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	$(x, y, z) \to f(x, y, z)$
House price	(surface, nb rooms, city) $\to$ price

- Classification

Image classification	pixel values $\to$ cat or dog
Text classification	list of words $\to$ spam or valid email

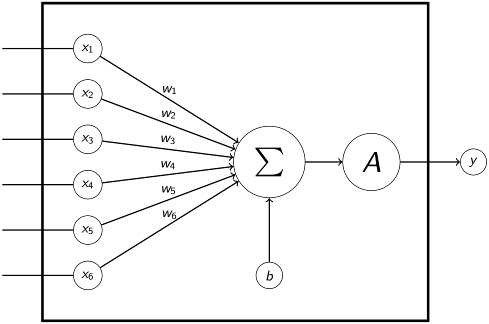
Deep learning

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

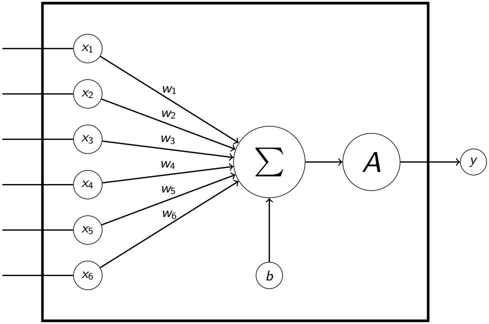
Neuron



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

Artificial neural network

Neuron

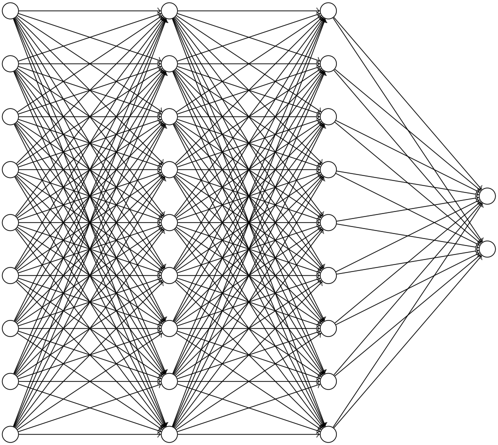


$$A(x) = \begin{cases} 0 & \text{if } x < 0 \\ 1 & \text{otherwise} \end{cases}$$

$$y = A(w_1 x_1 + w_2 x_2 + w_3 x_3 + w_4 x_4 + w_5 x_5 + w_6 x_6 + b)$$

Artificial neural network

Network



Artificial neural network

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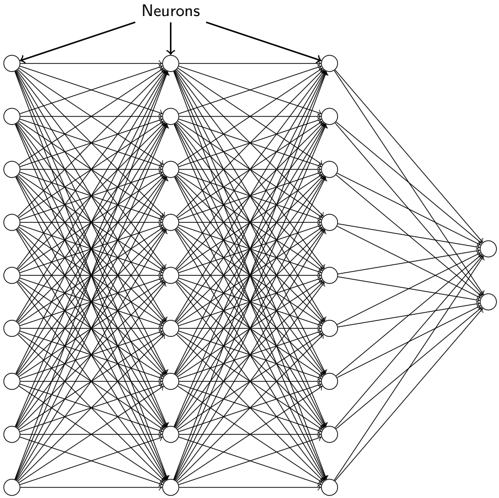
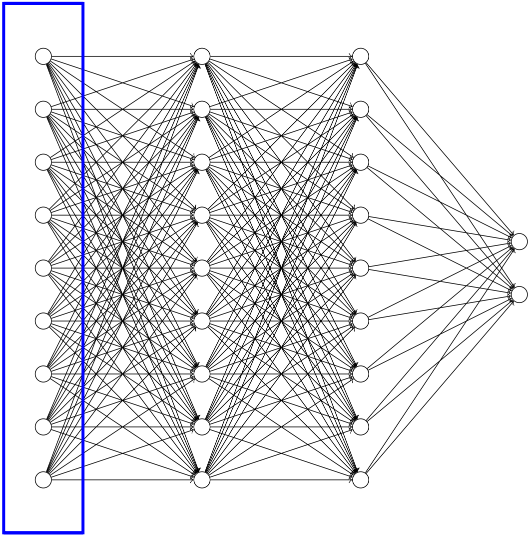


