Deep Learning and Neural Network

Marie Beurton-Aimar, LE Van Linh

November 28, 2024

Artificial Intelligence?

The fathers

- Lee Marvin Minsky and John McCarthy created the expression - Working at MIT in the fifties.
- Foundation at the Dartmouth conference on summer 1956.
- Minsky defined AI as "the science of making machines do things that would require intelligence if done by men."
- On the road to achieve the Turing machine.

Artificial Intelligence?

The fathers

- Lee Marvin Minsky and John McCarthy created the expression - Working at MIT in the fifties.
- Foundation at the Dartmouth conference on summer 1956.
- Minsky defined AI as "the science of making machines do things that would require intelligence if done by men."
- On the road to achieve the Turing machine.

Copying human being?

- Learning is the main characteristic of Intelligence.
- In the 80's symbolic approach wins against connexionist approach.
- End of the first turn !

Back to the futur

ECCV 2012

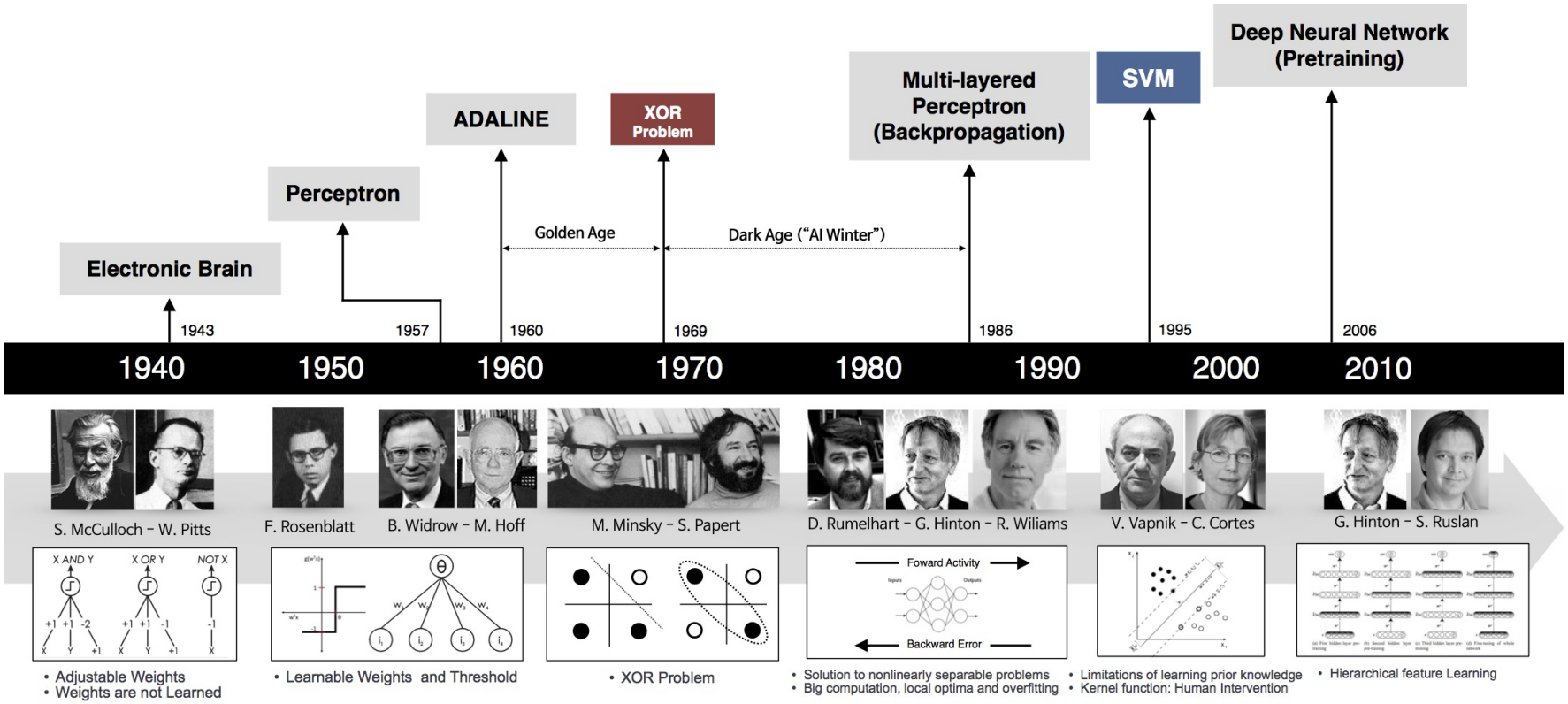
- Hinton, Krizhevsky and Sutskever propose the first model to classify ImageNet DB with a deep network - and outperform (g.t. 10%) all the results.

`https://hal.archives-ouvertes.fr/hal-01925644/document`

Neural Network revival

- Reuse the architecture proposed by Lecun more than 20 years before (listen the Collège de France talk of Y. Lecun to know more about the main principles).
- Intelligence is a connexionist system with layers - composition of simple layers.

History



[beamandrew, 2017]

Deep Learning today

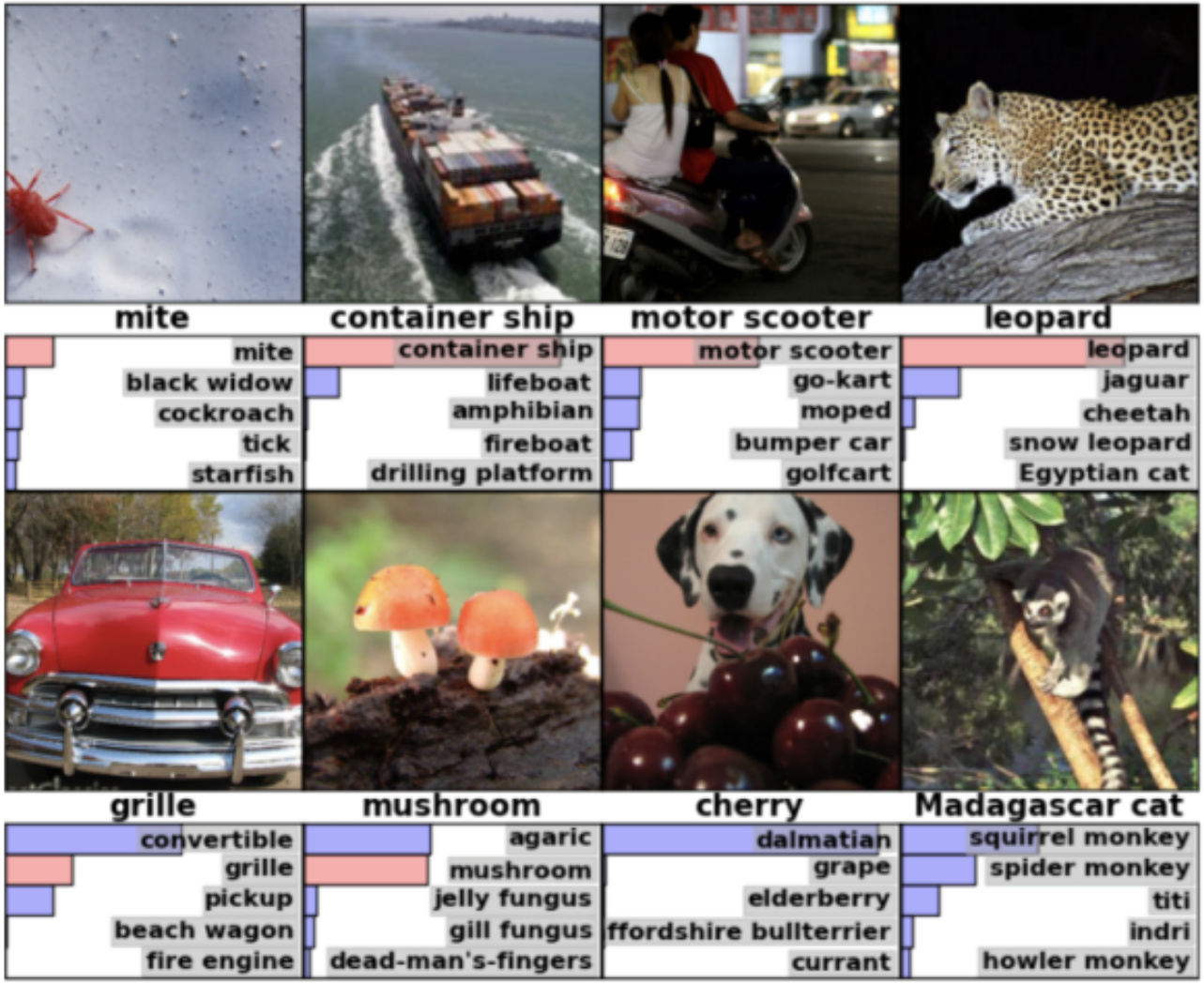
Why using Deep learning?

- Production of huge amount of Data by machines.
- Evolution of Data Mining domain/statistical methods.
- Extraction of features to classify data, to predict results ...
- Pretty all domains are concerned: machine log, images, medical/biological data ...

