Polynomial  $(x, y, z) \rightarrow f(x, y, z)$

House price (surface, nb rooms, city)  $\rightarrow$  price

- Classification

Image classification pixel values  $\rightarrow$  cat or dog

Text classification list of words  $\rightarrow$  spam or valid email

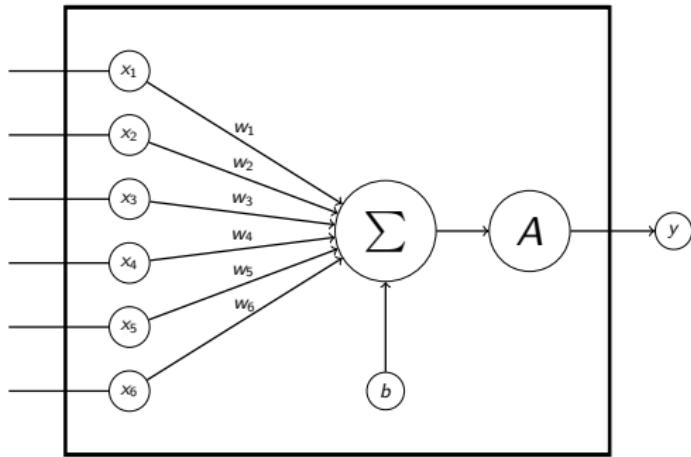
# Deep learning

Deep learning is a subfield of machine learning in which we use artificial neural networks to make predictions.

An artificial neural networks is a computation model *loosely* based on the human brain. It aims to mimic electric signals travelling through neurons in order to make computations.

# Artificial neural network

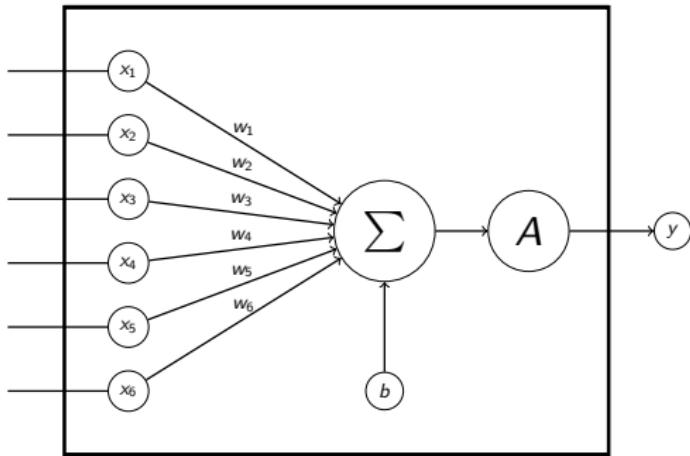
## Neuron



$$A(x) = \begin{cases} 0 & \text{if } x < 0 \\ 1 & \text{otherwise} \end{cases}$$

# Artificial neural network

## Neuron

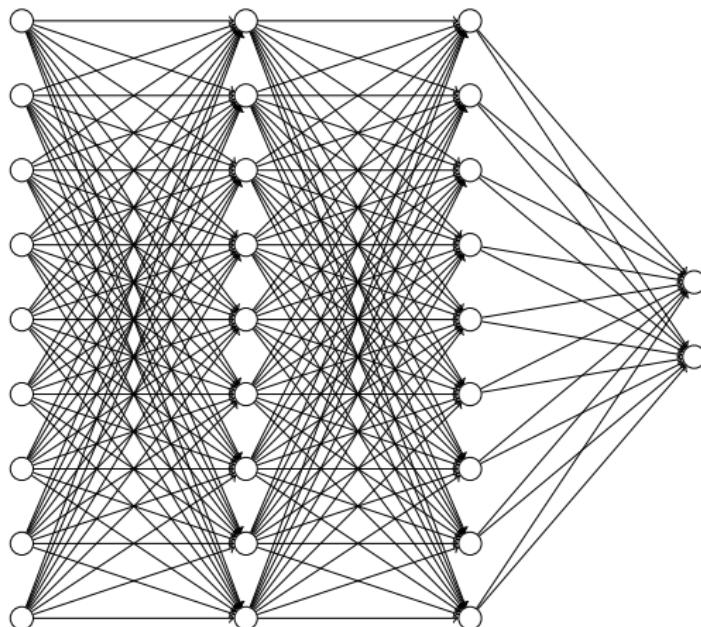


$$A(x) = \begin{cases} 0 & \text{if } x < 0 \\ 1 & \text{otherwise} \end{cases}$$

