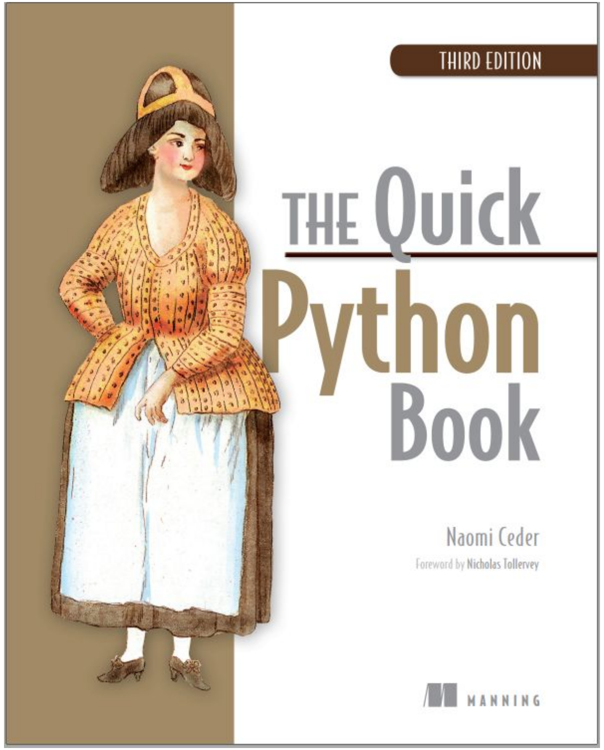
Introduction to PyTorch

An open source machine learning framework

25 September 2022

Department of Mathematics, Chiang Mai University

Why Python?



- Python is a modern programming language developed by Guido van Rossum in the 1990s

- *What Python does well*
  - *Python is easy to use*
  - *Python is expressive*
  - *Python is readable*
  - *Python is complete—"batteries included"*
  - *Python is cross-platform*
  - *Python is free*
- *What Python doesn't do as well*
  - *Python isn't the fastest language*
  - *Python doesn't have the most libraries*
  - *Python doesn't check variable types at compile time*
  - *Python doesn't have much mobile support*
  - *Python doesn't use multiple processors well*