Requirements

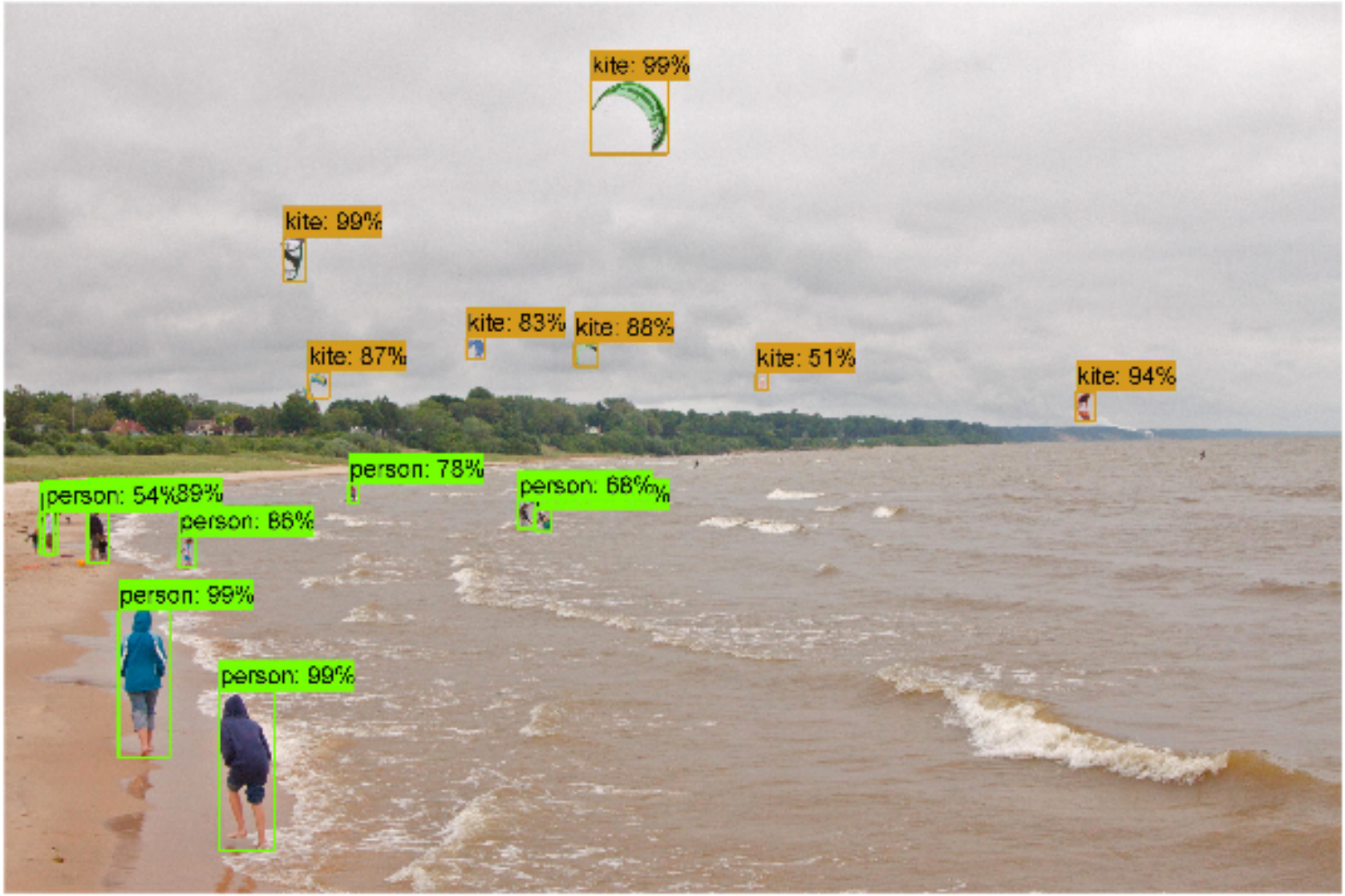
- Data storage and computing ressources.
- Way to display and to perform the results.
- Graphical interfaces and statistics tests are mandatory.

Deep Learning - Images classification



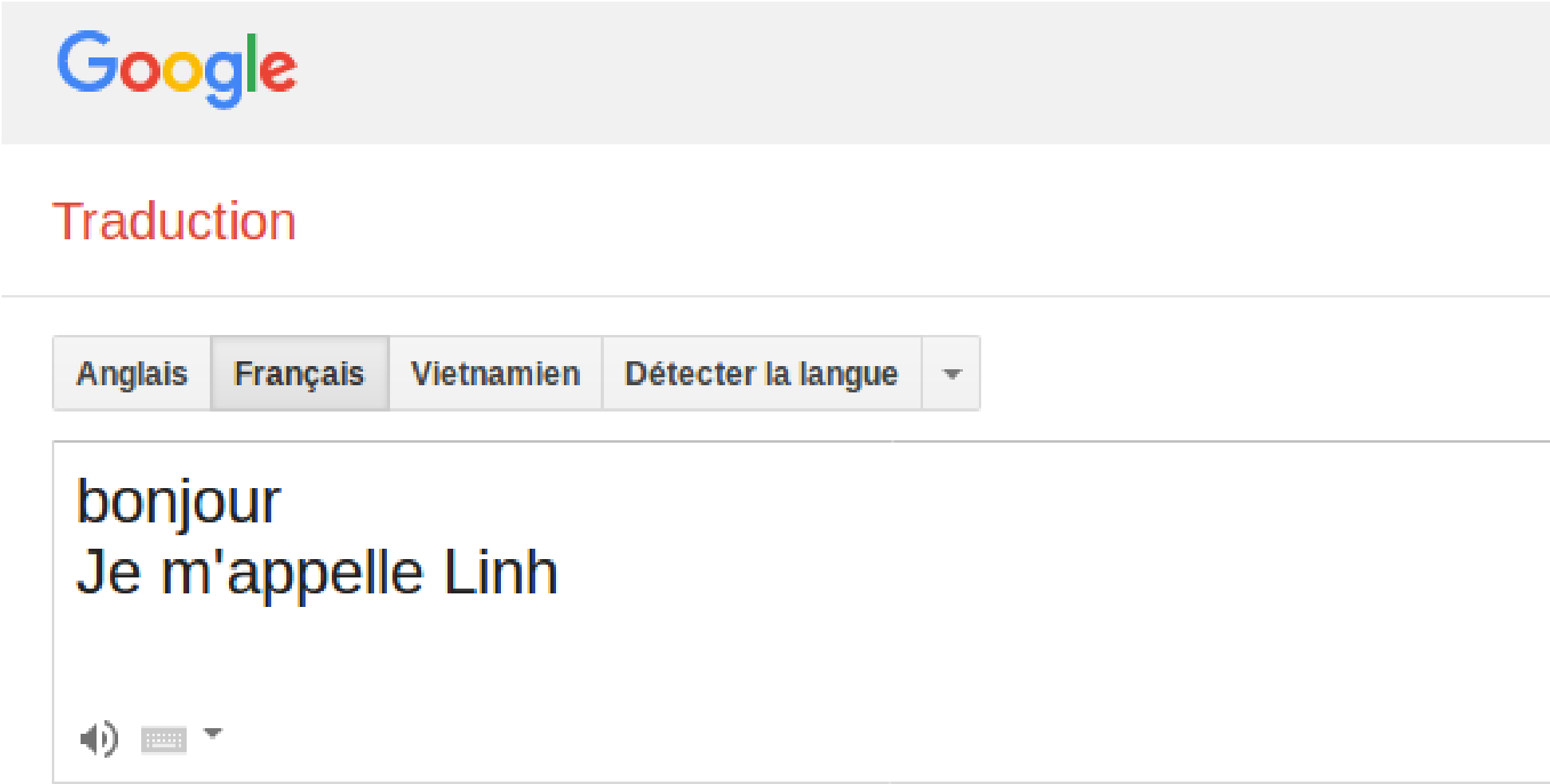
[Machine Learning Mastery, 2016]

Deep Learning - Object detection



[Medium, 2018]

Deep Learning - Machine translation



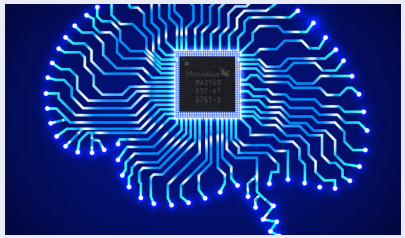
Deep Learning - Speech recognition

Deep learning is a class of machine learning that:

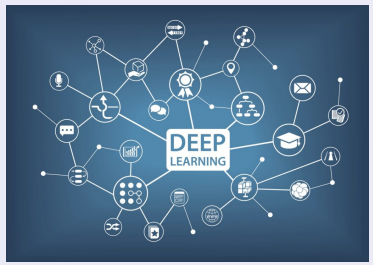
- use a cascade of multiple layers for extracting and transforming the features.
- learn in supervised or unsupervised mode
- learn with different levels of presentation

[ZDNet, 2018]

[Siecle Digital, 2016]



[Silicon ANGLE, 2016]