$$y = A(w_1x_1 + w_2x_2 + w_3x_3 + w_4x_4 + w_5x_5 + w_6x_6 + b)$$

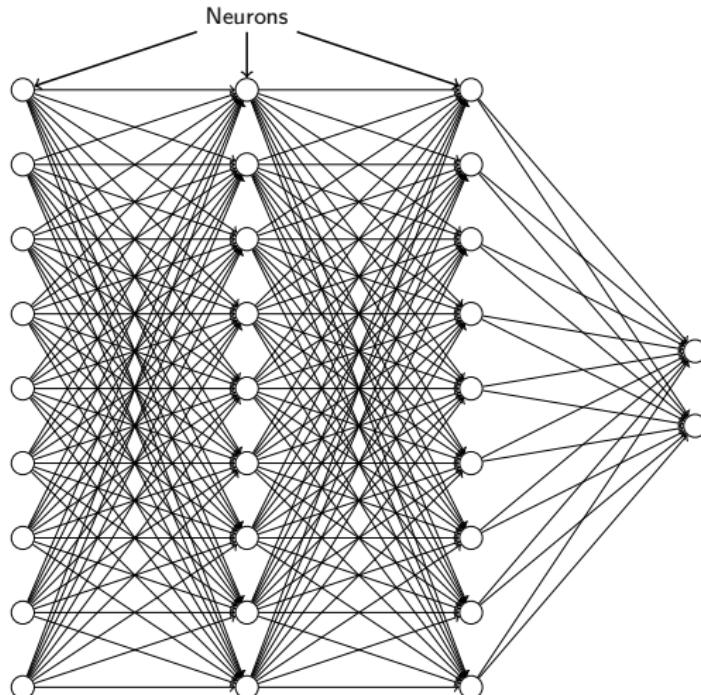
# Artificial neural network

## Network



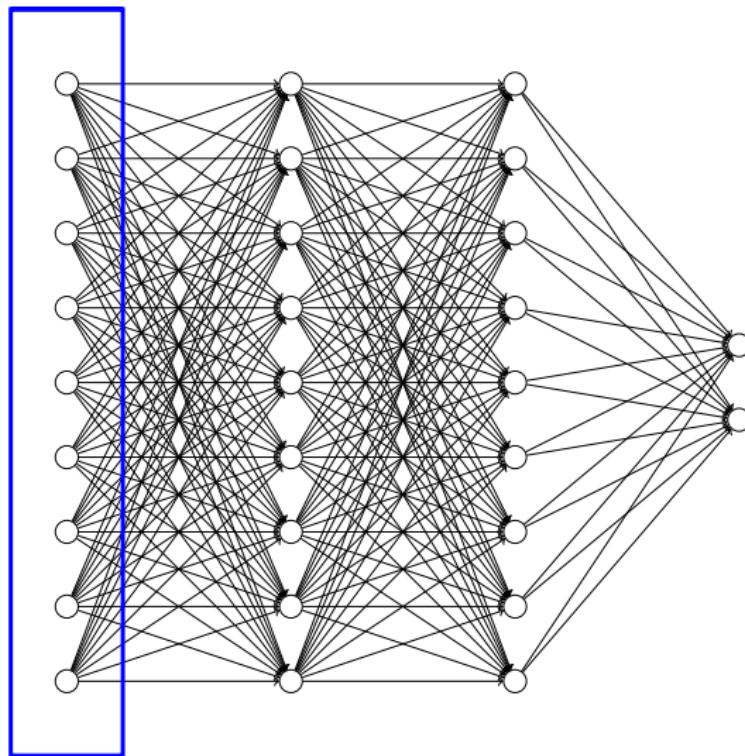
# Artificial neural network

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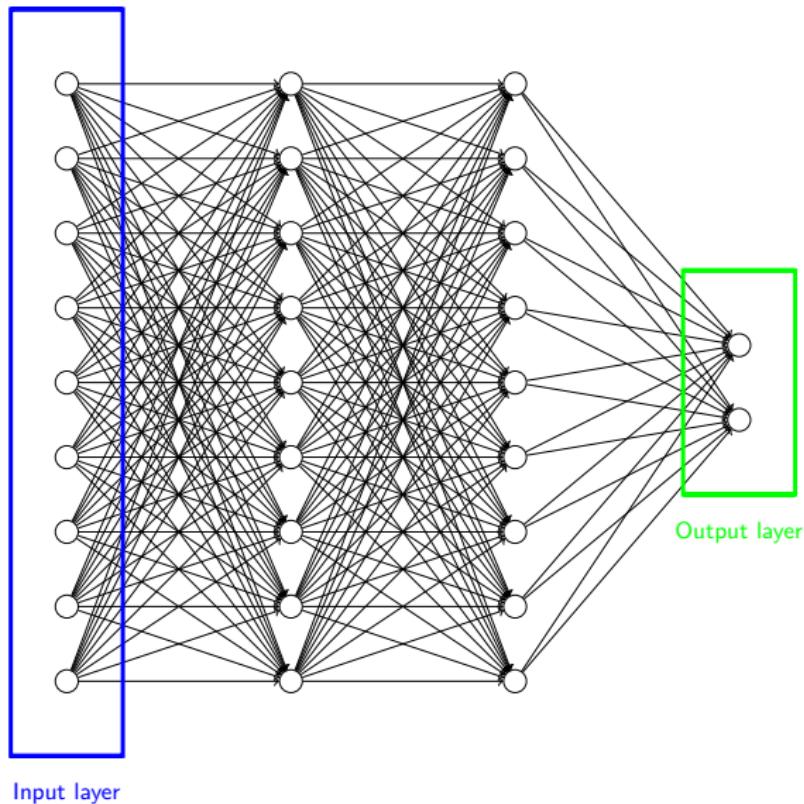
## Network



