Deep learning basics

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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

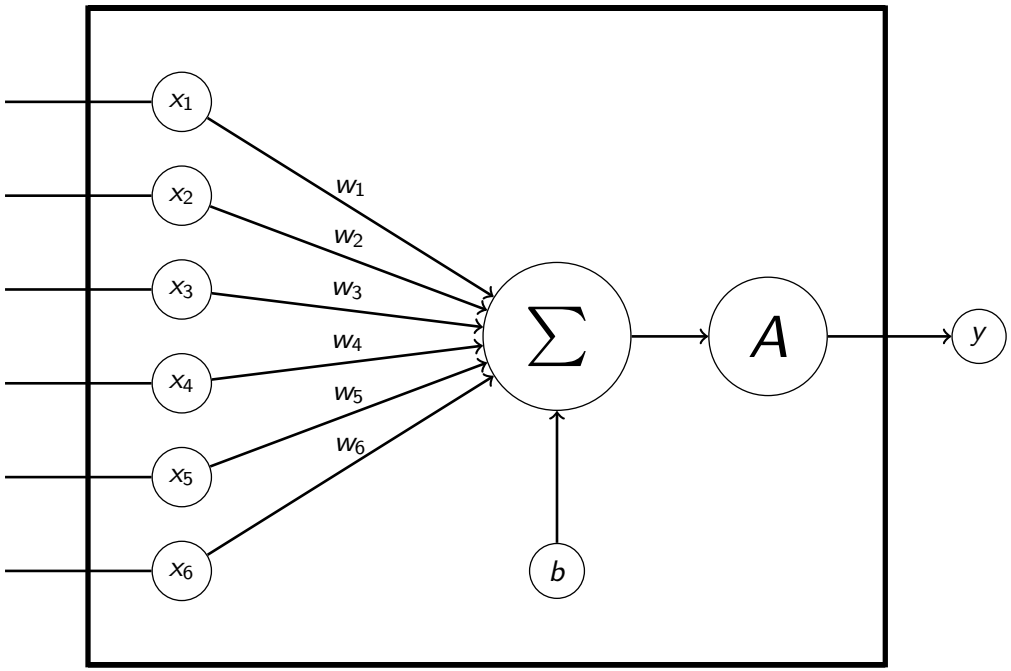
Deep learning

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

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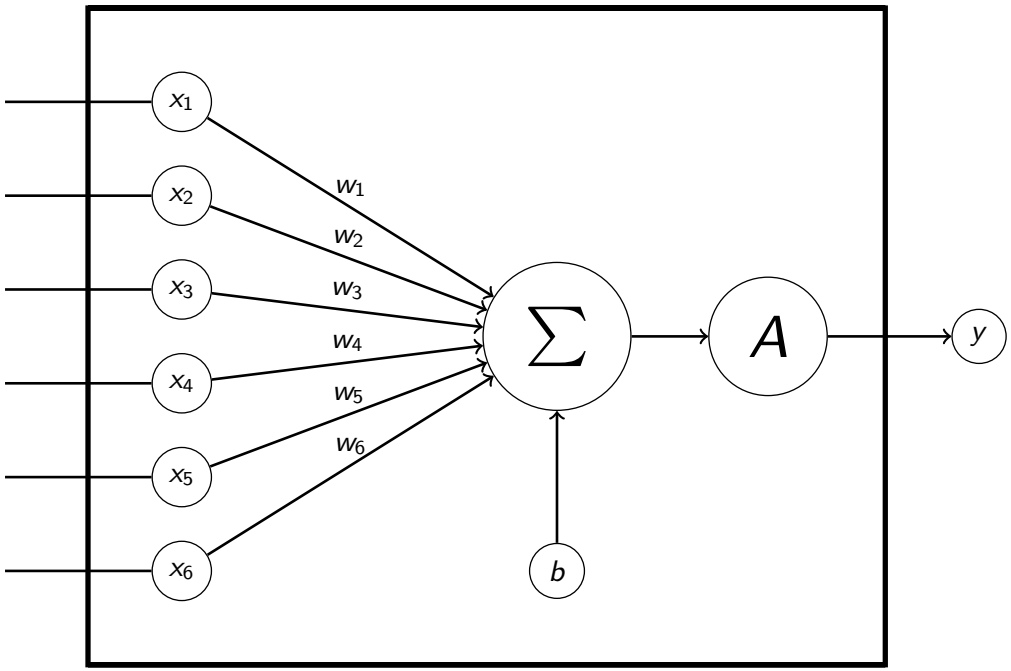
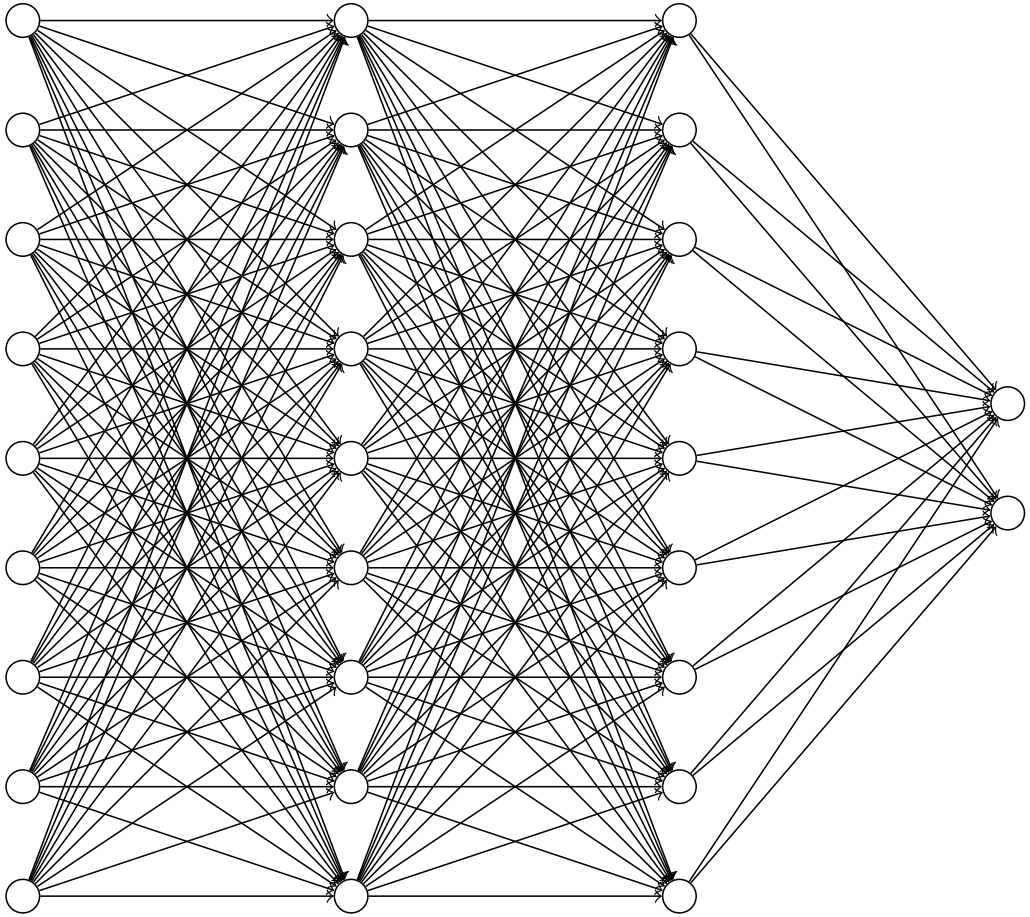


$$A(x) = \begin{cases} 0 & \text{if } x < 0 \\ 1 & \text{otherwise} \end{cases}$$

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

Artificial neural network

Network



Artificial neural network

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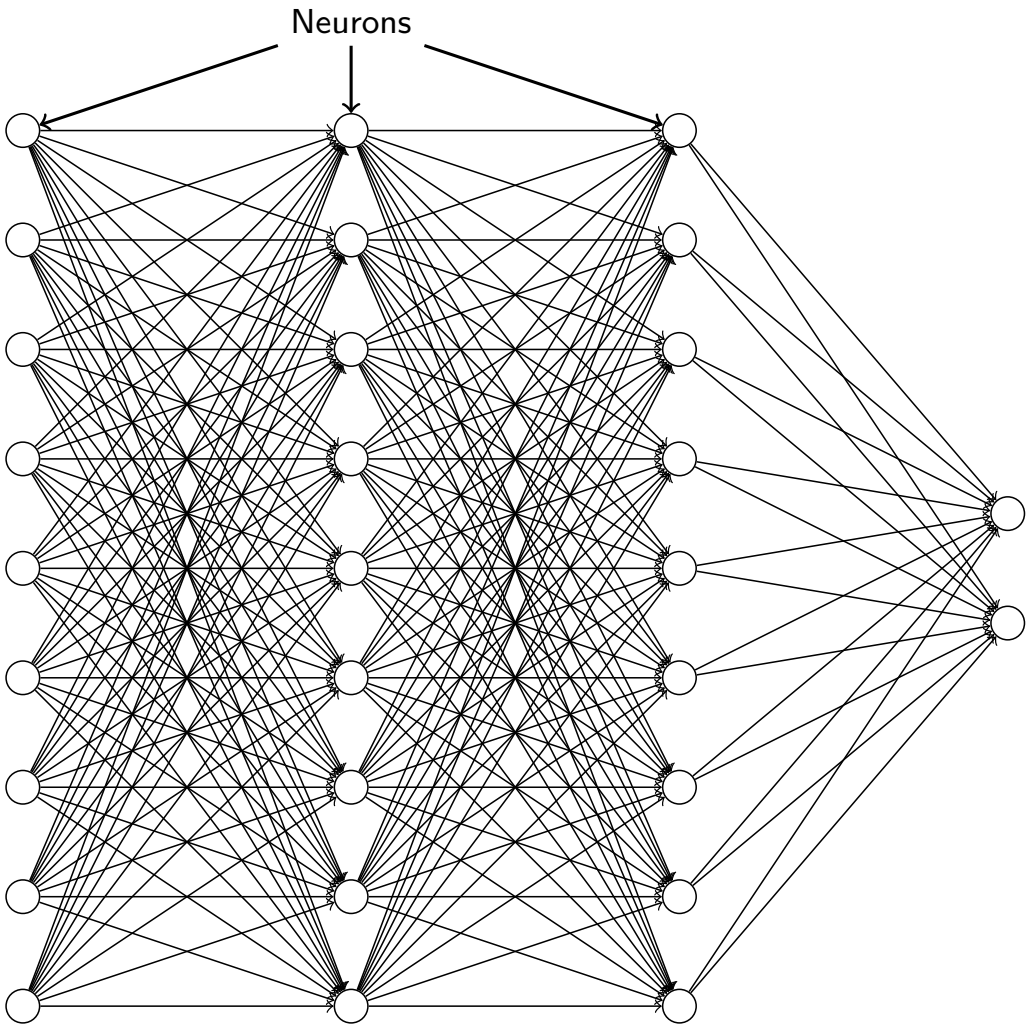