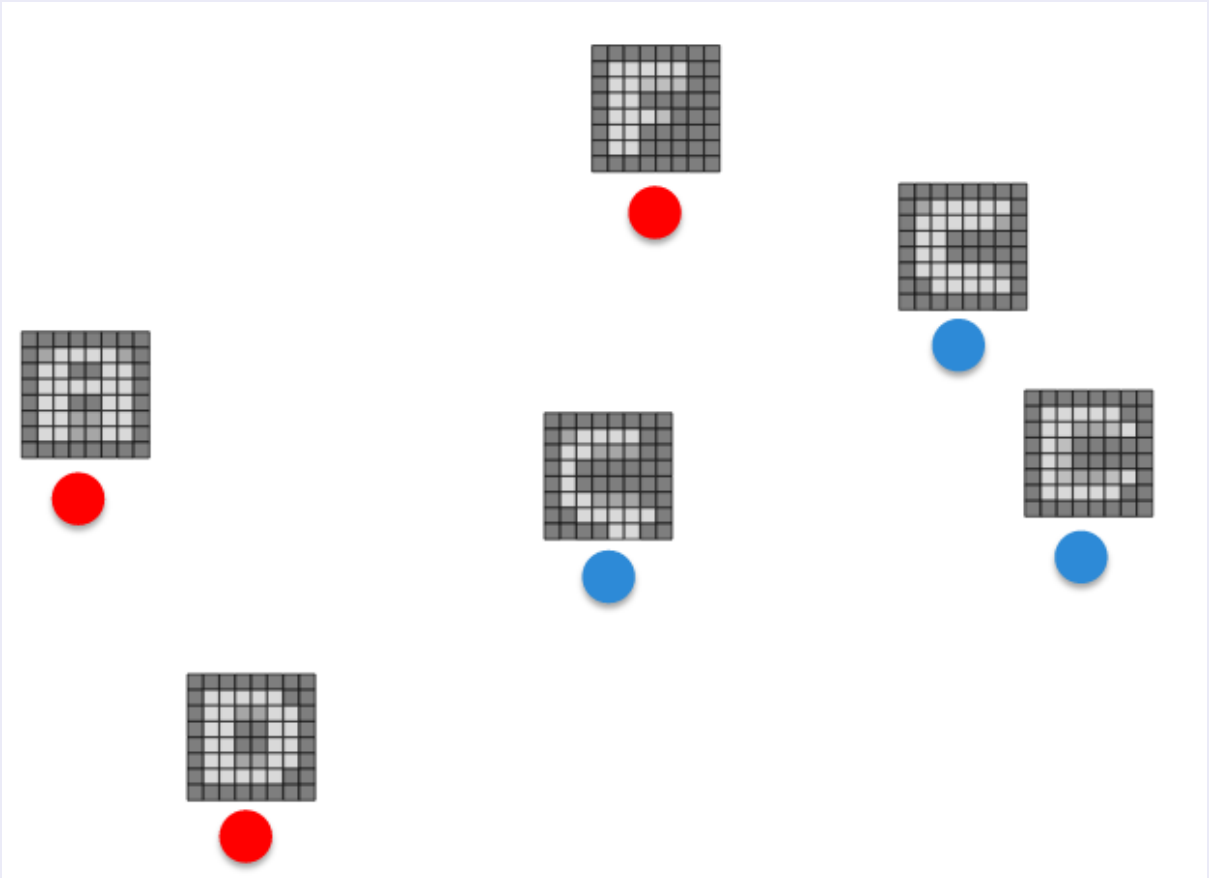


ROSS Intelligence, 2018

Neural architecture

Perceptron bases

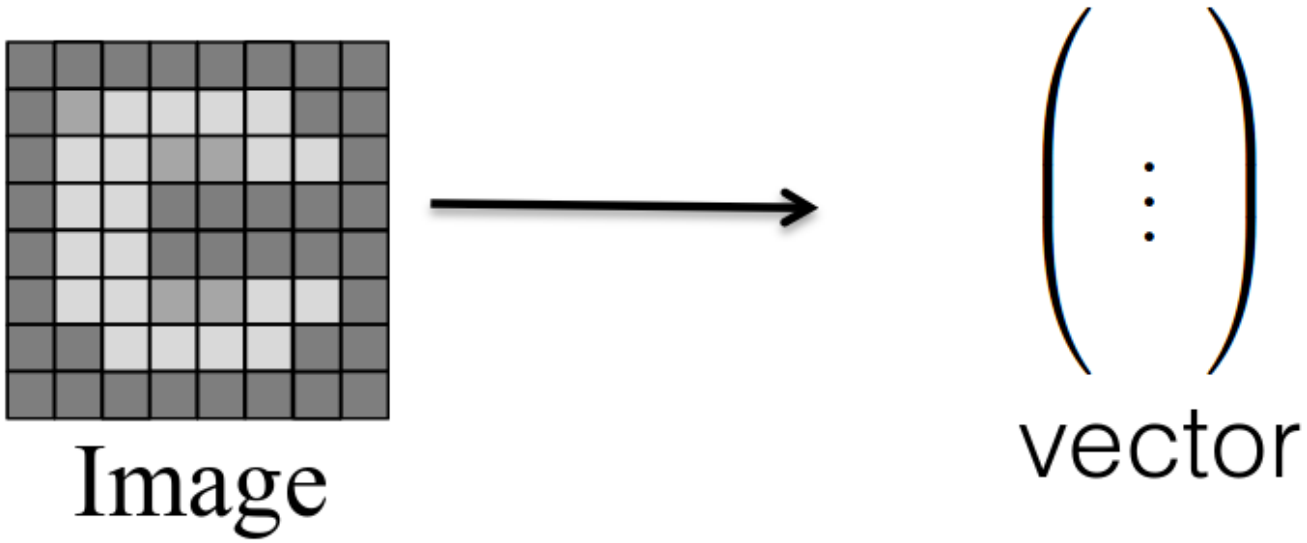
- Collect data for training: includes positive and negative examples



Neural architecture

Perceptron bases

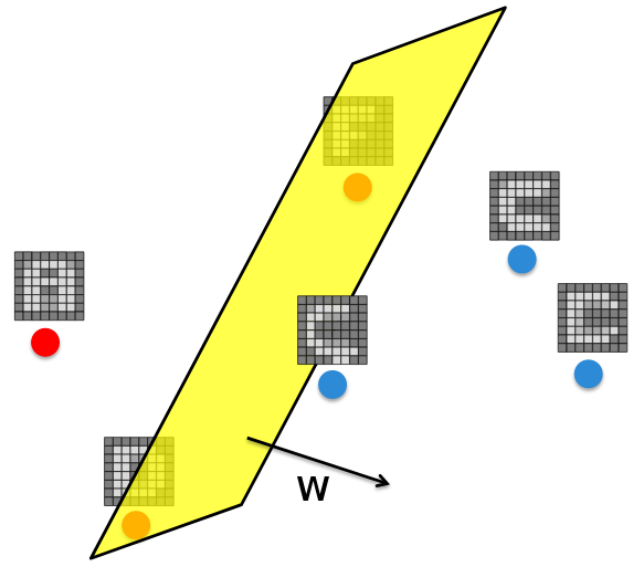
- Represent data as vectors:



Neural architecture

Perceptron bases

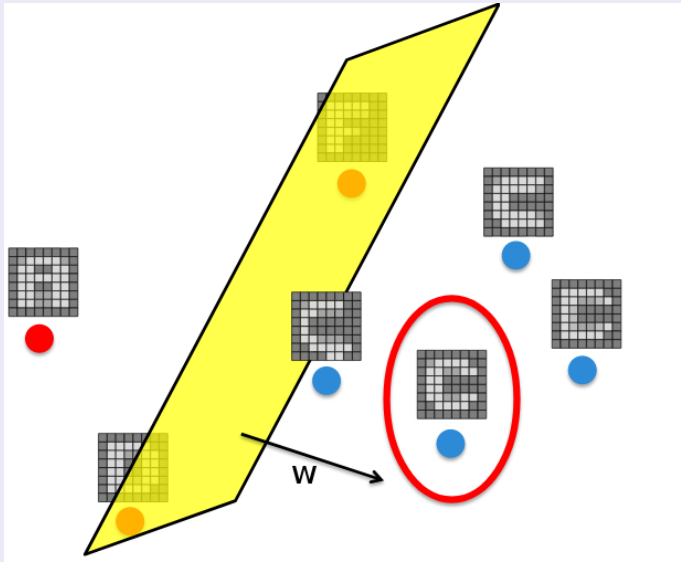
- Function: $f(x) = w^T x + b$
- Train the function on training data: find w and b so that
  - If sample x is positive, $f(x)$ is positive
  - If sample x is negative, $f(x)$ is negative