Input layer

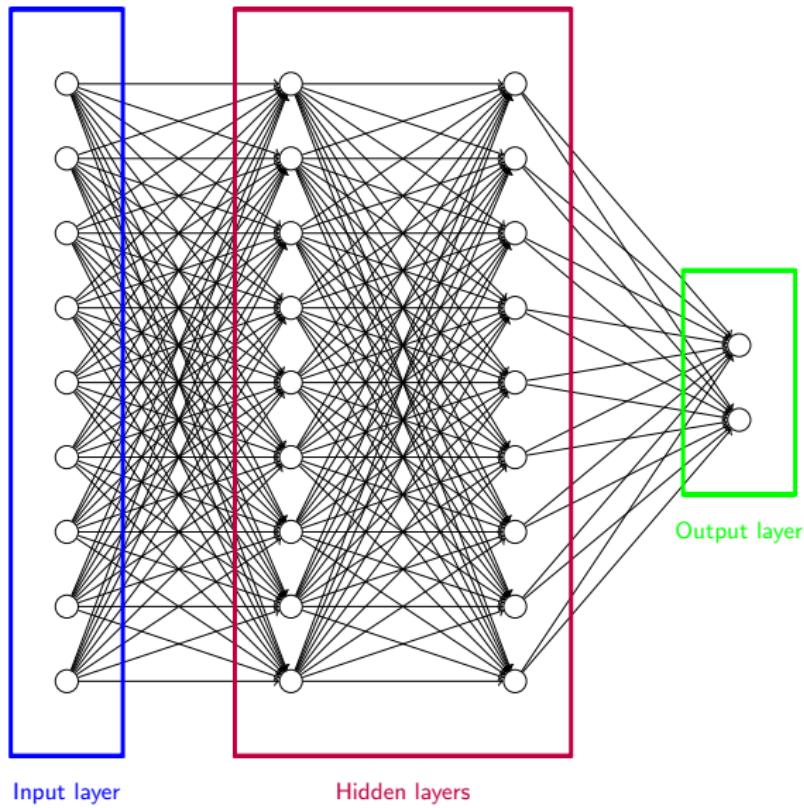
# Artificial neural network

## Network



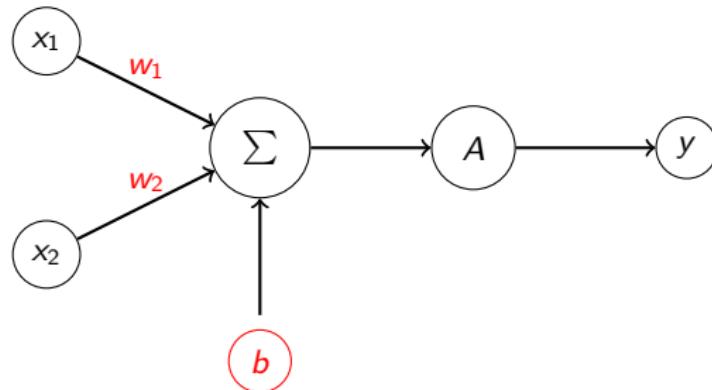
## Artificial neural network

## Network



## Computation example

Binary AND gate

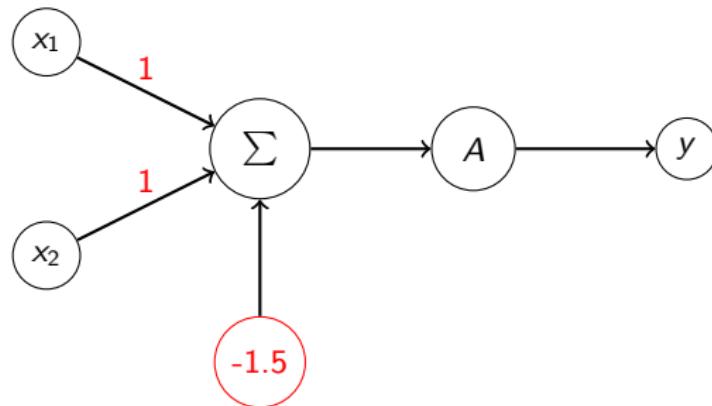


We want to set  $w_1$ ,  $w_2$  and  $b$  such that:

$$A(w_1x_1 + w_2x_2 + b) = x_1 \text{ AND } x_2$$

## Computation example

Binary AND gate

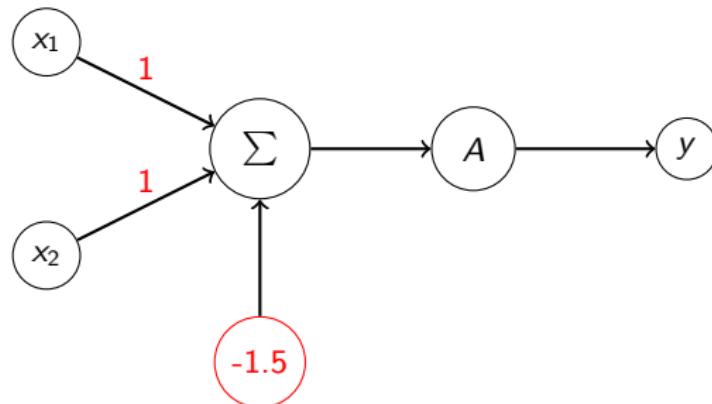