Notepad++ : https://notepad-plus-plus.org/downloads/

Visual Studio Code : https://code.visualstudio.com/

PC

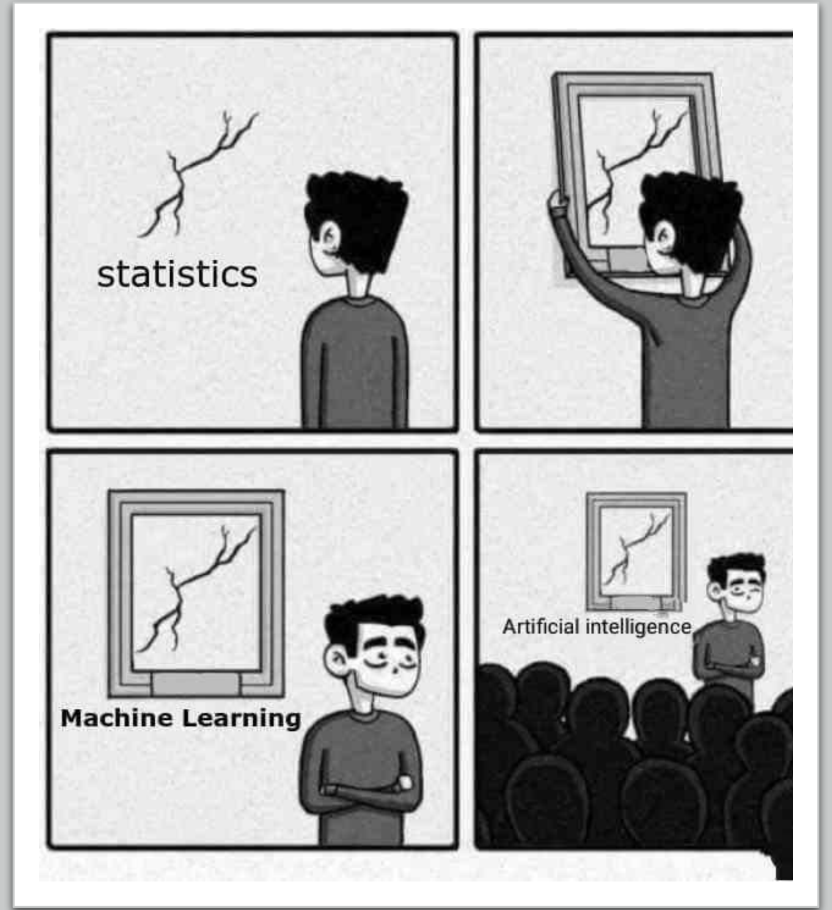
ANACONDA

co

SPYDER

jupyter

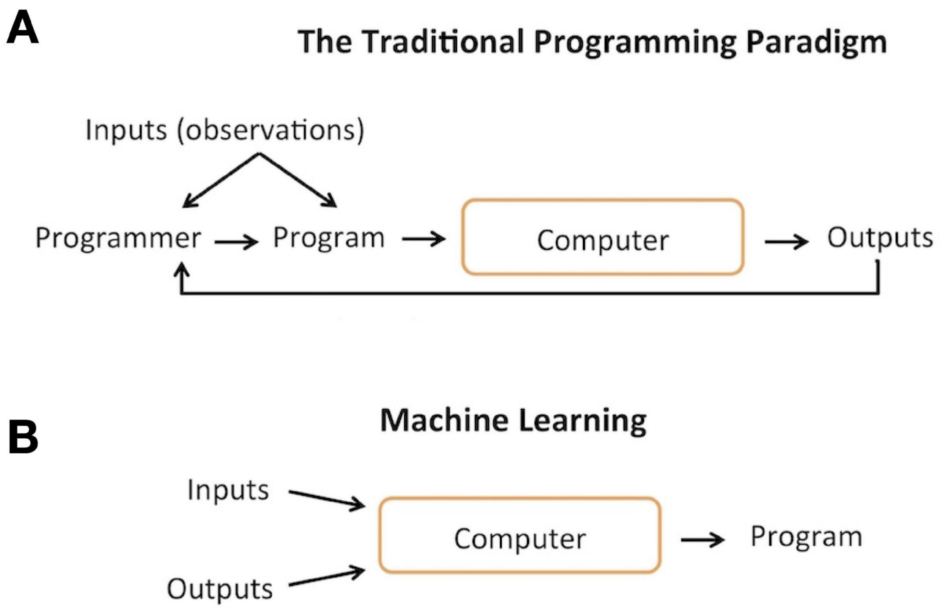

MACHINE LEARNING
MACHINE LEARNING
EVERYWHERE!
makeameme.org

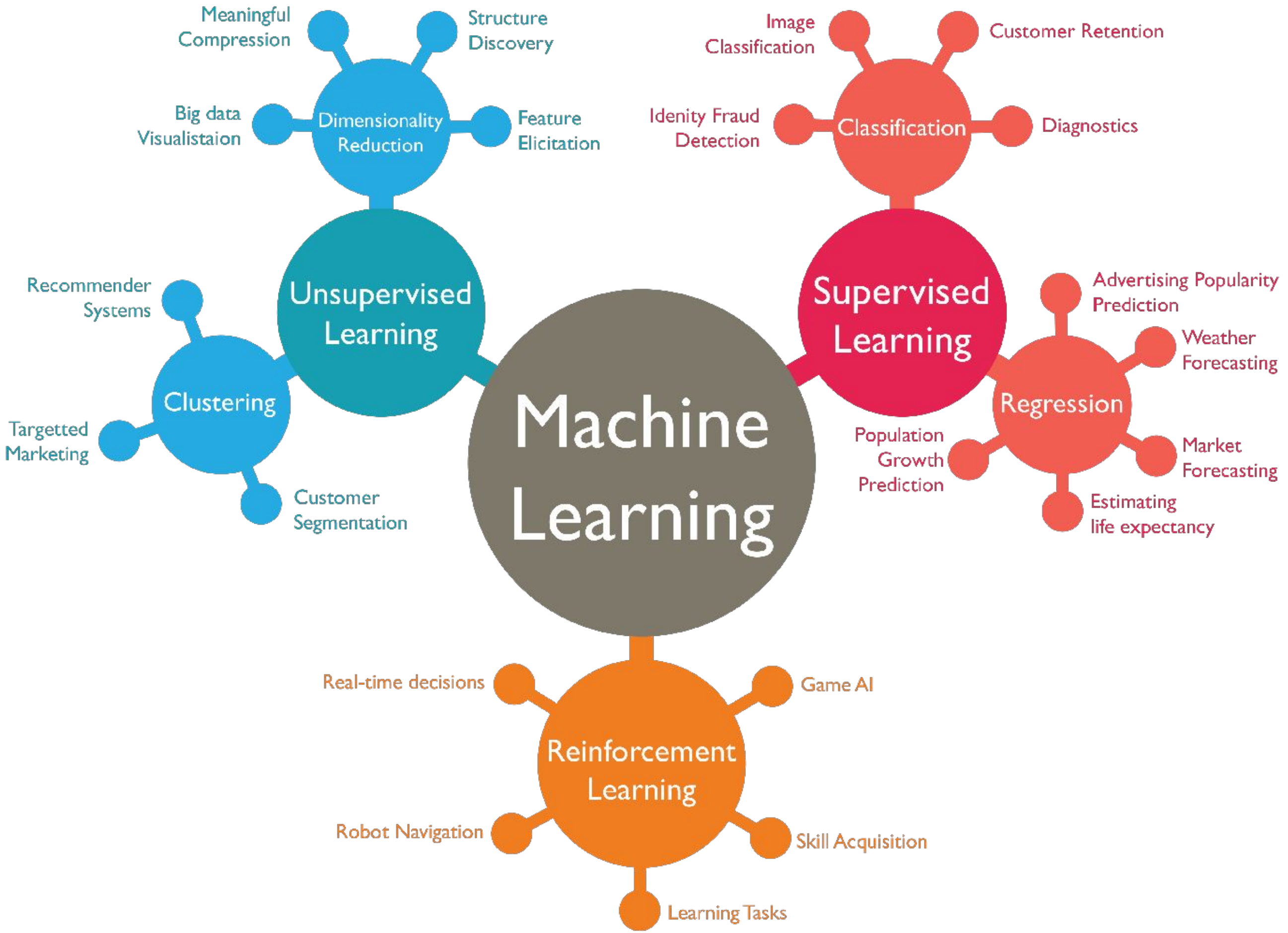


What is Machine Learning?

- Machine learning (ML) is the scientific study of algorithms and statistical models that computer systems use to perform a specific task without using explicit instructions, relying on patterns and inference instead.
- https://en.wikipedia.org/wiki/Machine_learning

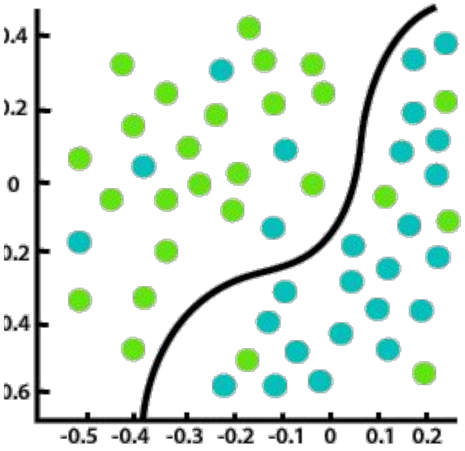
Comparison between traditional programming (A) and machine learning (B)