Artificial neural network

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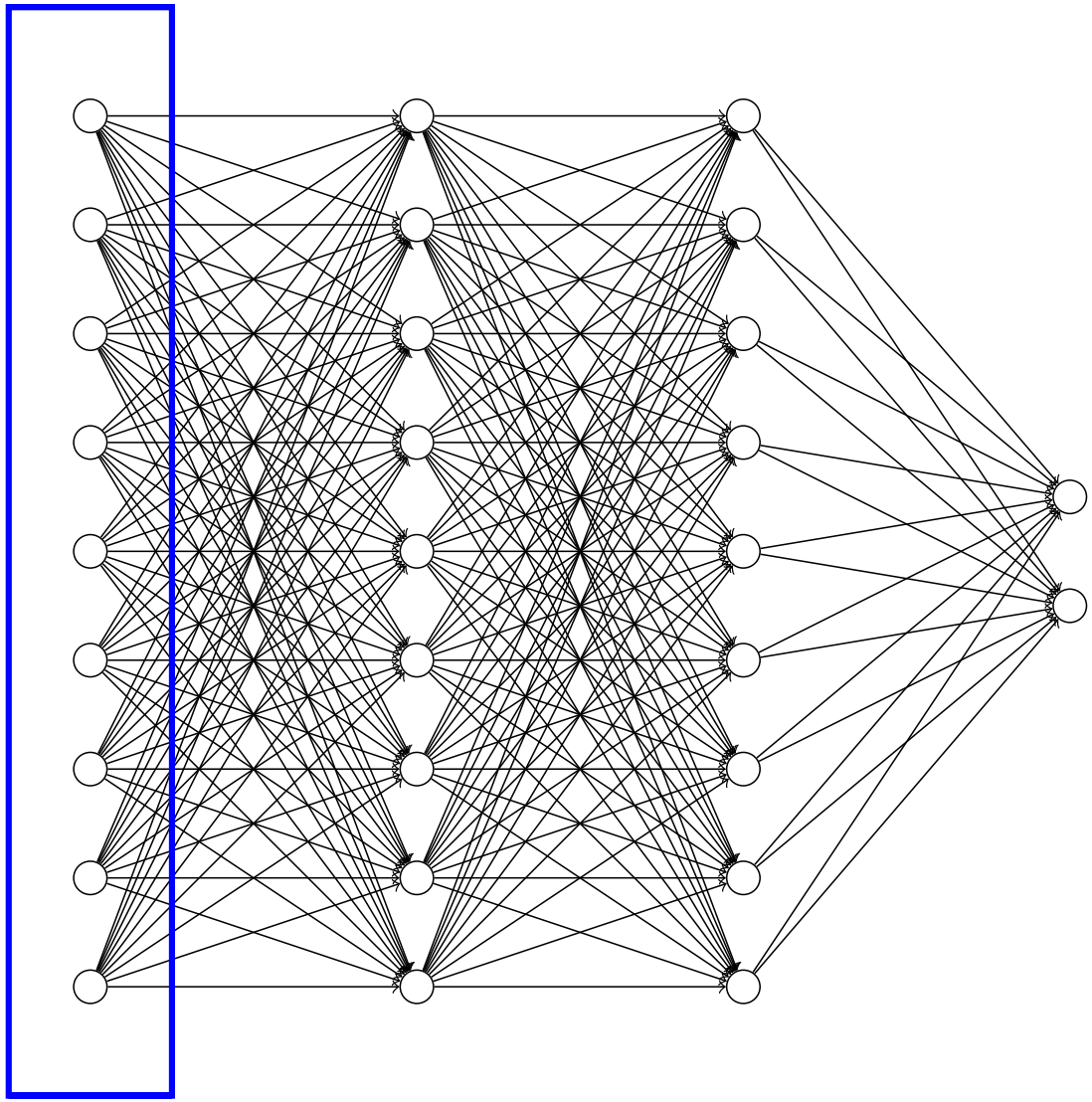
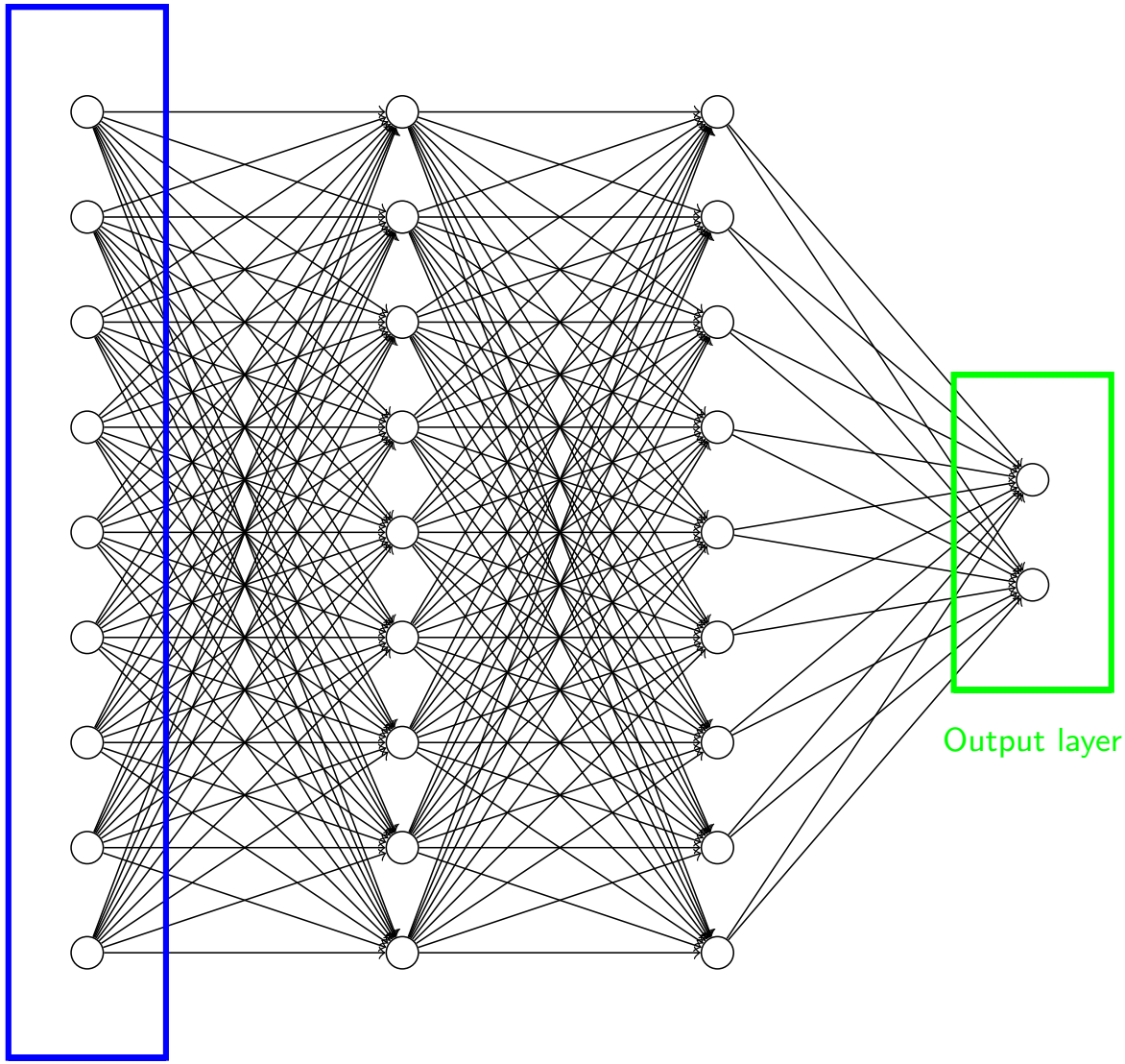