Artificial neural network

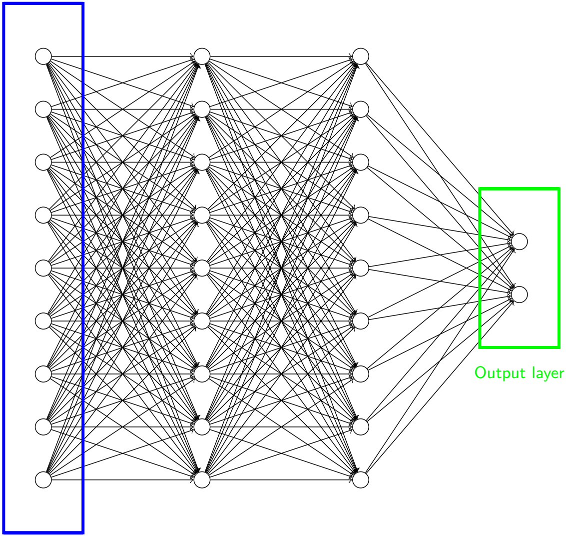
Network



Input layer

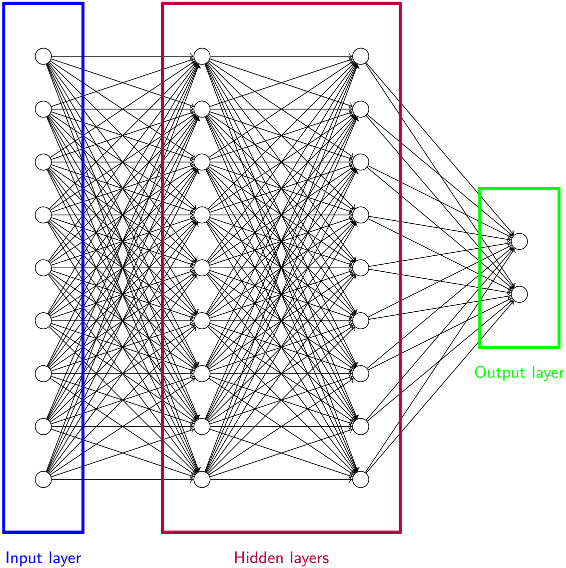
Artificial neural network

Network



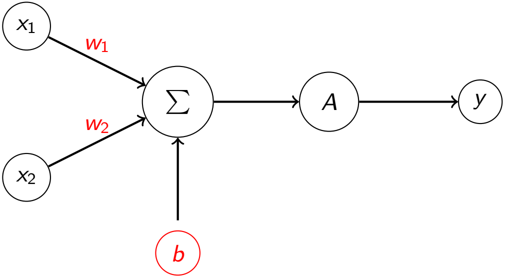
Artificial neural network

Network



Computation example

Binary AND gate

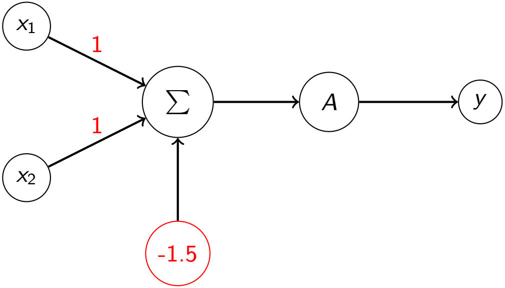


We want to set w_1, w_2 and b such that:

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

Computation example

Binary AND gate



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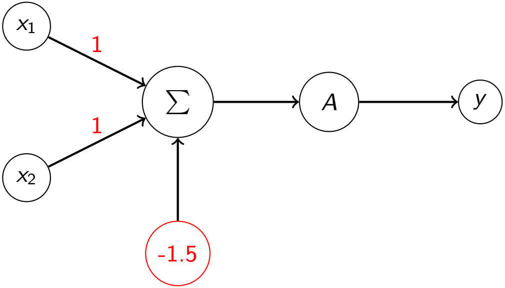

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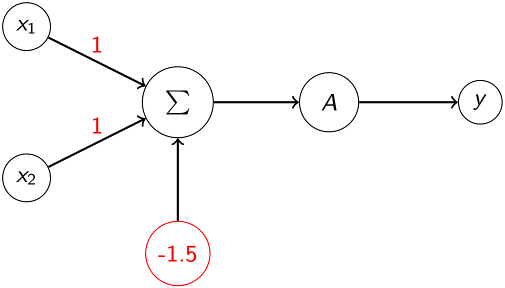
Computation example

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

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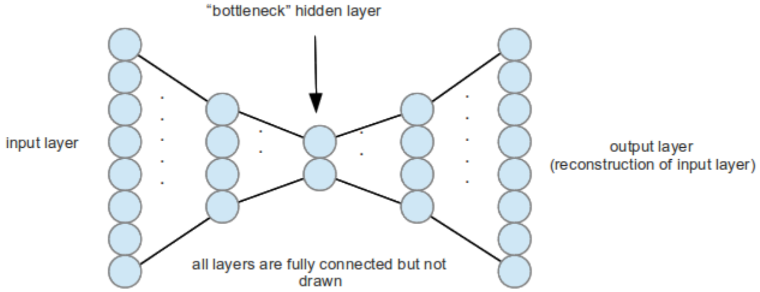
- AND network: 3 parameters
- dogs vs cats pictures (VGG16 network): 138,357,544 parameters