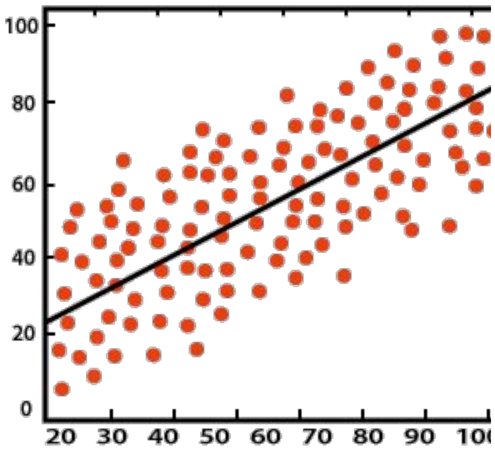


Machine Learning
Unsupervised Learning
Dimensionality Reduction
Meaningful Compression
Structure Discovery
Big data Visualistaion
Feature Elicitation
Clustering
Recommender Systems
Targetted Marketing
Customer Segmentation
Supervised Learning
Classification
Image Classification
Customer Retention
Idenity Fraud Detection
Diagnostics
Regression
Advertising Popularity Prediction
Weather Forecasting
Population Growth Prediction
Market Forecasting
Estimating life expectancy
Reinforcement Learning
Real-time decisions
Game AI
Robot Navigation
Skill Acquisition
Learning Tasks

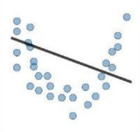
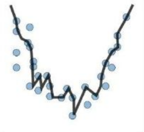
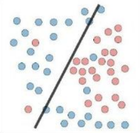
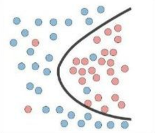
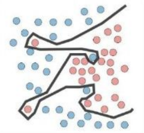
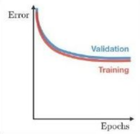
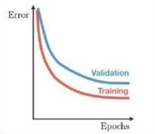
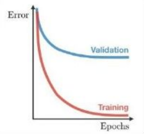
Regression vs Classification



Classification



Regression

	Underfitting	Just right	Overfitting
Symptoms	- High training error - Training error close to test error - High bias	- Training error slightly lower than test error	- Low training error - Training error much lower than test error - High variance
Regression			
Classification			
Deep learning			
Remedies	- Complexify model - Add more features - Train longer		- Regularize - Get more data

Introduction to Pytorch

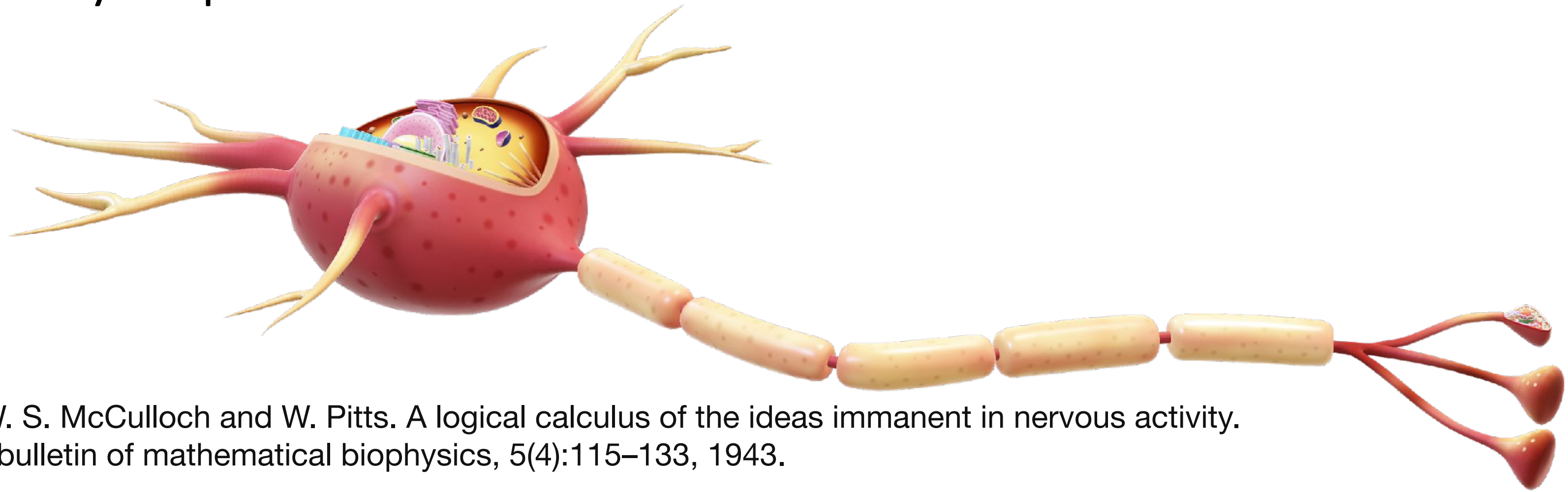
Neural Networks in brief

PyTorch package : Deep Learning Tools

Pytorch Linear Regression

1943 – The first mathematical model of a neural network

ANNs began with Warren McCulloch and Walter Pitts [1] who drew an analogy between biological neurons and simple logic gates with binary outputs.