Input layer

Artificial neural network

Network



Artificial neural network

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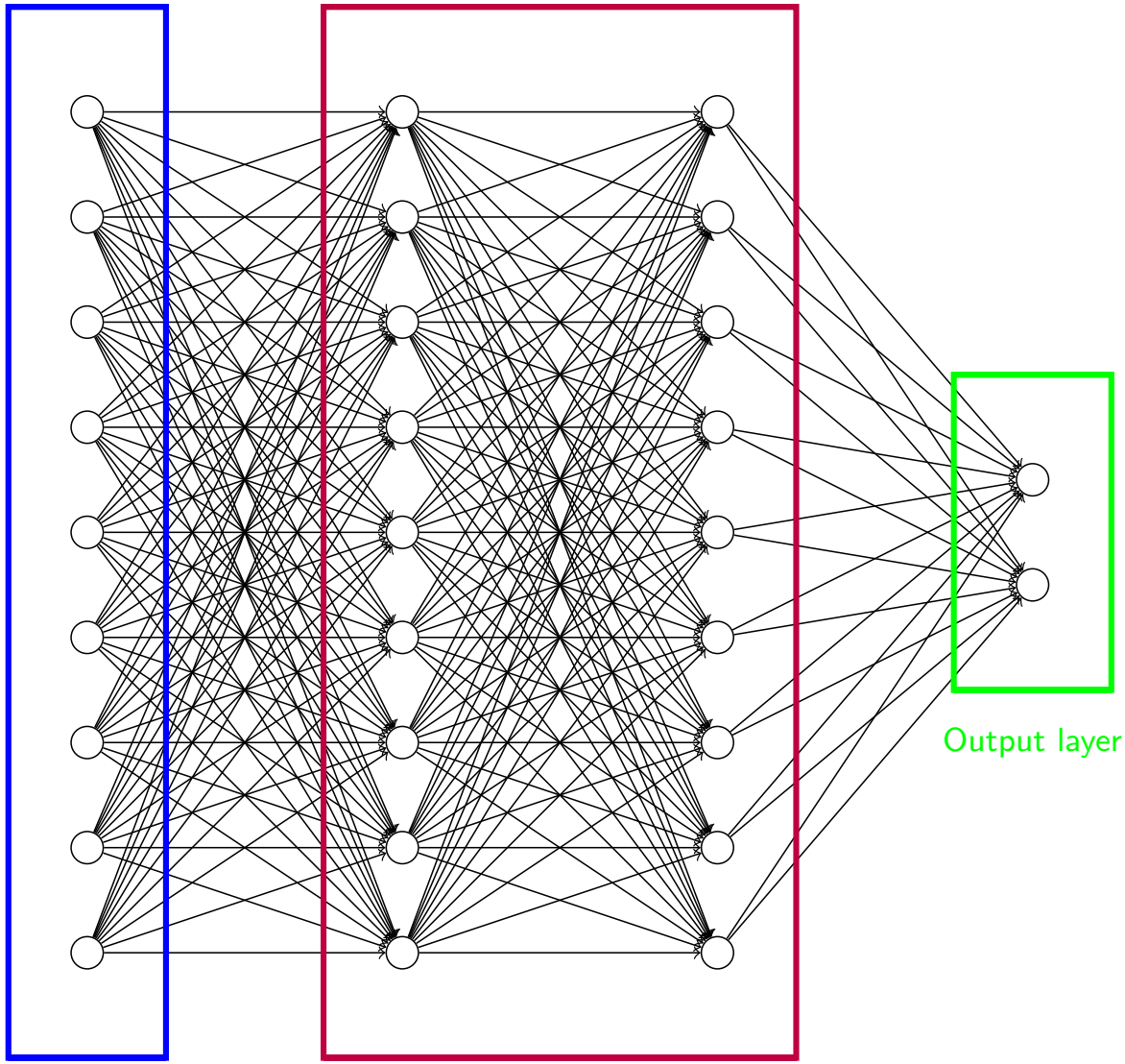
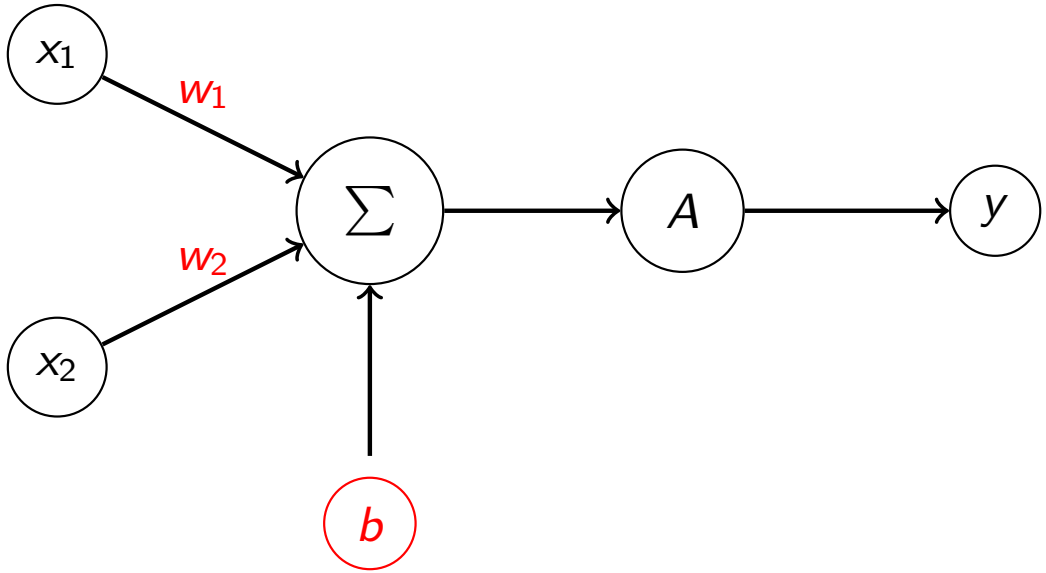


Computation example

Binary AND gate

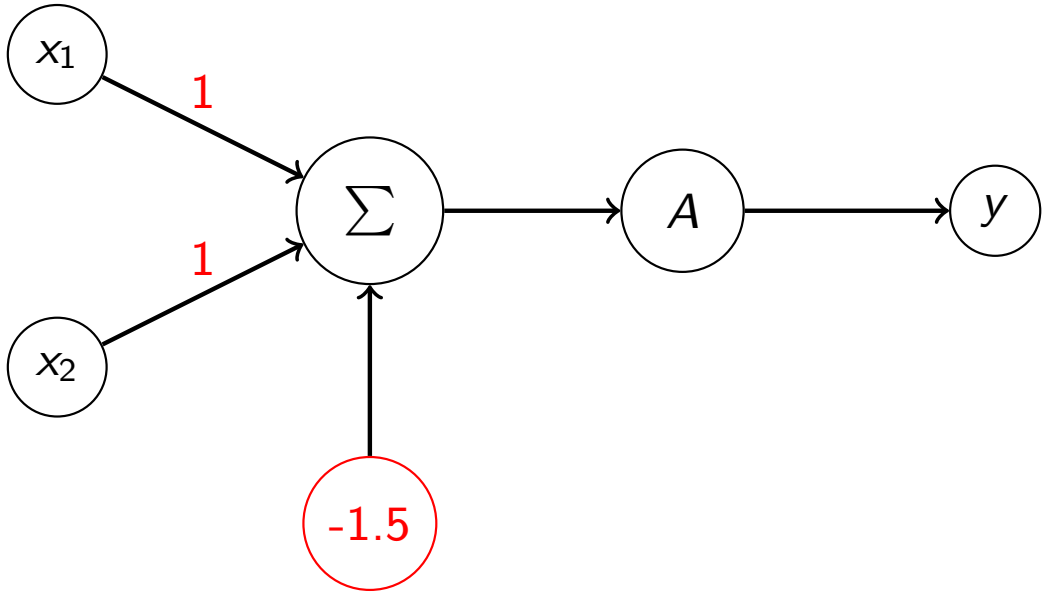


We want to set w_1, w_2 and b such that:

$$A(w_1 x_1 + w_2 x_2 + b) = x_1 \text{ AND } x_2$$

Computation example

Binary AND gate



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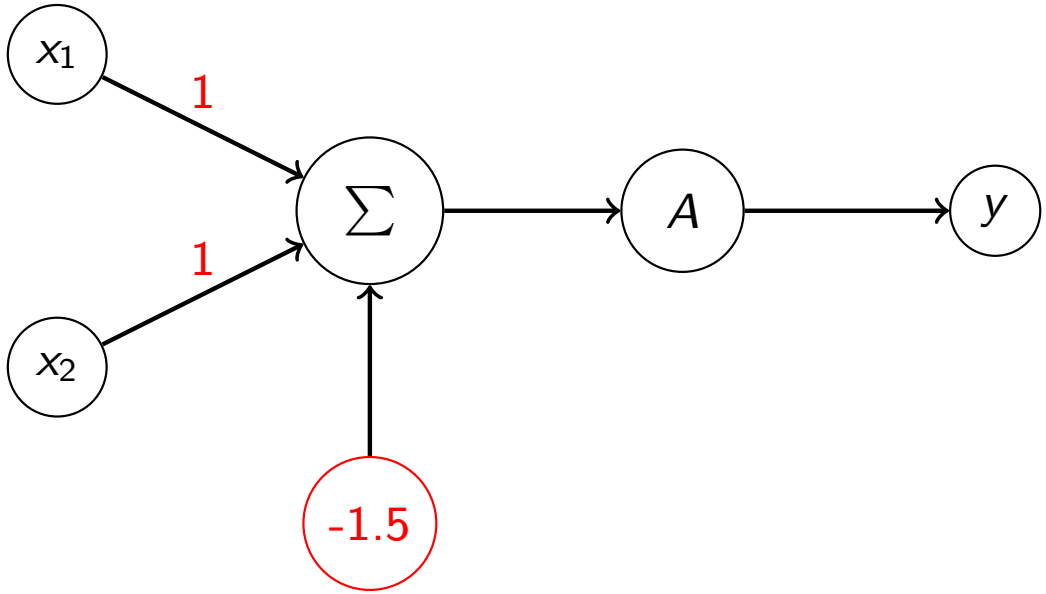