We want to set  $w_1, w_2$  and  $b$  such that:

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## Computation example

Binary AND gate



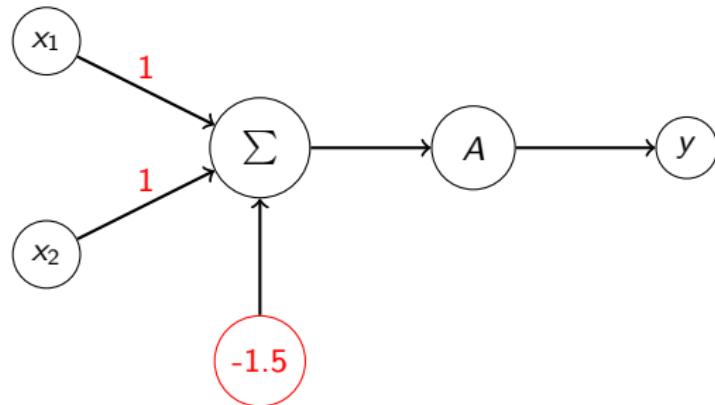
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Binary AND gate



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$$x_0 = 1, x_1 = 1. \quad y = A(1 + 1 - 1.5) = A(0.5) = 1$$

## Model complexity

One way to measure the complexity of a neural network is its number of parameters.