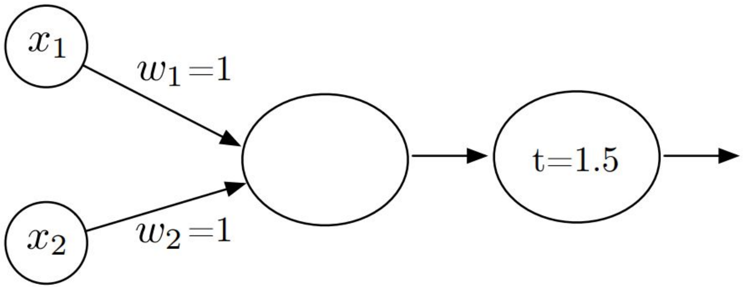


[1] W. S. McCulloch and W. Pitts. A logical calculus of the ideas immanent in nervous activity. The bulletin of mathematical biophysics, 5(4):115–133, 1943.

1943 – The first mathematical model of a neural network

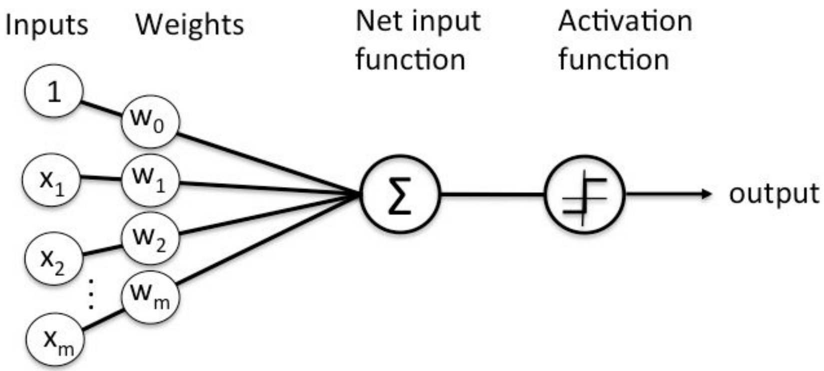
ANNs began with Warren McCulloch and Walter Pitts [1] who drew an analogy between biological neurons and simple logic gates with binary outputs.

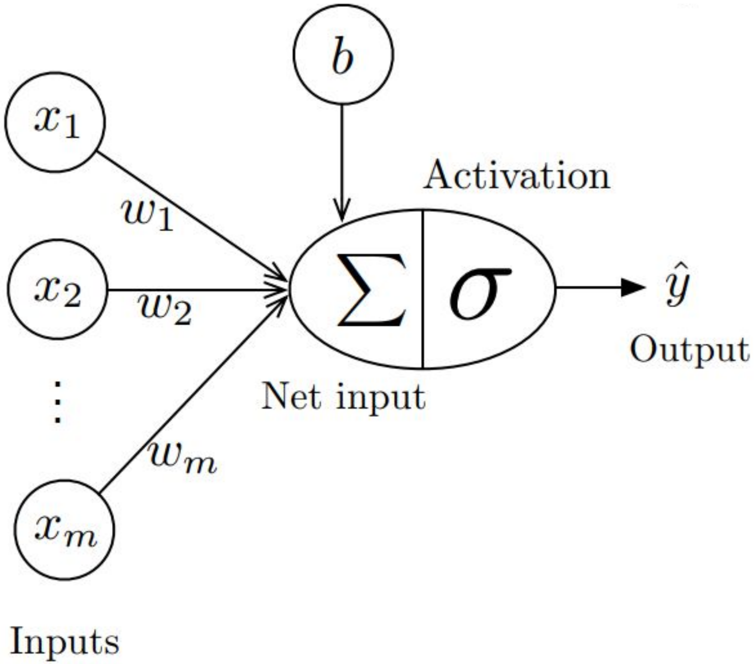
x_1	x_2	Out
0	0	0
0	1	0
1	0	0
1	1	1



[1] W. S. McCulloch and W. Pitts. A logical calculus of the ideas immanent in nervous activity. The bulletin of mathematical biophysics, 5(4):115–133, 1943.