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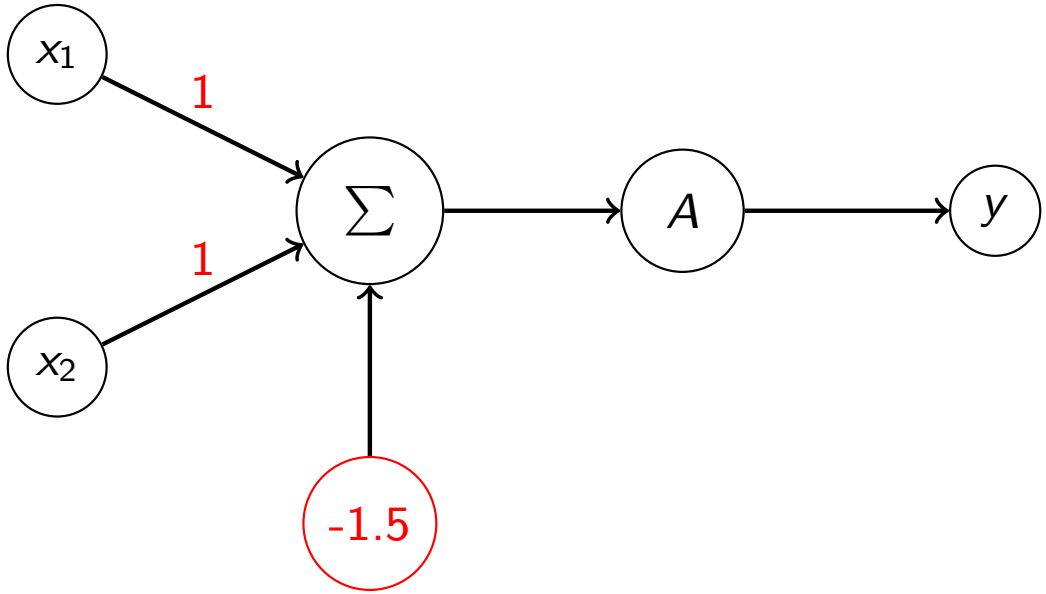

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Model complexity

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

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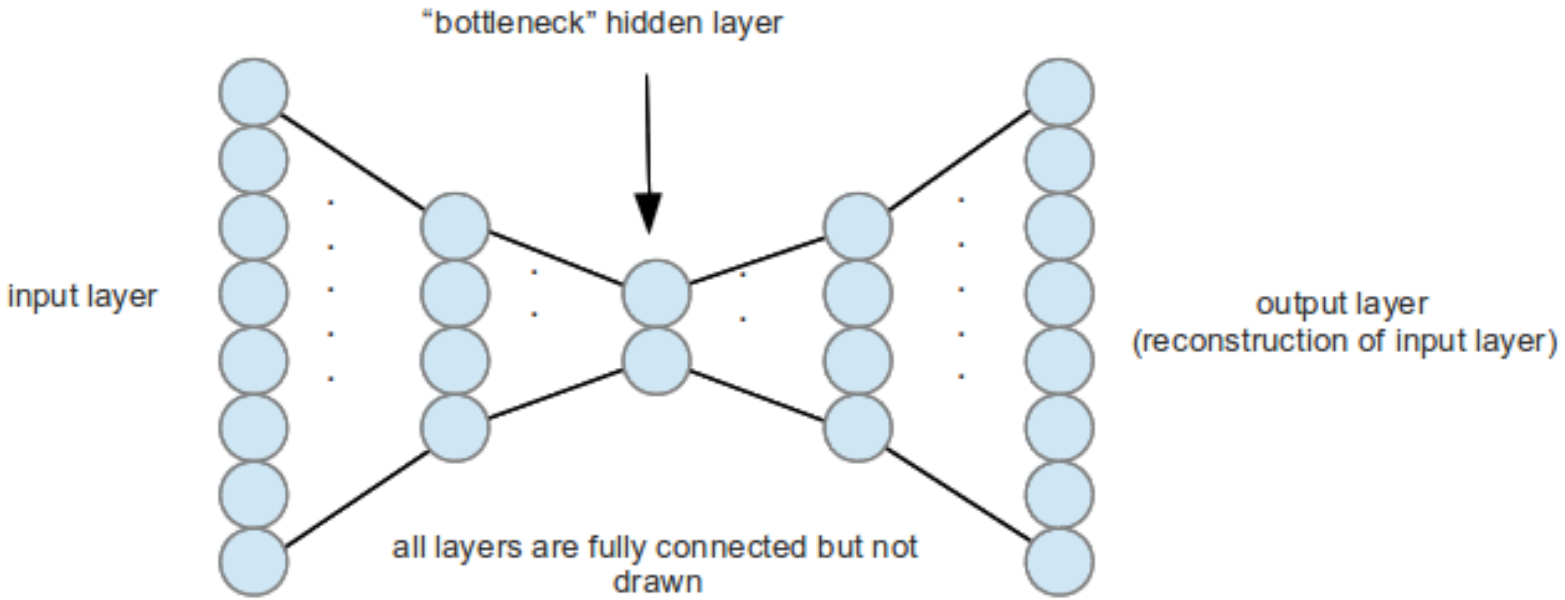
- AND network: 3 parameters
- dogs vs cats pictures (VGG16 network): 138,357,544 parameters

Architecture examples

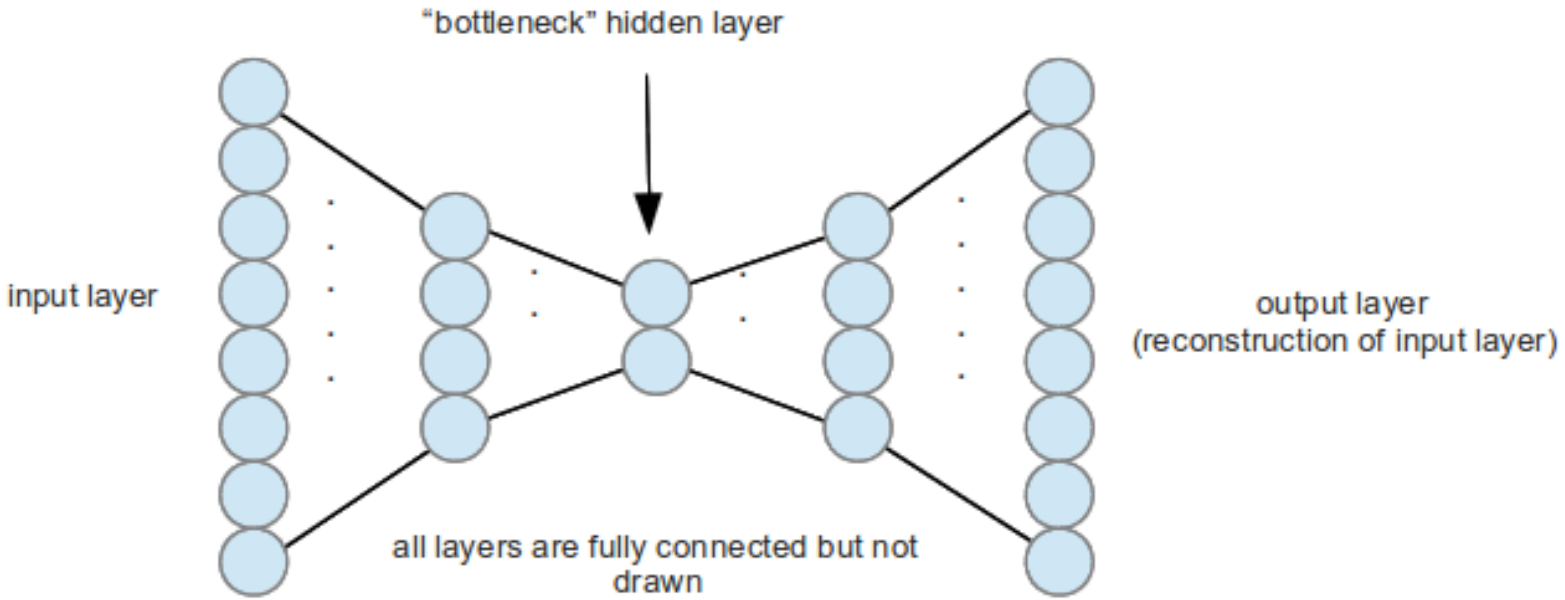
Autoencoder: data encoding



Hinton, Salakhutdinov (2006)