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- AND network: 3 parameters

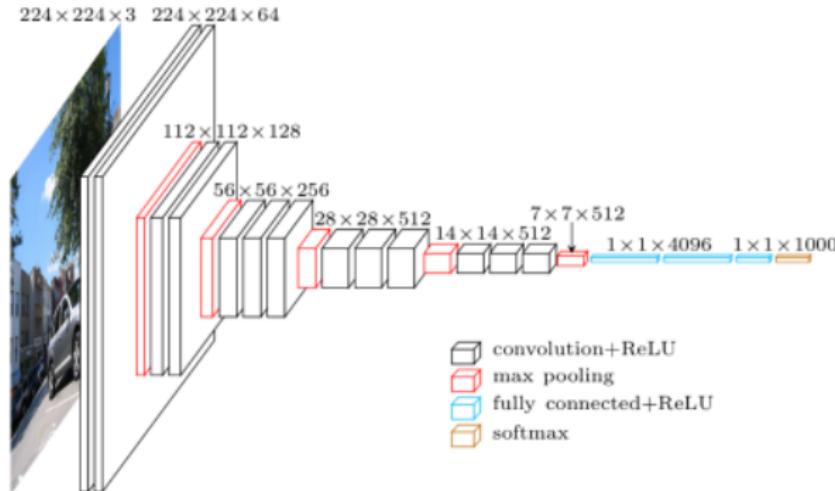
## Model complexity

One way to measure the complexity of a neural network is its number of parameters.

- AND network: 3 parameters
- dogs vs cats pictures (VGG16 network): 138,357,544 parameters

# Convolutional neural network

VGG network (2014)



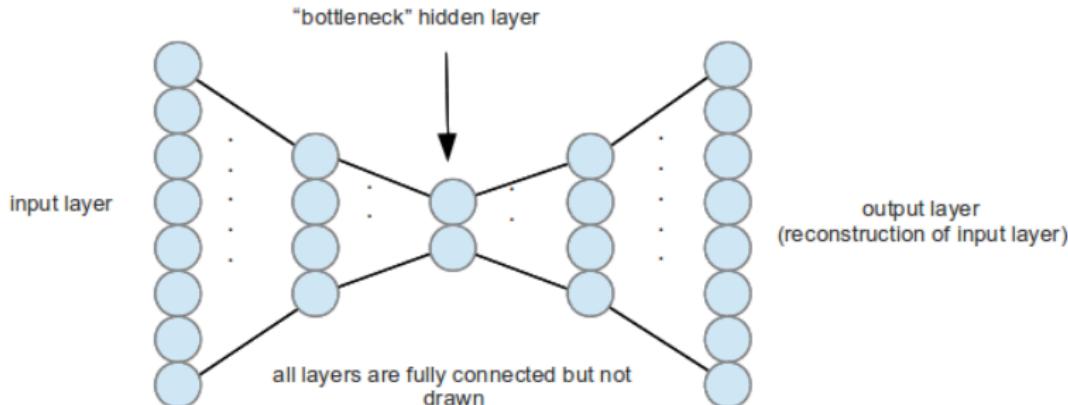
Classify natural images into 1000 categories. (92.7% top-5 accuracy).

Image from <https://www.cs.toronto.edu/~frossard/post/vgg16/>

Simonyan, K., & Zisserman, A. (2014). Very deep convolutional networks for large-scale image recognition. arXiv preprint arXiv:1409.1556.

# Architecture examples

## Deep autoencoder



If we cut this autoencoder at the bottleneck, we get two parts: an encoder and a decoder. The encoder is an encoder highly specific to the content the network has been trained with.

Hinton, G. E., & Salakhutdinov, R. R. (2006). Reducing the dimensionality of data with neural networks. *science*, 313(5786), 504-507.

# Architecture examples

## Deep autoencoder: Compression

		bits/px	PSNR	SSIM
UT Zappos50k 11 bits/px				
JPEG2000 16x compression		0.693	19.64	0.705
JPEG 15x compression		0.750	19.90	0.707
NCode(16) 28x compression		0.391	18.82	0.732
NCode(4) 112x compression		0.098	17.14	0.693
NCode(2) 224x compression		0.049	11.13	0.523

If we force the output image to be realistic, we lose *semantic information* rather than resolution.