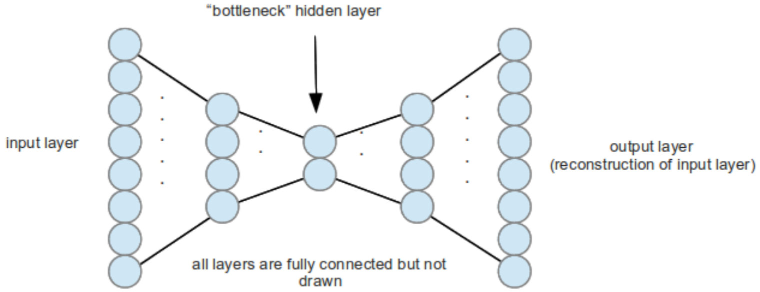
Architecture examples

Autoencoder



Hinton, Salakhutdinov (2006)

Architecture examples
Autoencoder



Hinton, Salakhutdinov (2006)

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

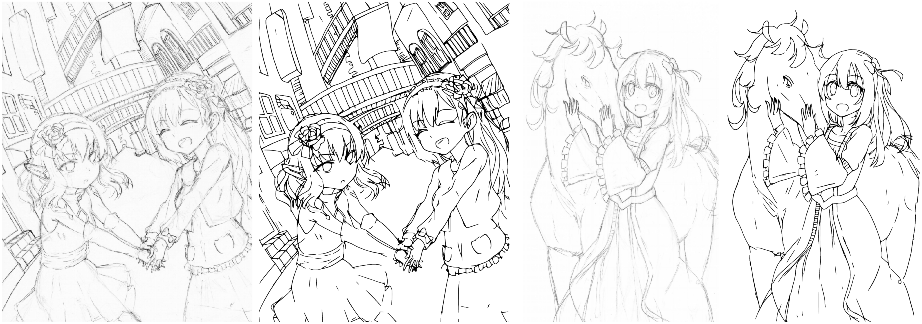
Autoencoder: Compression

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.

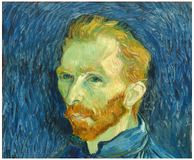
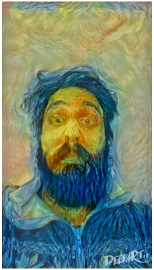
Architecture examples

Neural style transfer

Let's take a random image from the internet.

Architecture examples

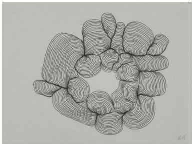
Neural style transfer

α content() $+ \beta$ style() $=$ 

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

Architecture examples

Neural style transfer

α content() + β style() = 

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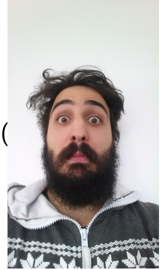
Architecture examples

Neural style transfer

α content() $+ \beta$ style() $=$ 

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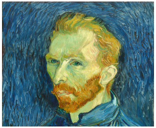
Architecture examples