Architecture examples

Autoencoder: data encoding



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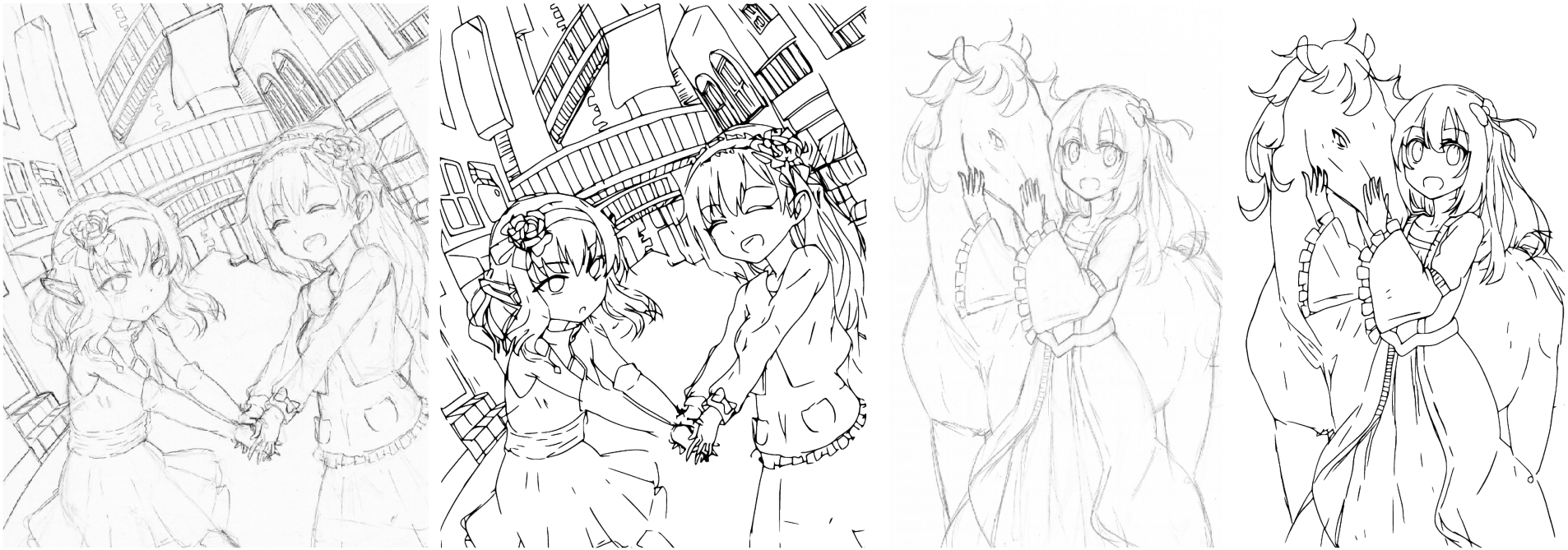
If we cut this autoencoder at the bottleneck, we get two parts: an encoder and a decoder. The encoder is an encoder highly specific to the content the network has been trained with.

Architecture examples

CNN + Autoencoder network: drawing simplification



Simo-Serra, Iizuka, Sasaki, Ishikawa (2016)

Architecture examples

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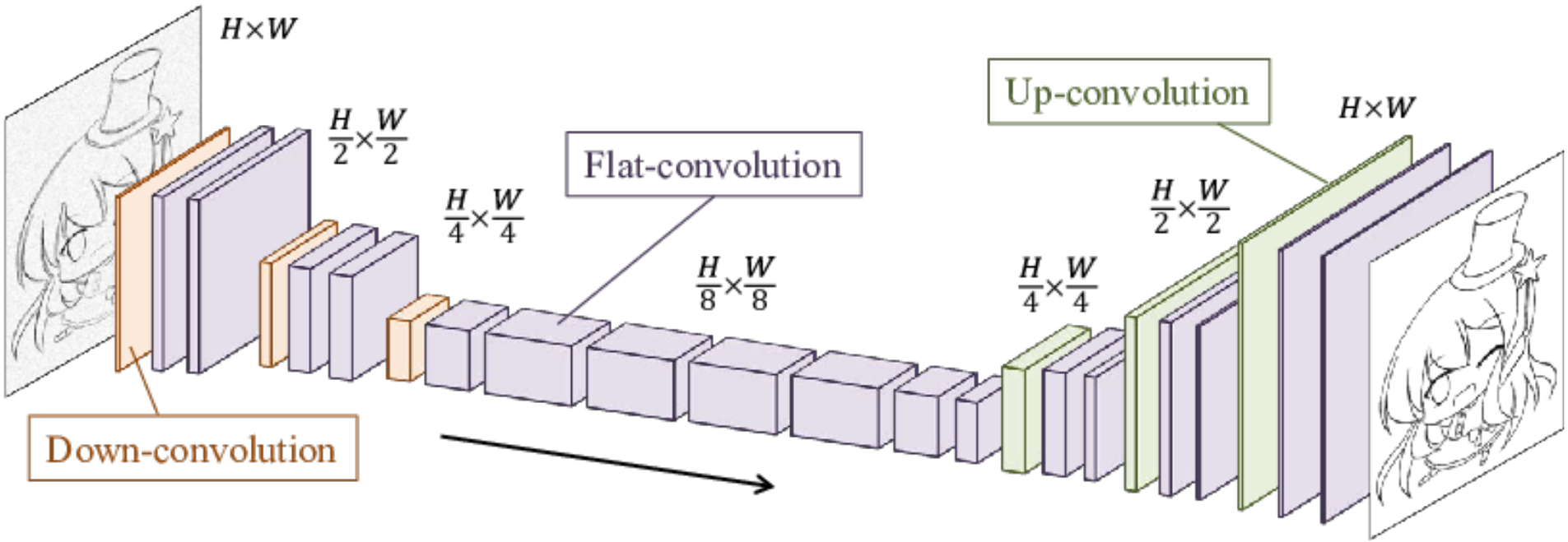

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Architecture examples

Neural style

Consider an image I and its image by the convolution layers of the VGG network $Conv(I)$.

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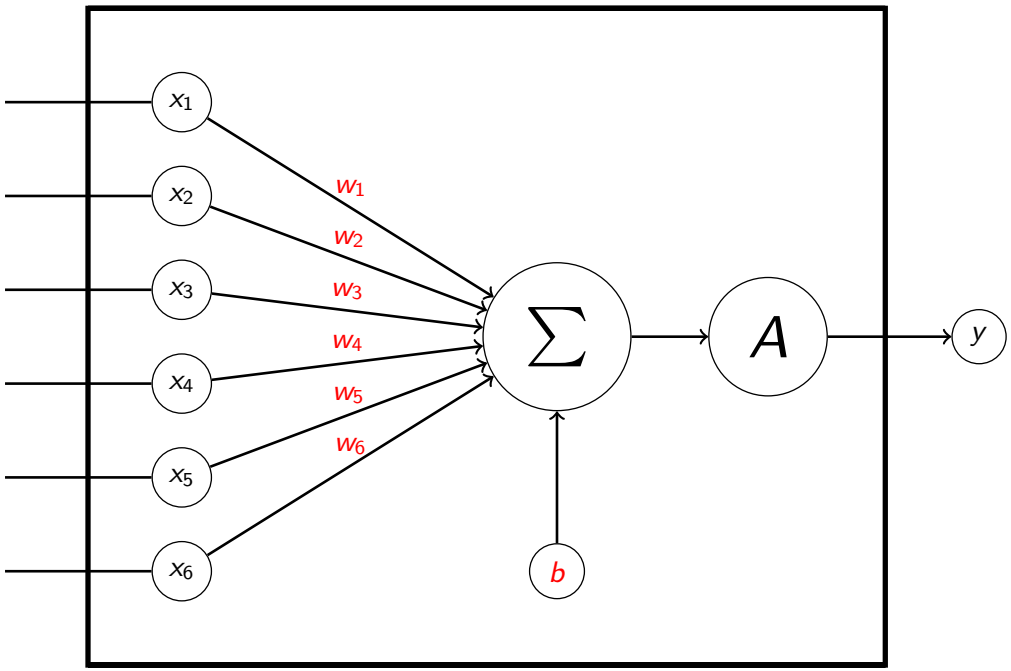
We can reconstruct a picture I' with the same content as I by applying gradient descent on the pixels in order to obtain $Conv(I)$ as output, starting with white noise.



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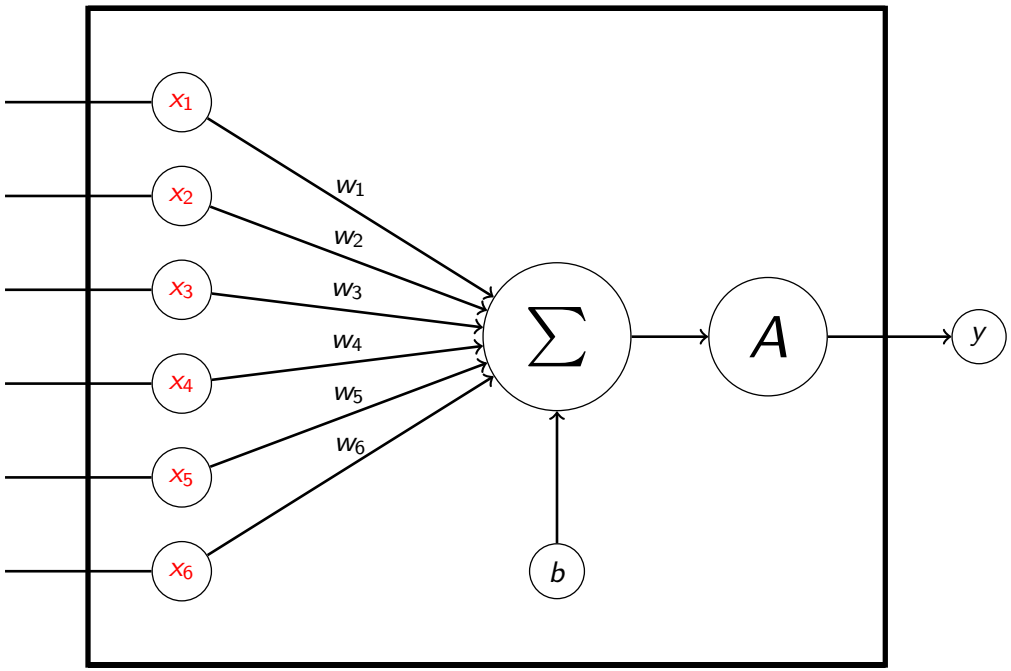


Gatys, Ecker and Bethge built a formula to extract the *style* of an image using the convolutional layers of the VGG network (2015).