Santurkar, S., Budden, D., & Shavit, N. (2017). Generative compression. arXiv preprint arXiv:1703.01467.

# Architecture examples

## Drawing cleanup



Simo-Serra, E., Iizuka, S., Sasaki, K., & Ishikawa, H. (2016). Learning to simplify: fully convolutional networks for rough sketch cleanup. ACM Transactions on Graphics (TOG), 35(4), 121.

# Architecture examples

## Neural style transfer

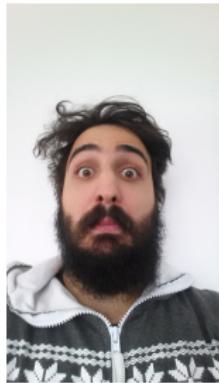
Let's take a random image from the internet.



# Architecture examples

## Neural style transfer

$\alpha$  content(



) +  $\beta$  style(



) =



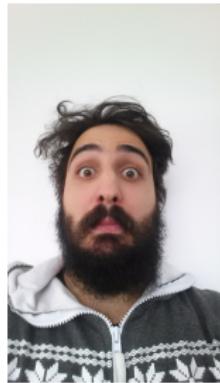
Image created using <https://deepr.io>

Gatys, L. A., Ecker, A. S., & Bethge, M. (2015). A neural algorithm of artistic style. arXiv preprint arXiv:1508.06576.

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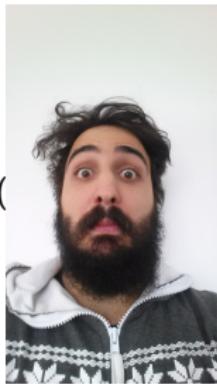
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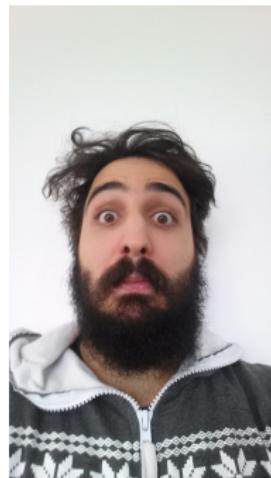
# Architecture examples

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# Reinforcement learning

Deepmind's AlphaGo

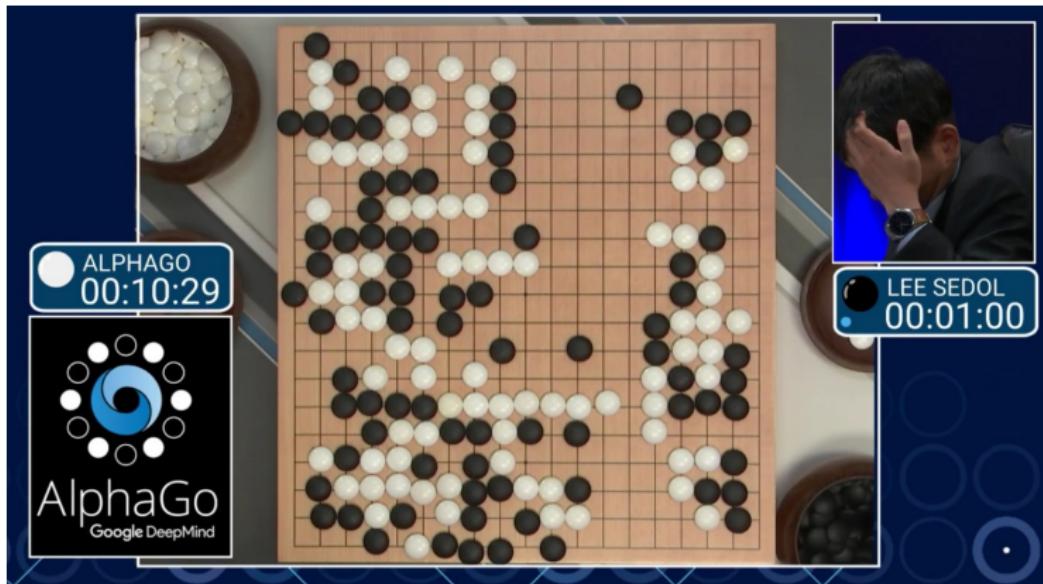
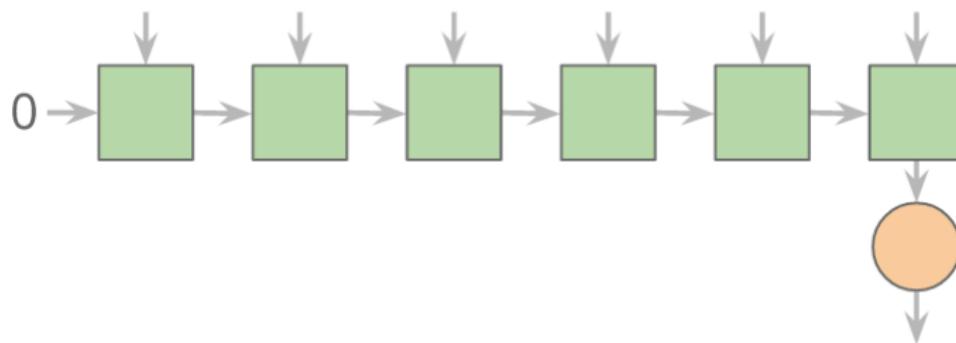