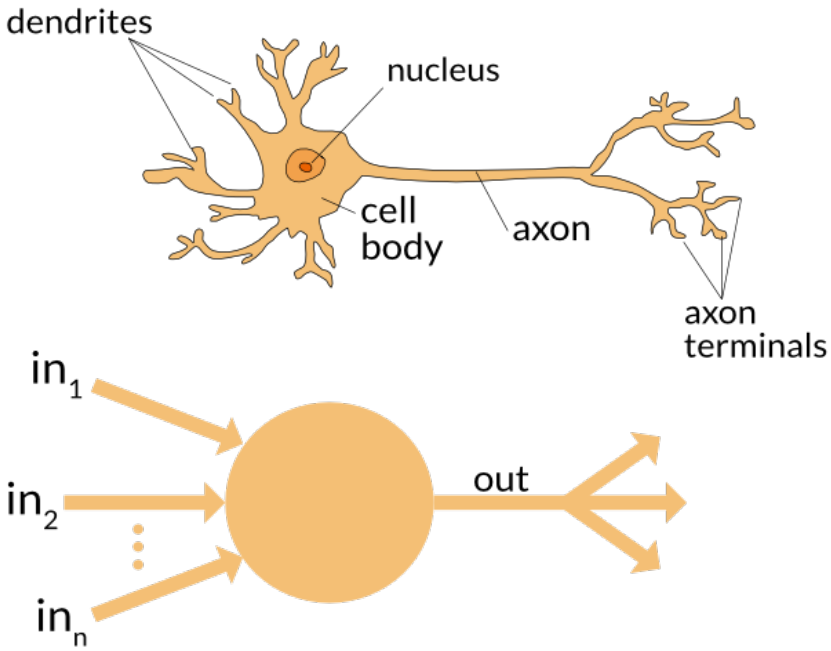
Neural architecture

Perceptron bases

- Testing on new examples

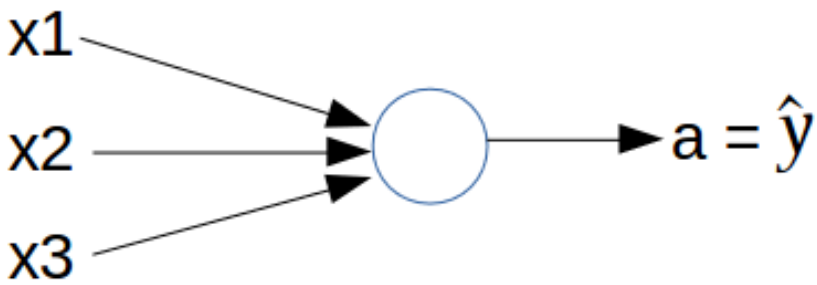


Biological Inspiration

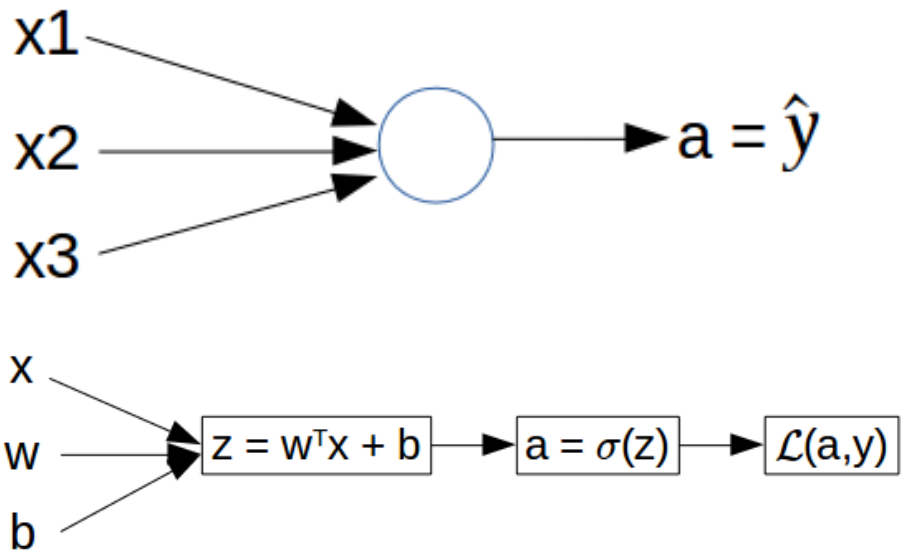


[appliedgo, 2016]

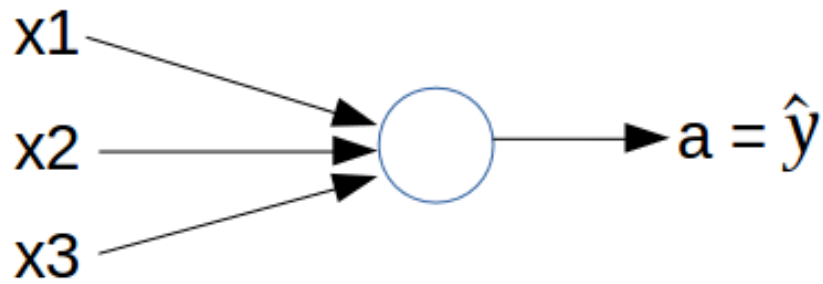
What is an artificial neural network?

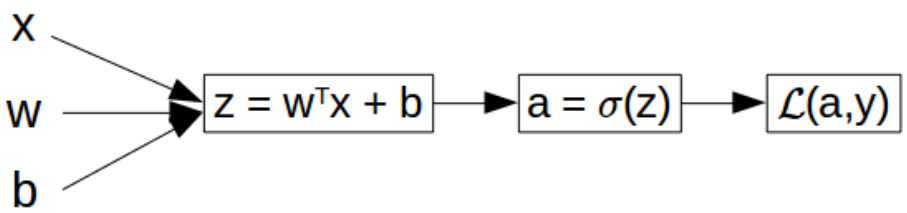


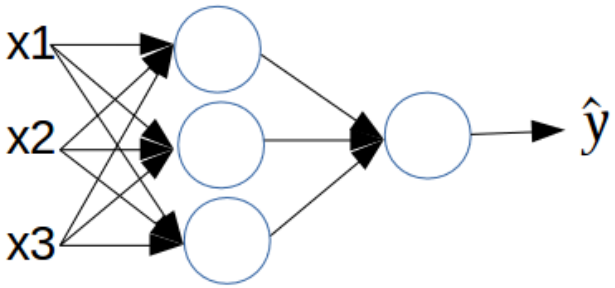
What is an artificial neural network?



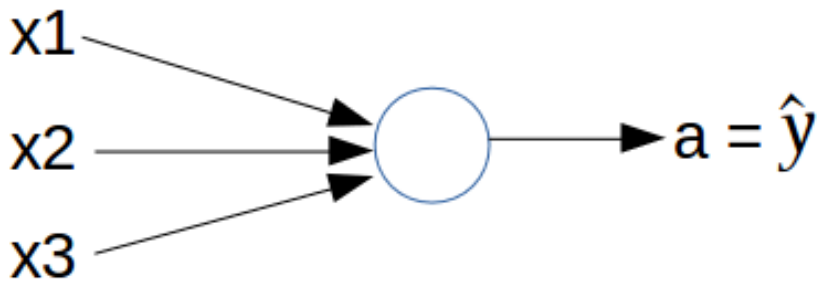
What is an artificial neural network?

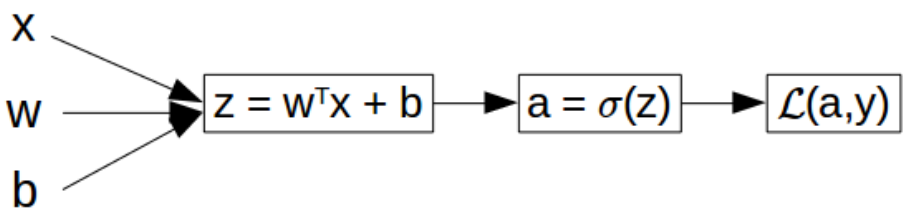


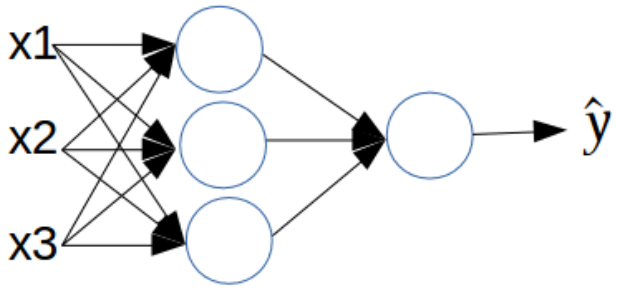


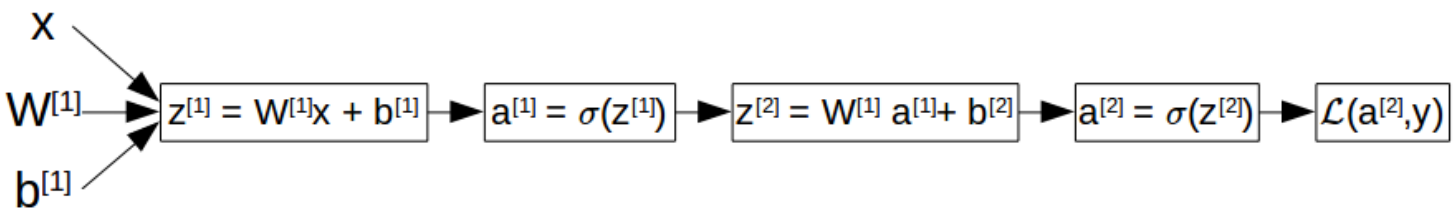


What is an artificial neural network?