Neural style transfer

α content() $+ \beta$ style() = 

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Architecture examples

Sequence to class network: text classifier

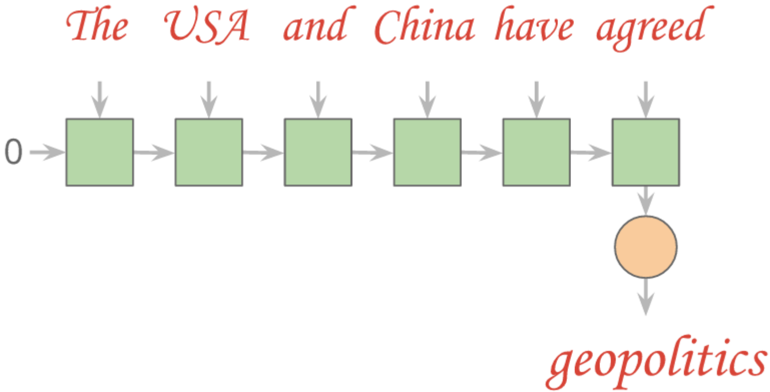

Image from Martin Gorner

Architecture examples

Sequence to sequence network: Neural Machine Translation

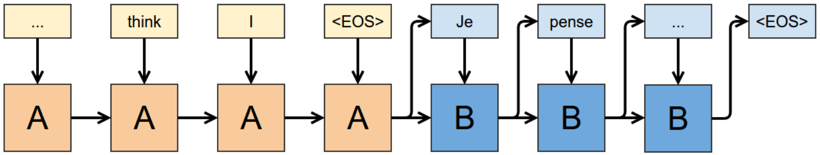

Image from `https://colah.github.io`

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

Image to sequence: automatic captioning

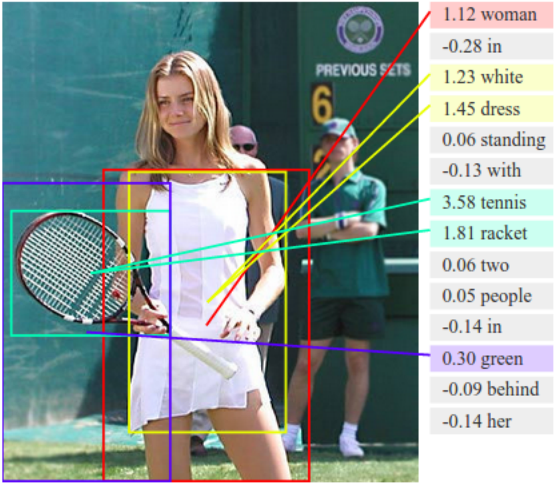

Image from `https://quantumfrontiers.com`

Architecture examples

Image to sequence: automatic captioning

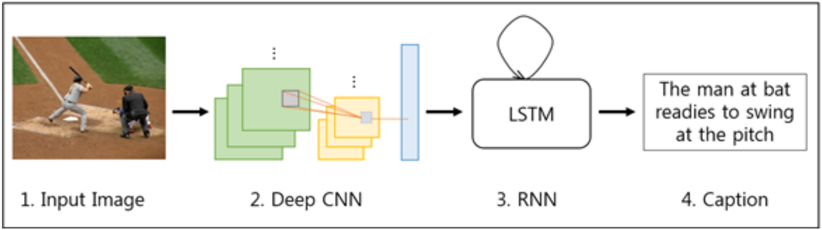

Image from `http://brain.kaist.ac.kr/`

Architecture examples

Generative adversarial network

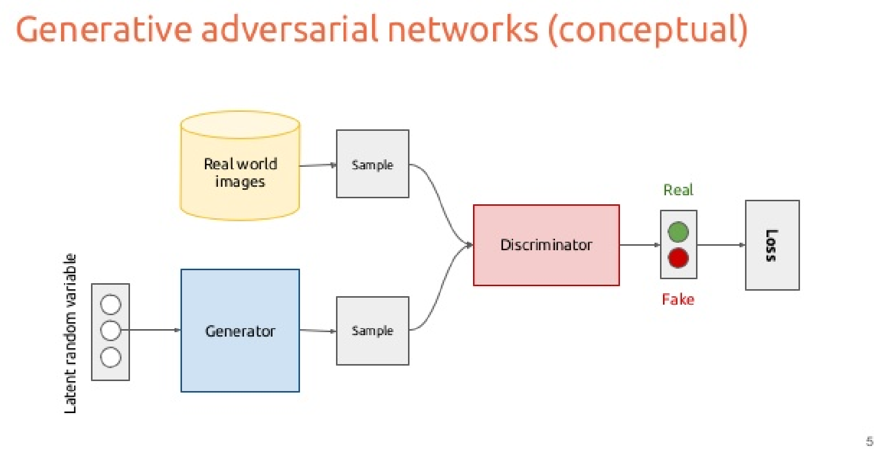

Image from `http://wiki.tum.de/`

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)

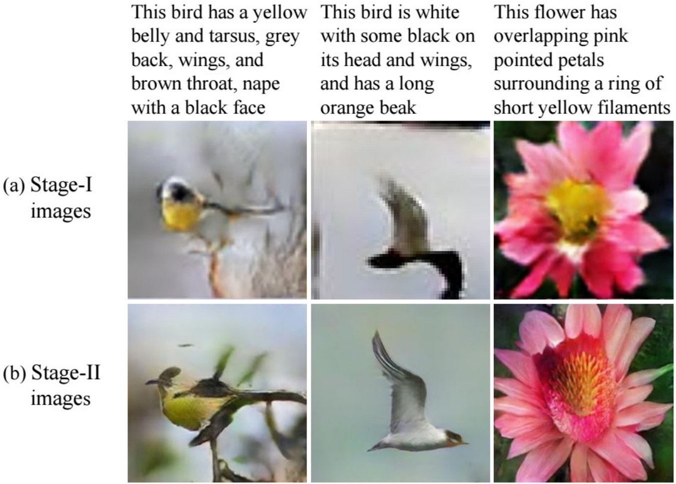

Image from `https://arxiv.org/pdf/1612.03242.pdf`