Image from Martin Gorner

## Architecture examples

Sequence to class network: text classifier

*The USA and China have agreed*



*geopolitics*

Image from Martin Gorner

## Architecture examples

Sequence to sequence network: Neural Machine Translation

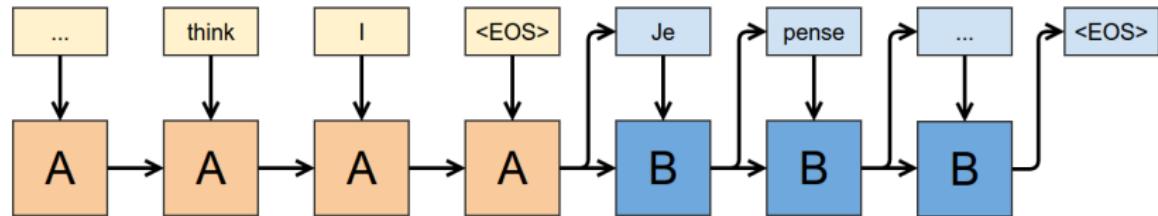


Image from <https://colah.github.io>

Google, September 2016: “The Google Translate mobile and web apps are now using GNMT (Google NMT) for 100% of machine translations from Chinese to English—about 18 million translations per day.”

# Architecture examples

Image to sequence: automatic captioning

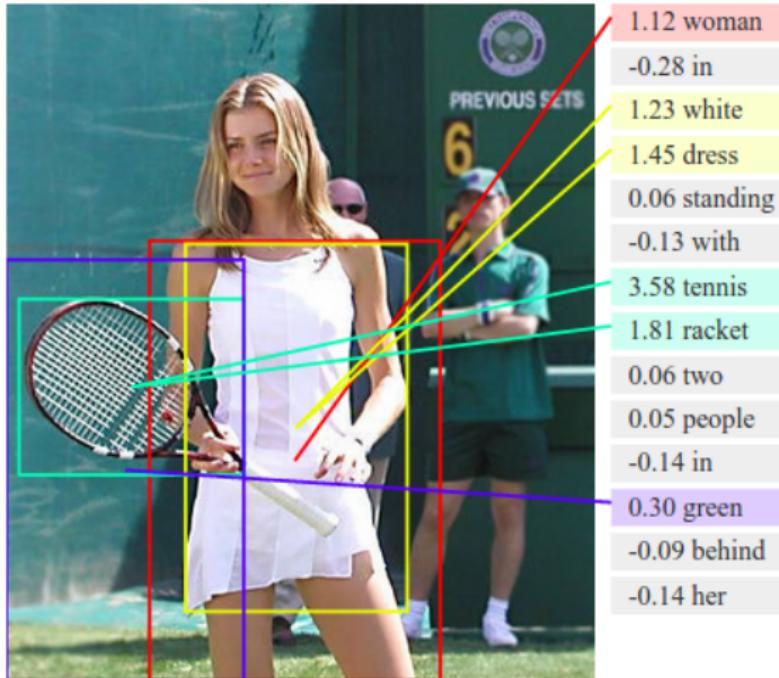


Image from <https://quantumfrontiers.com>

# Architecture examples

Image to sequence: automatic captioning

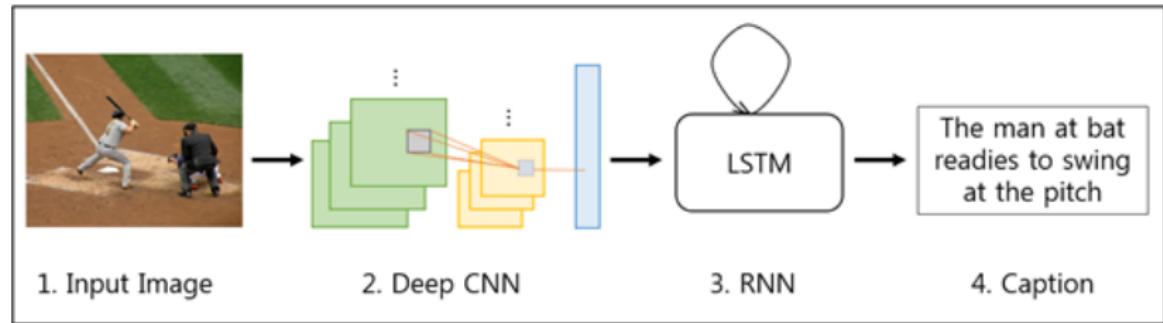


Image from <http://brain.kaist.ac.kr/>