They build the following Gram matrix:

$$G_{ij}^{l} = \sum_{k} F_{ik}^{l} F_{jk}^{l}$$

where F_{ij}^{l} is the j-th output of the i-th filter of the l-th convolutional layer.

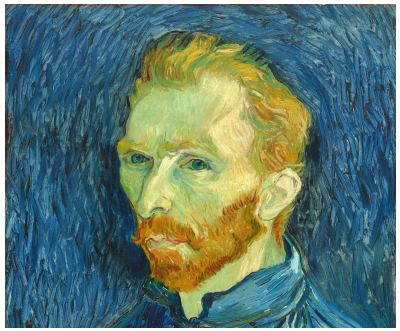
Architecture examples

Neural style

Let's take a random image from the internet.

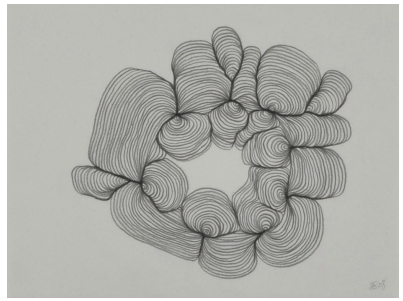
Architecture examples

Neural style

α content() + β style() = 

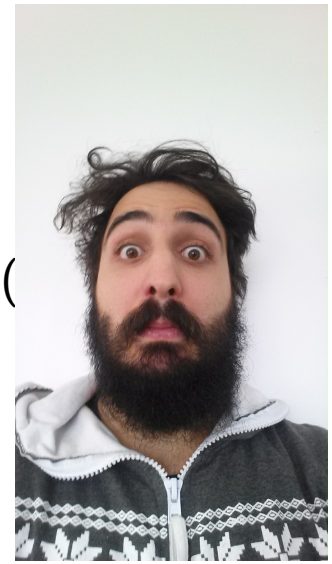
Architecture examples

Neural style

α content() + β style() = 

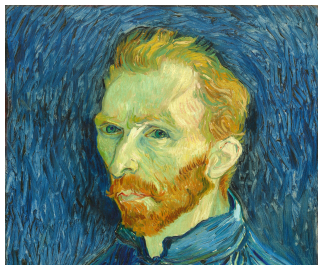
Architecture examples

Neural style

α content() + β style() = 

Architecture examples

Neural style

α content() + β style() = 

Architecture examples

Recurrent neural network

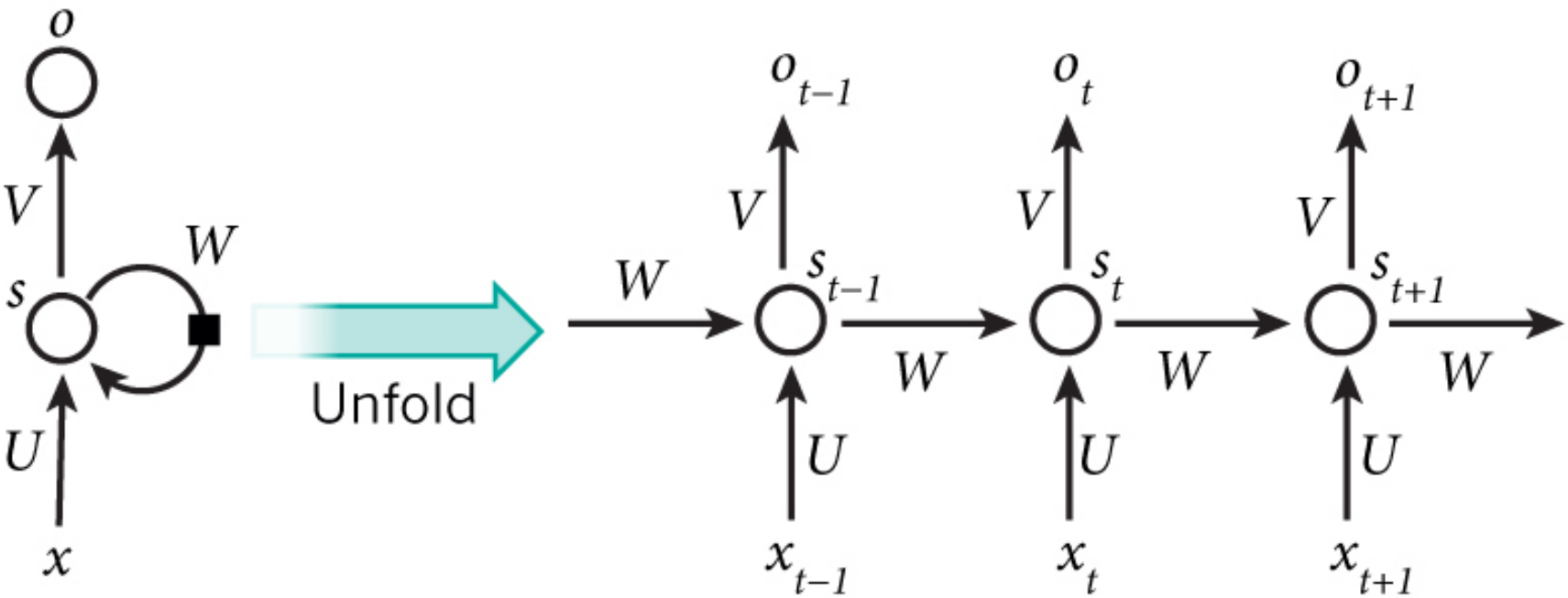


Image from `http://www.wildml.com`

Architecture examples

Sequence to class network: text classifier

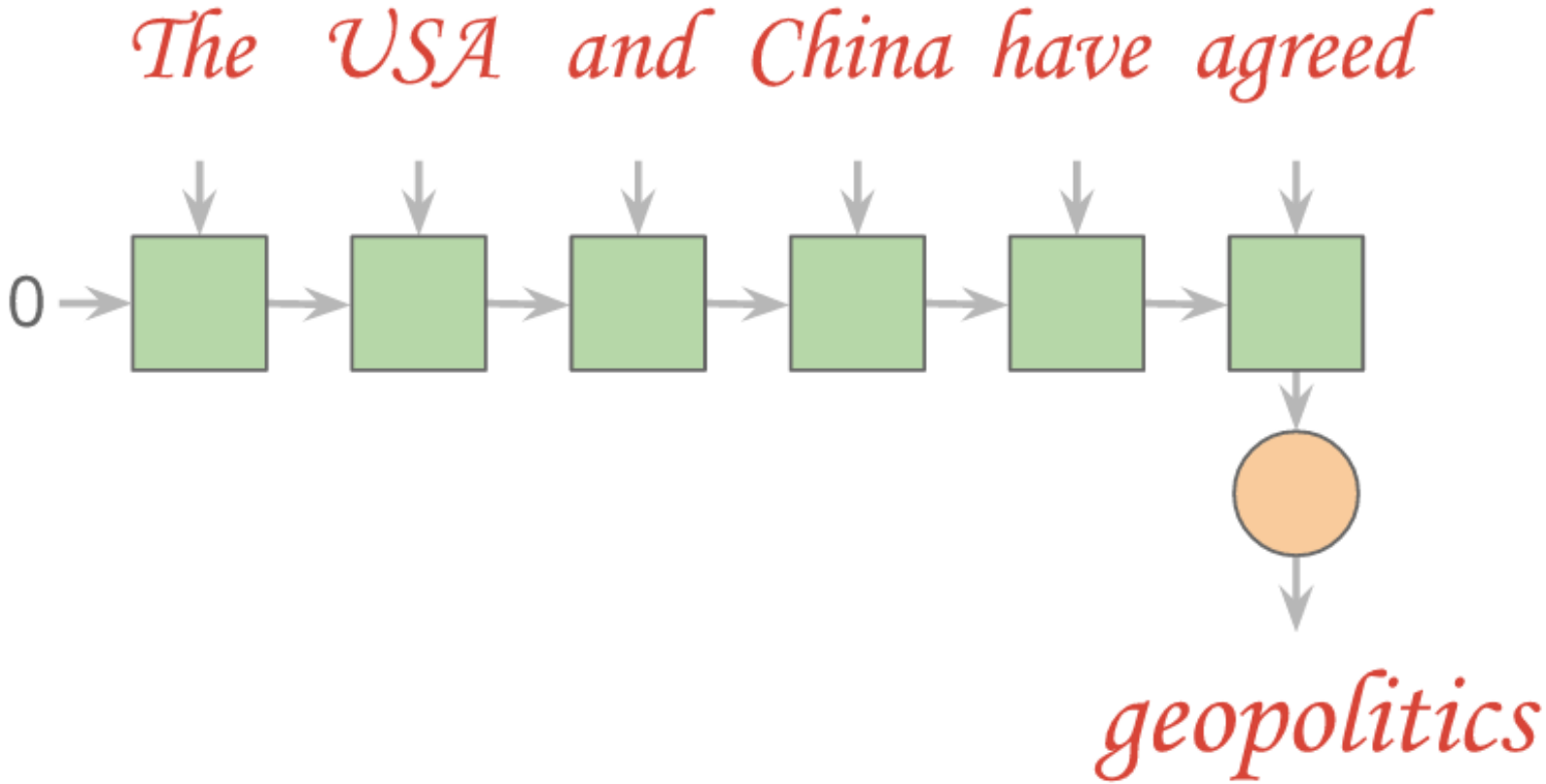


Image from Martin Gorner

Architecture examples

Sequence to sequence network: Neural Machine Translation

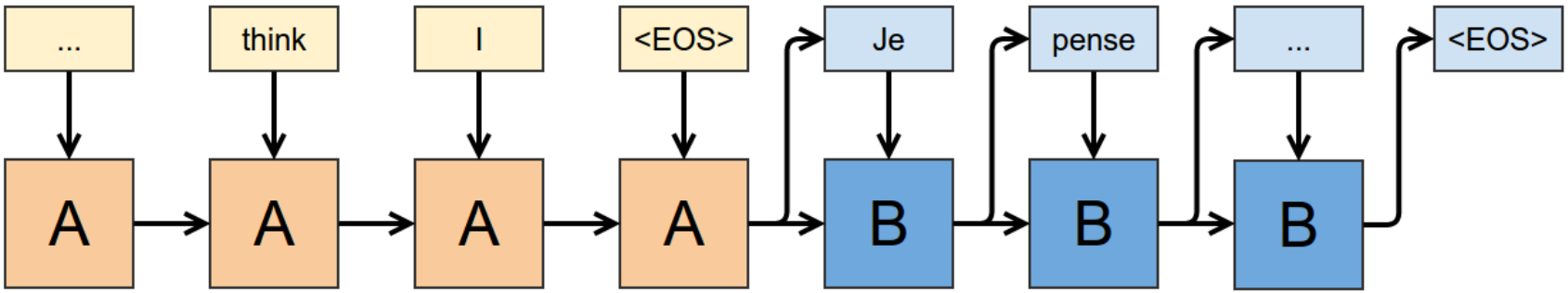


Image from `https://colah.github.io`

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

Sequence to sequence network: Neural Conversation Model

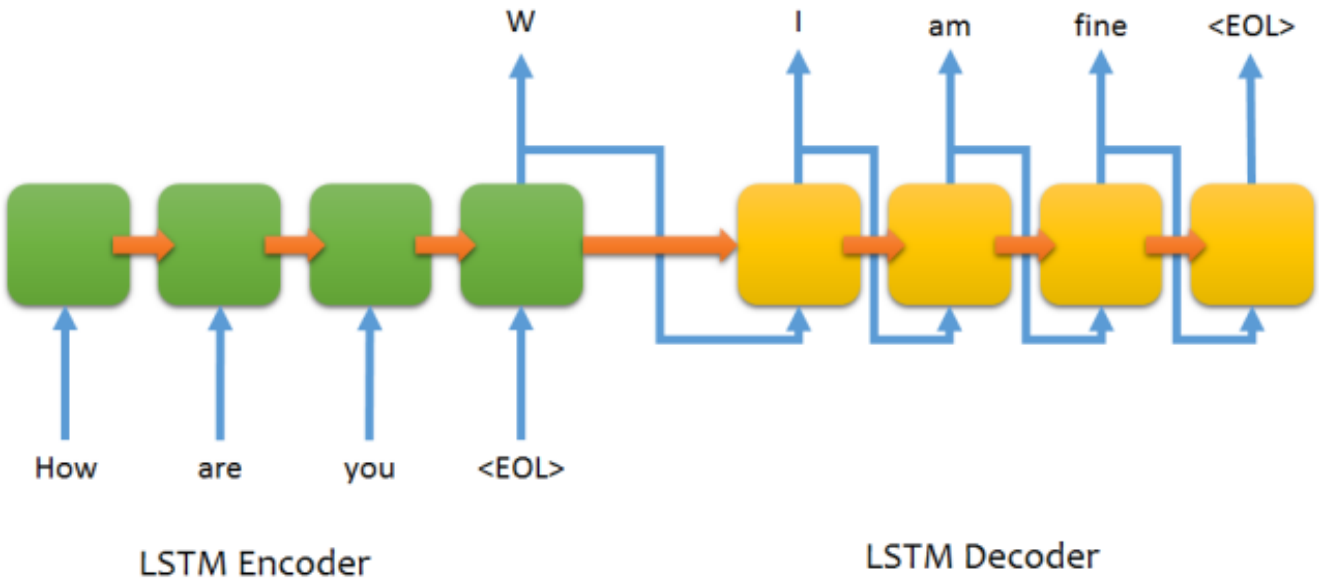


Image from `https://github.com/farizrahman4u/seq2seq`

Really early stage, hard to overcome challenges (context, coherent personality, . . .)