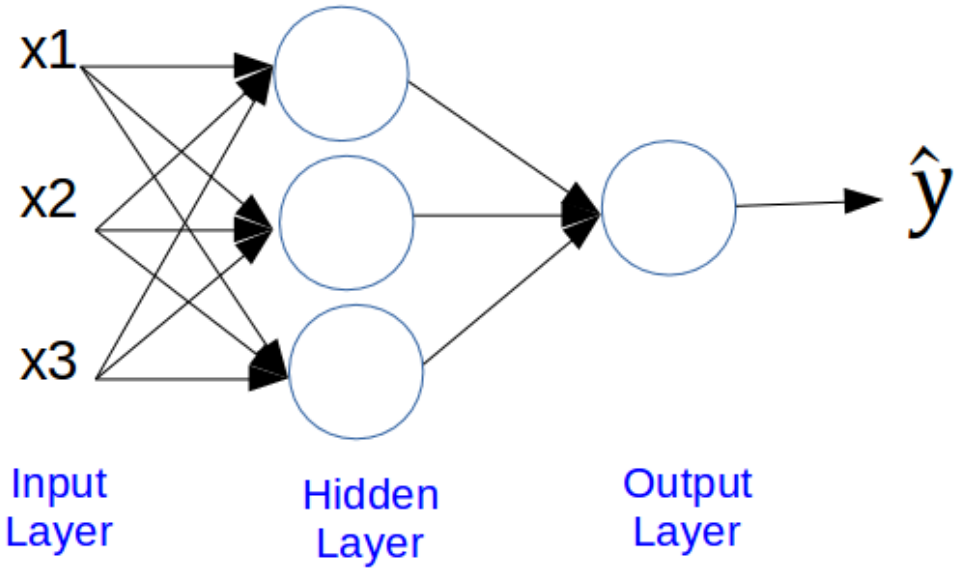








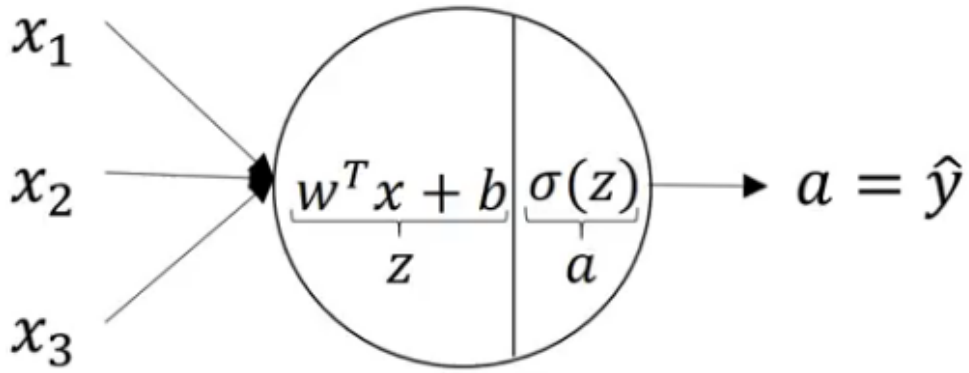
NN Representation



This is a:

- 2 layers neural network
- The hidden layers and output layer (sometime) will have the parameters (W,b)

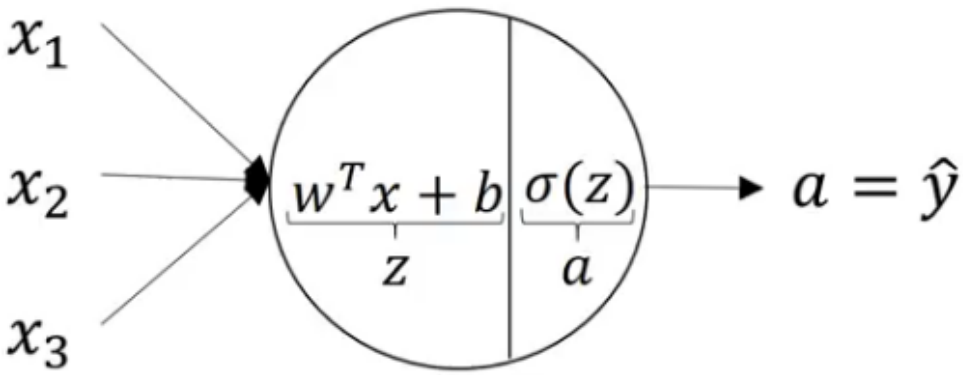
NN Computing

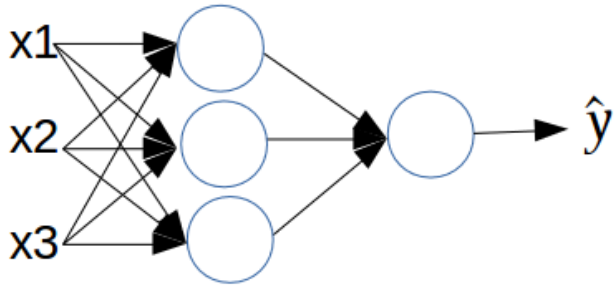


$$z = w^T x + b$$

$$a = \sigma(z)$$

NN Computing

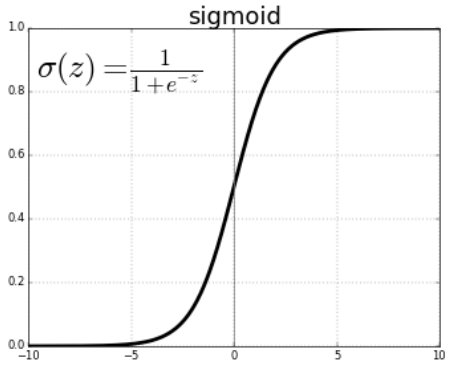


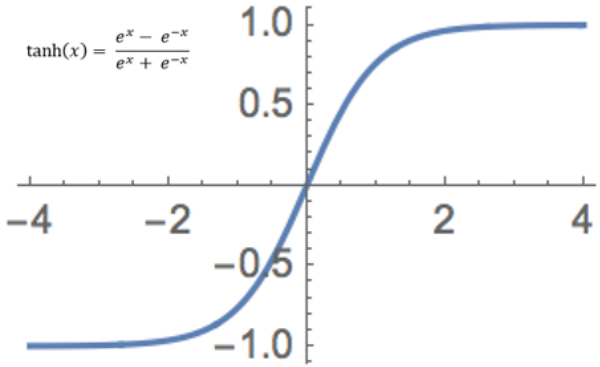


$$z = w^T x + b$$

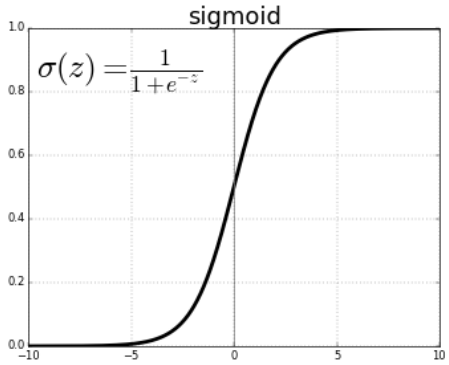
$$a = \sigma(z)$$

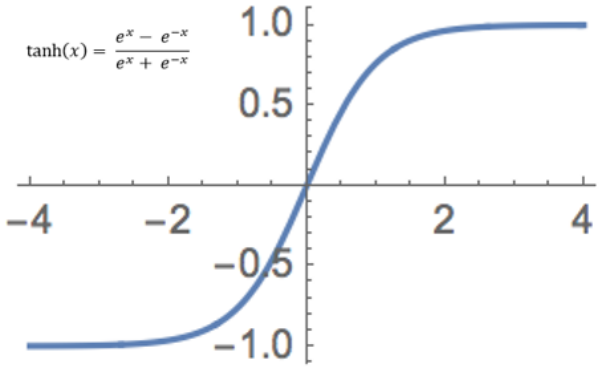
Activation functions

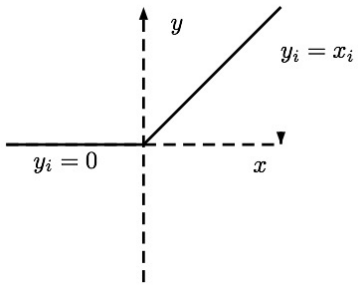


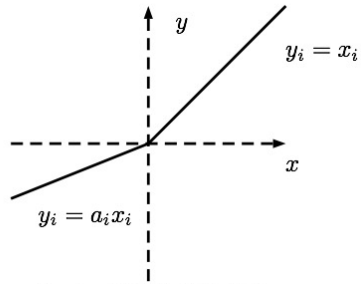


Activation functions





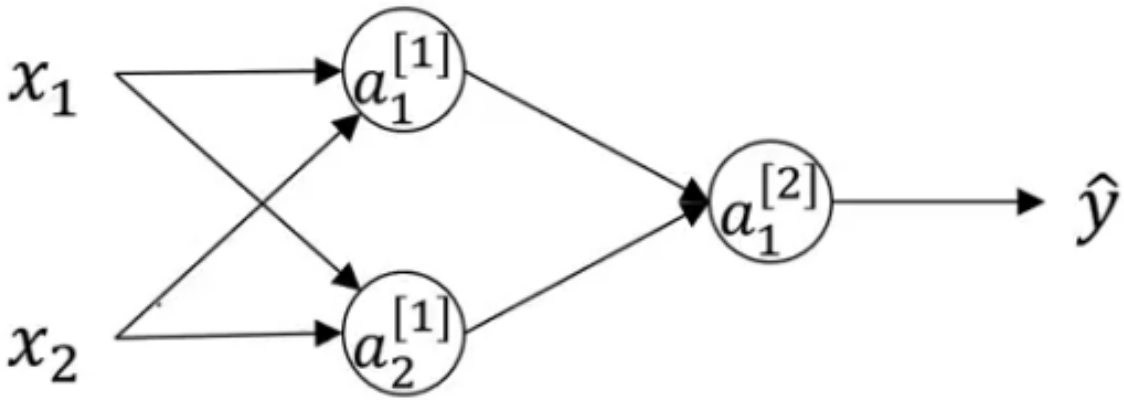




- For hidden units: use tanh, ReLU should be better than sigmoid
- For output layer ($0 \leq \hat{y} \leq 1$), we can use sigdmoid