# Architecture examples

## Generative adversarial network

### Generative adversarial networks (conceptual)

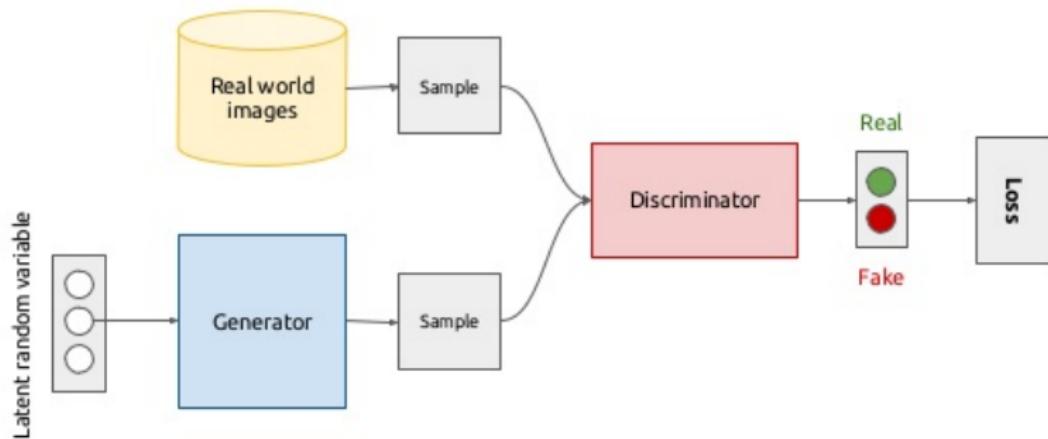


Image from <http://wiki.tum.de/>

# Architecture examples

Generative adversarial network: Celebrity faces generation



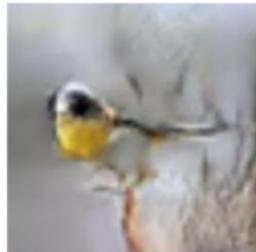
Karras, T., Aila, T., Laine, S., & Lehtinen, J. (2017). Progressive growing of gans for improved quality, stability, and variation. arXiv preprint arXiv:1710.10196.

# Architecture examples

Generative adversarial network: text to image

Han Zhang et al. (2016)

This bird has a yellow belly and tarsus, grey back, wings, and brown throat, nape with a black face



This bird is white with some black on its head and wings, and has a long orange beak



This flower has overlapping pink pointed petals surrounding a ring of short yellow filaments



(a) Stage-I images



(b) Stage-II images

Image from <https://arxiv.org/pdf/1612.03242.pdf>