Architecture examples

Image to sequence: automatic captioning

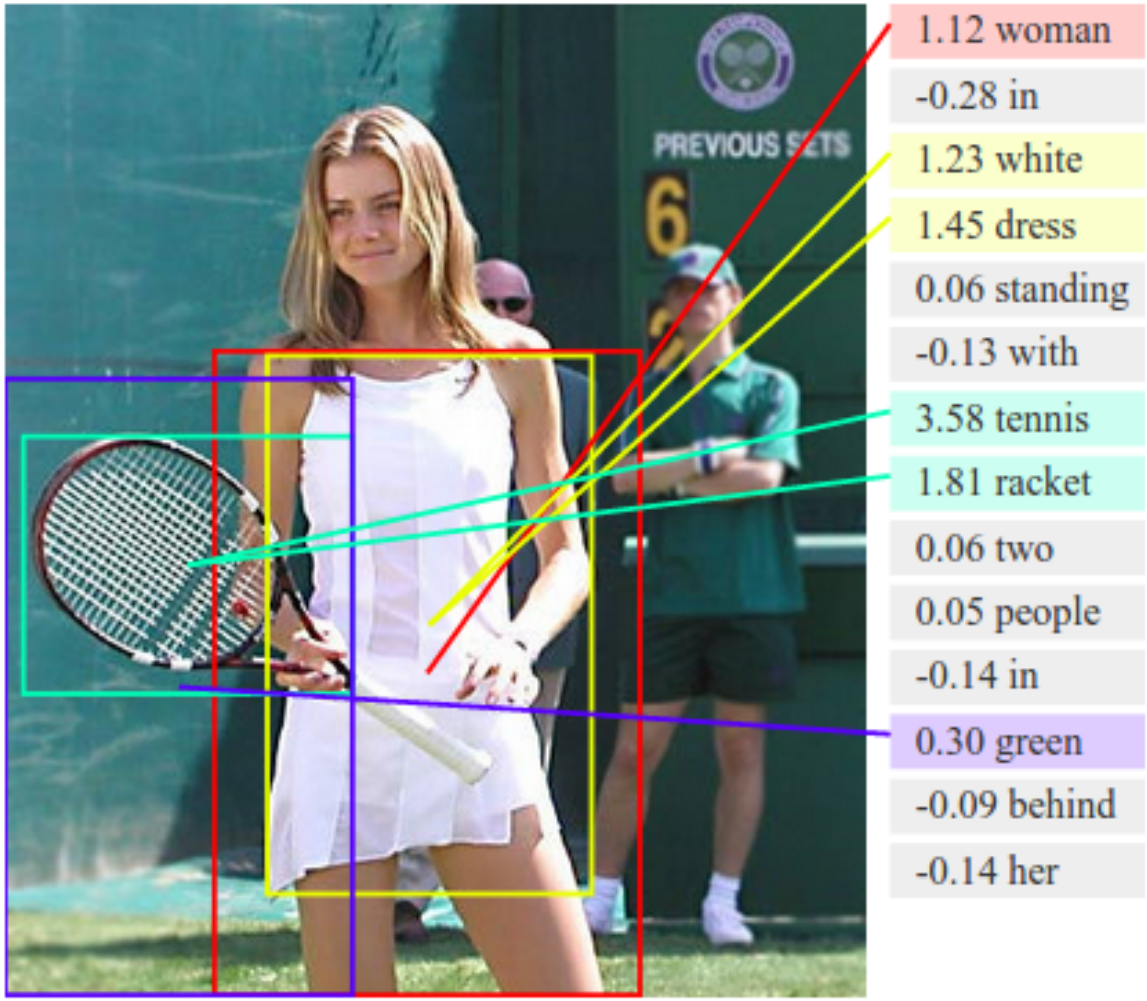


Image from `https://quantumfrontiers.com`

Architecture examples

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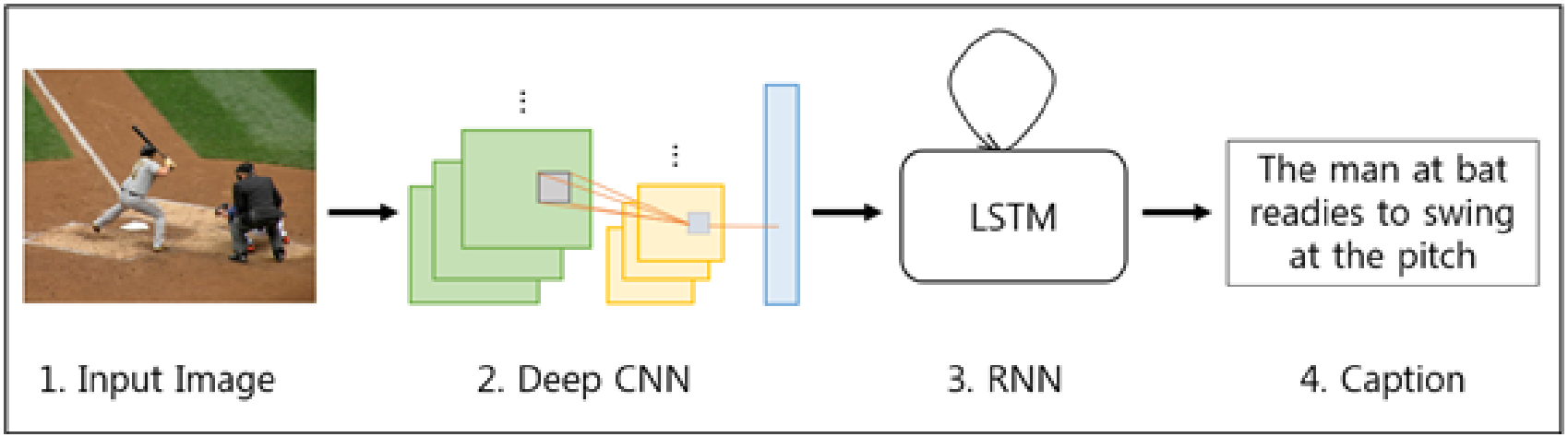