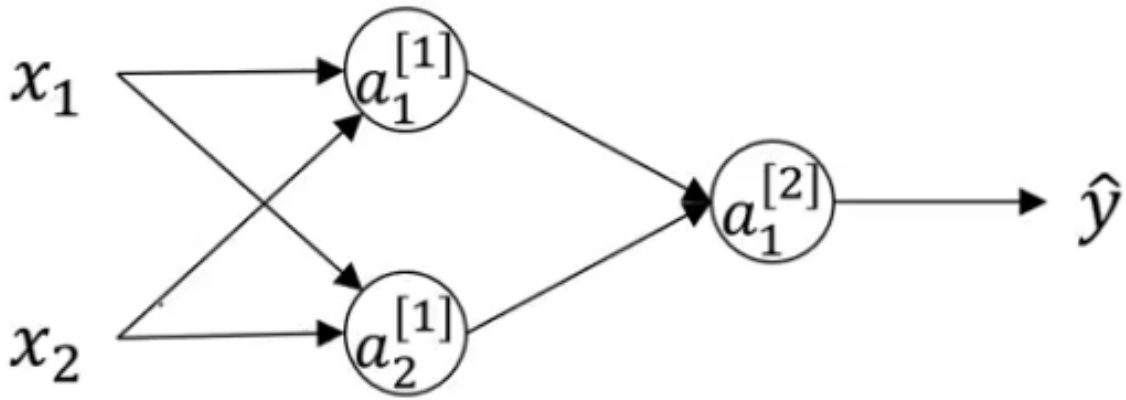
Parameters random initialization

If $W = [0]$ then the computing of neural network is exactly the same function at every layer?



Parameters random initialization

If $W = [0]$ then the computing of neural network is exactly the same function at every layer?



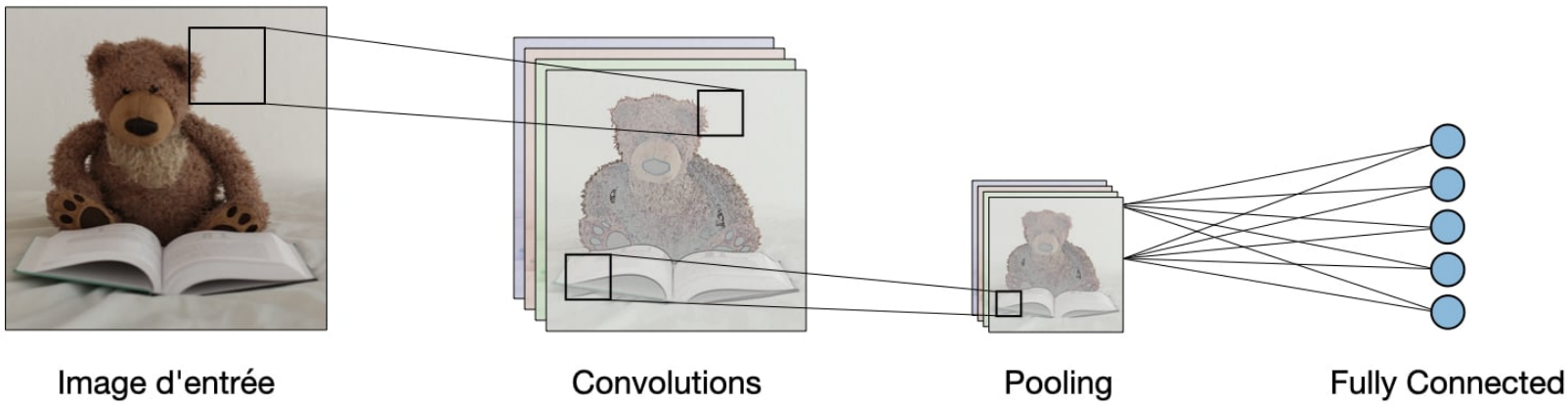
Solution: Randomly initialization the parameters

- $W = \text{np.random.randn}((2,2)) * 0.01$
- $b = \text{np.zero}((2,1))$

Convolutional Neural Network

Introduction

- In CNN we identify :
  - Input data that has to be transform.
  - Convolutional layers
  - Pooling layer(s)
  - Fully connected layer.



Convolutional Neural Network

Goal

- Extract features of the input volume.
- Need to set the size of each filter on the layers. Could be different for each layer.

1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

Input

1	0	1
0	1	0
1	0	1

Filter / Kernel

Convolutional Neural Network

Goal

- Extract features of the input volume.
- Need to set the size of each filter on the layers. Could be different for each layer.

1x1	1x0	1x1	0	0
0x0	1x1	1x0	1	0
0x1	0x0	1x1	1	1
0	0	1	1	0
0	1	1	0	0

Input x Filter

4		

Feature Map

Convolutional Neural Network

Goal

- Extract features of the input volume.
- Need to set the size of each filter on the layers. Could be different for each layer.

1	1x1	1x0	0x1	0
0	1x0	1x1	1x0	0
0	0x1	1x0	1x1	1
0	0	1	1	0
0	1	1	0	0

Input x Filter

4	3	

Feature Map

Convolutional Neural Network

Goal

- Extract features of the input volume.
- Need to set the size of each filter on the layers. Could be different for each layer.

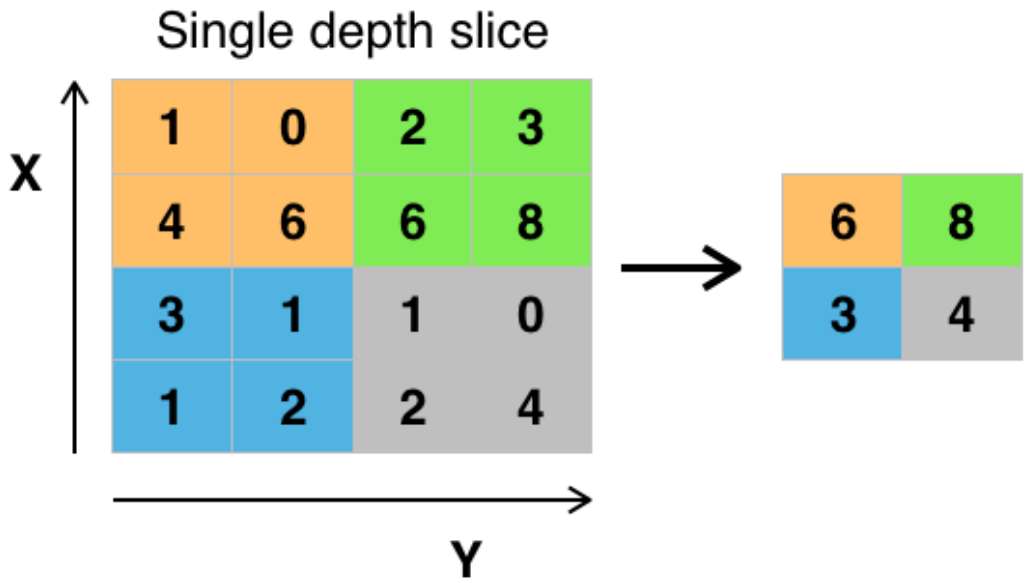
1	1	1	0	0
0	1	1	1	0
0	0	1x1	1x0	1x1
0	0	1x0	1x1	0x0
0	1	1x1	0x0	0x1

4	3	4
2	4	3
2	3	4

Convolutional Neural Network

Pooling Layer

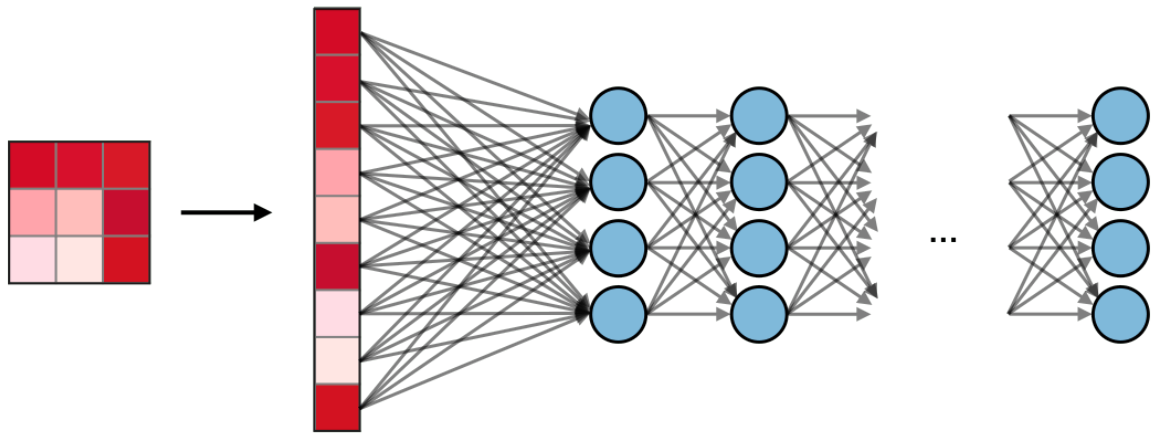
- Pooling layer reduces the spatial dimensions of the input.
- Allows to control **overfitting**.
- Several functions are available: max pooling, average pooling, L2-norm ....



Convolutional Neural Network

Fully Connected Layer

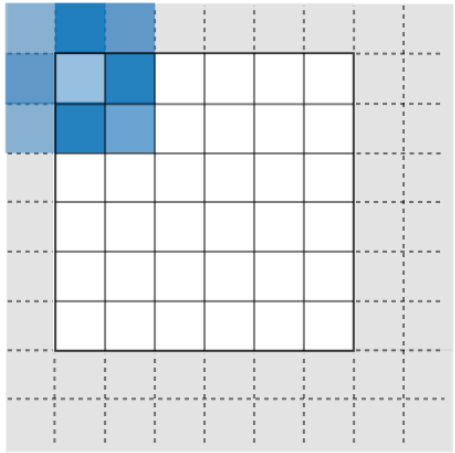
- Use as input a vector where each data is connected to a neurone.
- Main goal is to achieve the task - classification, scores...



Convolutional Neural Network

Parameters

- Stride : pixel number of the sliding window for convolution or pooling.
- Zero-padding : adding value to adjust image/matrix size.



Convolutional Neural Network

Parameters

- Batch size : define the number of samples to work through before updating the internal model parameters.
- Learning rate : control how much to change the model in response to the estimated error each time the model weights are updated.
- Epochs number : define the number times that the learning algorithm will work through the entire training datase.

Convolutional Neural Network

Evaluation - Metric

- Loss value : evaluate how the madel is training - produced from the loss function that estimates the loss of the model so that the weights can be updated to reduce the loss on the next evaluation.
- Accuracy : a metric to measure the algorithm performance at the end.
- Mean Average Precision : compute the average precision value for recall value over 0 to 1. Seee Precision/Recall.
- F1 Score : combine precision and recall relative to a specific positive class. It is a weighted average of the precision and recall, where an F1 score reaches its best value at 1 and worst at 0

Activation Functions -

Goals

- Modified in a non-linear way the representation of data.
- As multi-layers are activated, several modifications can occur.
- Don't confuse between activation function and loss function.

Way to work

- Each neurone of one layer will apply the activation function of this layer to the data, as each neurone has a different weight, this will have a different effect.

Activation Functions

ReLU Layer[a]

[a] Relu Module http://cs231n.github.io/convolutional-networks/

- Layer to correct data - take into account the non-linearity of the process of classification.
- One example of Relu fonction $f(x) = max(0, x)$
- By consequences all values less than 0 are set as 0.

PyTorch coding

- Just define a layer : `relu1=nn.ReLU(inplace=False)`
- Add a module with this layer : `model.add_module(‘‘Relu1’’, relu1)`
- It is authorized to define and add module at the same time.
- Never use the ReLU function in the last layer. It is only for the intermediate layers.

Activation Functions

SoftMax

- Transform a vector of reals in a vector of probability.
- Use a score vector as inputs.
- Often used in the final layer of classifier model.

PyTorch coding

- calling Softmax :

```
y=torch.softmax(x,dim=0)
// dim=-1 if your input is a vector.
```

Using a Deep Network

Data organisation

- Training and Validation data set are rebuild at each epoch.
- Don't miss to shuffle at each epoch.
- Usual parameters are 80% for training and 20% for validation.
- Test data has to be kept apart and never seen before the test step.

Re-using a model

- Saving the model to apply to test data or to fine-tune another CNN.
- Transfert learning or fine-tuning: re-use a training model to feed another one for another task - and another data set.

CNN Architecture

AlexNet

- Creating in 2010 for the ILSVRC challenge, won in 2012 with an error-rate of 15.3%.
- Original paper : ImageNet Classification with Deep Convolutional Neural Networks by Alex Krizhevsky et al.
- Imagenet dataset : 22 000 classes and 15 millions of images.
- 8 Layers - including Dropout layer. producing 60 millions of parameters.
- Replace `tanh` function by Rectified Linear Units (ReLU), fastest computing.
- Able to use multiple GPU.
- Special pooling with overlap.
- Data augmentation : 2048 times.

AlexNet Architecture

AlexNet

- Conv. layer 1: input 224X224X3 image tensor, 96(11X11) kernels, stride 4 and padding 2. Produced a 55X55X96 output tensor to pass to ReLu activation function - This layer contains 34,944 parameters to train.
- Max-Pooling layer 2: 55X55X96 tensor as input. Perform a zero-padding with a kernel 3X3 and a stride 2. Produce a 27X27X96 output tensor.
- Conv. Layer 3: convolution layer input 27X27X96, apply a convolutional operation 256 (5X5) kernels with a stride 1 and a padding 2. Produce 27X27X256 output tensor, passed to ReLu function. Contain 614,656 parameters to train.
- Max-Pooling layer 4: 27X27X256 input tensor, zero padded operation and 3X3 kernel with a stride 2. Produce a 13X13X256 output tensor to pass to ReLU function.

AlexNet Architecture

AlexNet

- Conv. Layer 5: receive a 13X13X256 input tensor. Conv operation uses 384(3X3) kernels with stride and padding 1. Produce 13X13X384 output tensor to feed the ReLU function. Contain 885,120 parameters.
- Conv. Layer 6: perform the same operation than layer 5 with same kernel. Contain 1.327.488 parameters.
- Conv. Layer 7: 13X13X384 input tensor, convolutional operation with a 256(3X3) kernels with stride and padding 1. Produce a 13X13X256 output tensor to feed the ReLU function. Contain 884,992 parameters.

AlexNet Architecture

AlexNet

- Max-Pooling layer 8: receive a 13X13X256 input tensor. Perform a zero-padding, apply a 3X3 window with a stride 2. Produce a 6X6X256 output tensor to pass to the ReLU function.
- Fully-Connected layer 9: accept the 6X6X256 input tensor. Perform a weighted sum operation including a bias term. Produce a 456X1 output tensor to pass to the ReLU function. Contain 37,752,832 parameters.
- Fully-connected layer 10: accept the 4096X1 inpmut tensor, perform the same operation than layer 9 and produce the same size output tensor.
- Fully-connected layer 11: accept the input tensor from the previous layer, perform the same operation and produce a 1000X1 output tensor, i.e. number of waited classes, to pass to the softmax activation function.

AlexNet Architecture

AlexNet

- For ImageNet experiment, the other parameters values are:
  - Batch size 128
  - Momentum 0.9
  - Learning rate 0.0005
  - Dropout has been added in the first two fully-connected layer.
- A graphic card with 2 GPU has been used.