Image from `http://brain.kaist.ac.kr/`

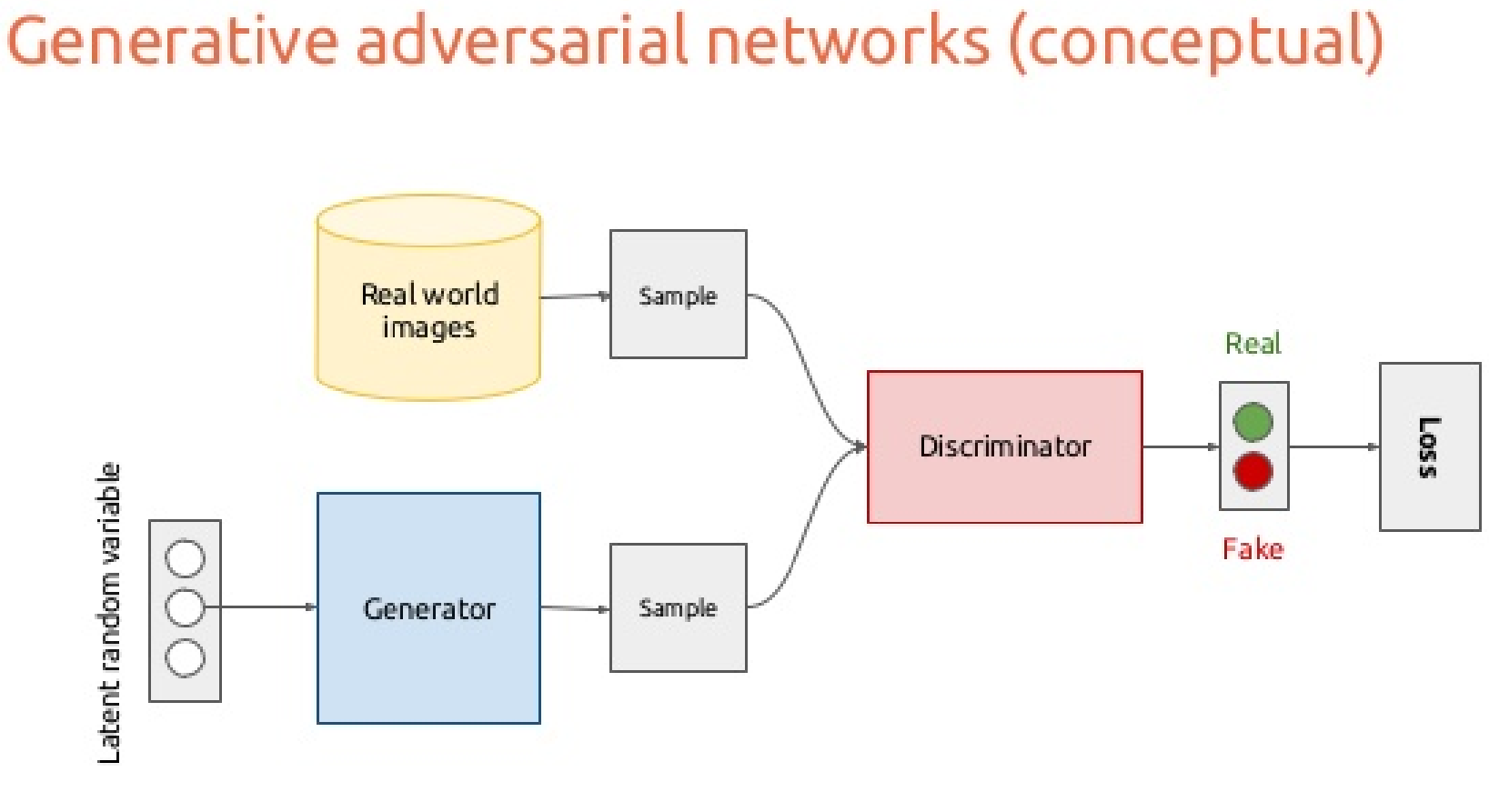

Image from `http://wiki.tum.de/`

Architecture examples

Generative adversarial network: text to image

Han Zhang et al. (2016)

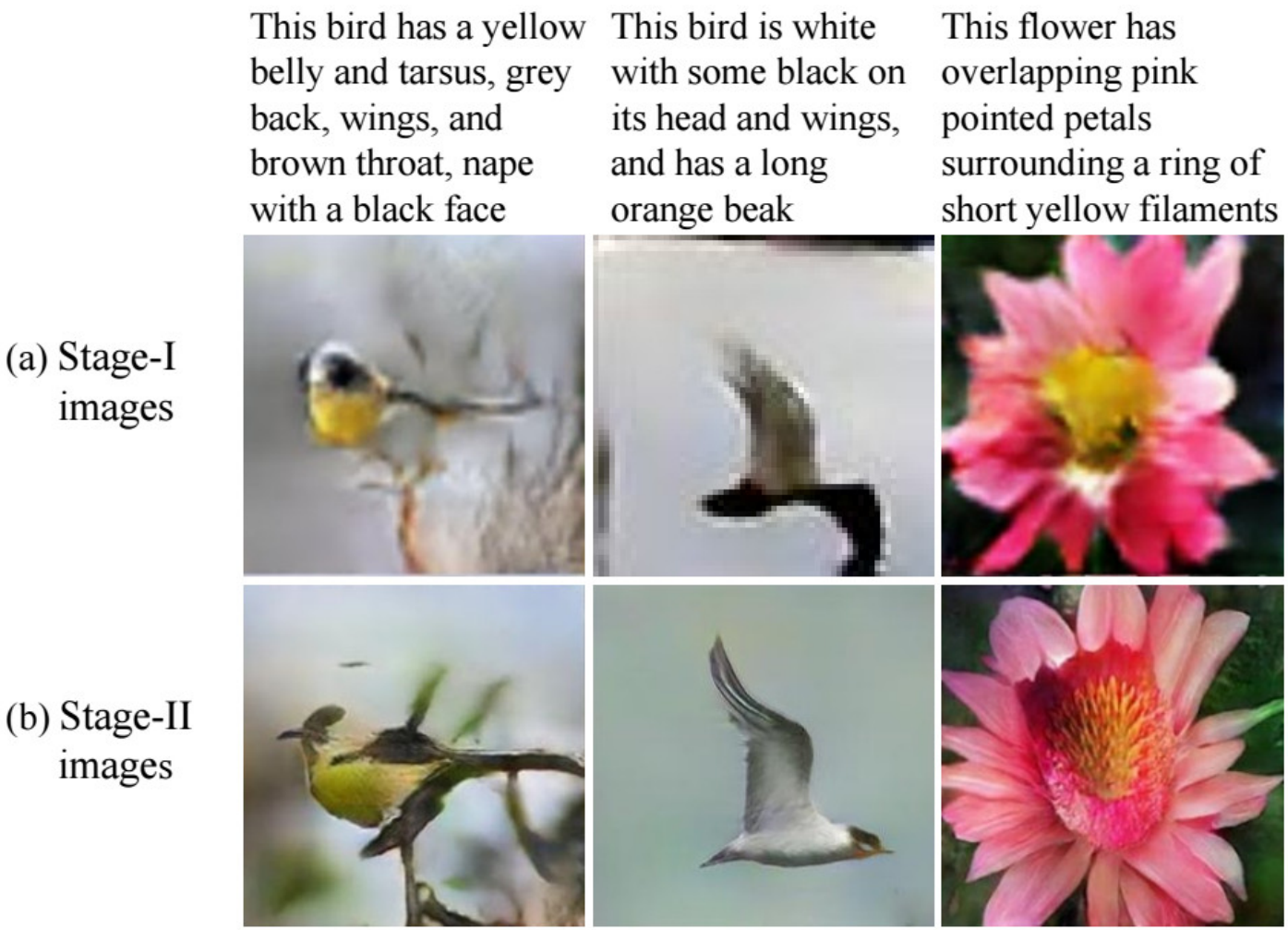

Image from `https://arxiv.org/pdf/1612.03242.pdf`