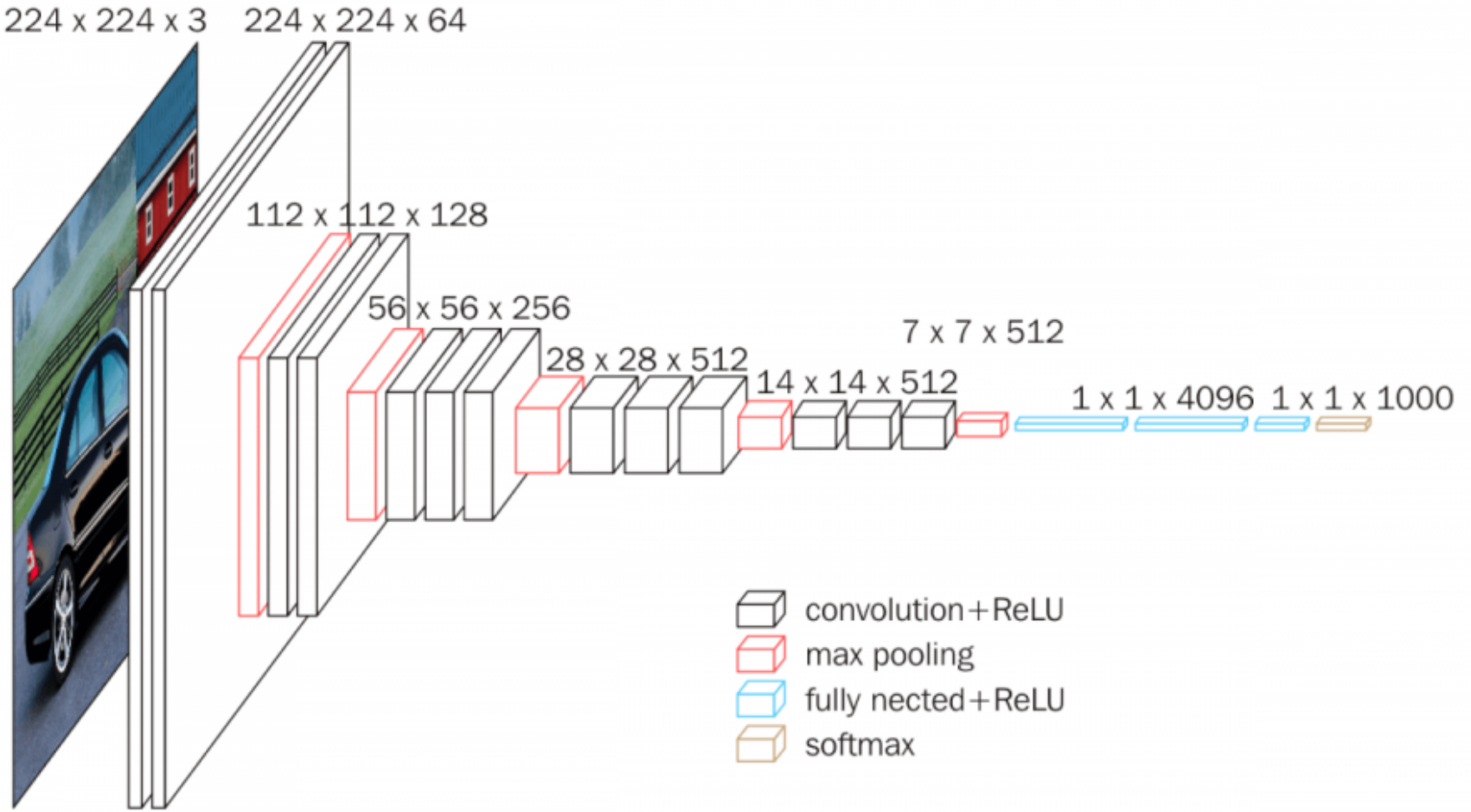
CNN Architecture

VGG Family

- Creating in 2014 for the ILSVRC challenge.
- VGG16: 16 convolutional layers. 138 millions of parameters.
- 13 convolutional layers, Reduce the size filter to 3X3.
- 3 fully connected layers.
- Original paper : Very Deep Convolutional Networks for Large Scale Image Recognition by Karen Simonyan et al.

CNN Architecture

Full description at :
https://neurohive.io/en/popular-networks/vgg16/



ResNet Architecture

Residual Block

- Adding the input of the previous layer to the output of a subsequent layer.
- Give a solution to the vanishing/exploded gradient.
- Skipping a connection does not add additional computational load.

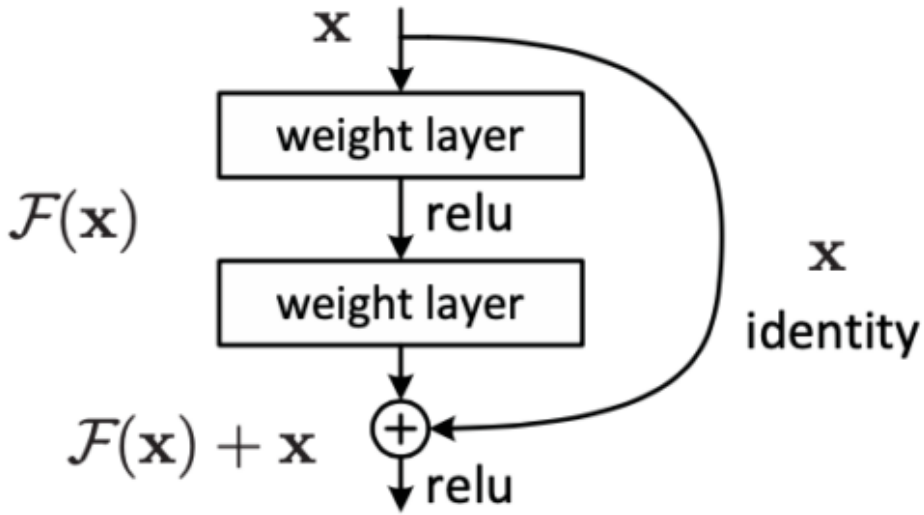


Figure 2. Residual learning: a building block.

Transfer Learning

Re-Use learning from large dataset

- Deep Learning needs large (huge) dataset.
- Data Augmentation could be a solution.
- Pre-training with a large dataset - ImageNet.
- Re-use the weights beside to train from scratch.
- Fine tune and retrain the network.

GAN to Generate new data

Creating data

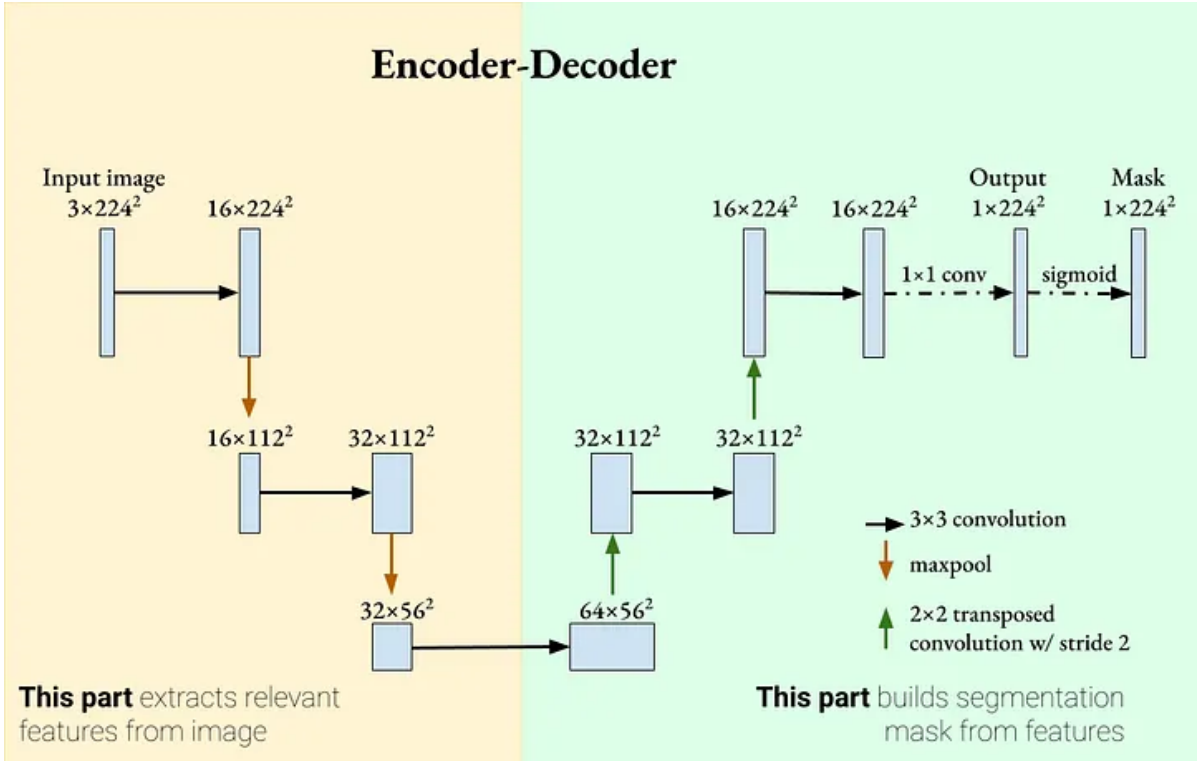
- A way to obtain new data from an initial one.
- Very popular for some applications as face recognition.
- Contains two submodels - Generator to create new examples, Discriminator to classify/discriminate generated examples from real ones.

Encoder - Decoder

Sequence to Sequence model

- Encoder takes in an input sequence and produces a fixed-length vector representation of it, often referred to as a hidden or "latent representation"
- Decoder takes the latent representation and generates an output sequence based on it.
- Used in natural language processing, computer vision ...
- Could include CNN layers or LSTM ones.
- U-Net is the most famous.

Encoder - Decoder - U-Net



Transformer Network

A new network without convolution

- Use the mechanism attention, i.e. differentially weighing the significance of each part of the input data.
- Built using encoder/decoder architecture.
- Can be understood in terms of its 3 components :
  - An Encoder to encode an input sequence into state representation vectors.
  - An Attention mechanism to enable the Transformer model to focus on the right aspects of the sequential input stream.
  - An Decoder to decode the state representation vector to generate the target output sequence
- The most popular to work with language ... translation, generation (ChatGPT) or video analysis.