Neural Networks Mathematical Model



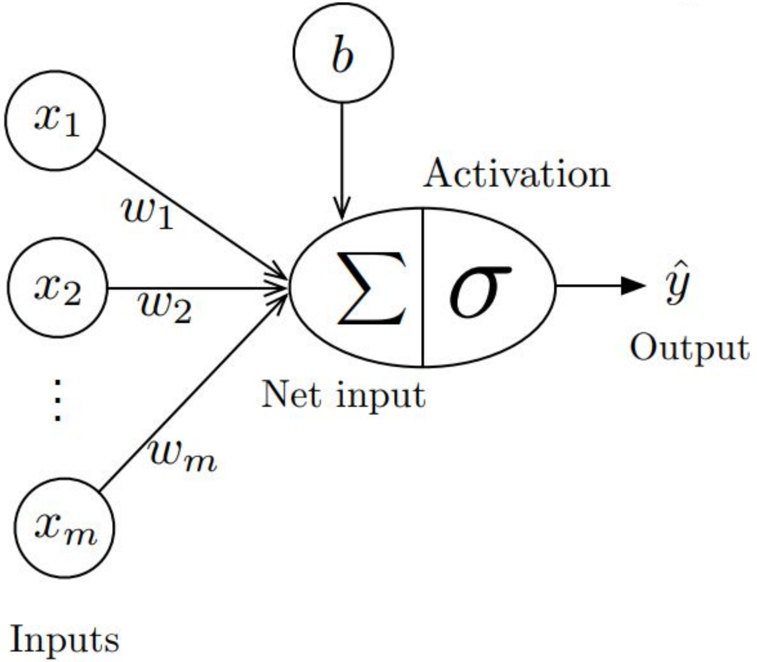


Linear Algebra inside NNs model

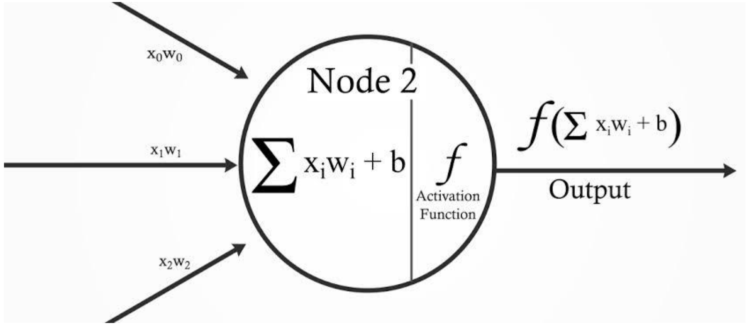
- Output $\hat{y} \coloneqq \sigma(z)$ where $z = x^T\boldsymbol{w} + b, \boldsymbol{w} \in \mathbb{R}^{m\times 1}$

- For 1 example : $x \in \mathbb{R}^{m\times 1}$,
  - $z = x^T\boldsymbol{w} + b$
  - $\hat{y} = \sigma(z)$

- For n examples : $X \in \mathbb{R}^{n\times m}$
  - $X\boldsymbol{w} + b = \begin{bmatrix} (x^{[1]})^T\boldsymbol{w} + b \\ \vdots \\ (x^{[n]})^T\boldsymbol{w} + b \end{bmatrix} = \begin{bmatrix} z_1 \\ \vdots \\ z_n \end{bmatrix} = \boldsymbol{z} \in \mathbb{R}^{n\times 1}$
  - $\hat{y} = \begin{bmatrix} \sigma(z_1) \\ \vdots \\ \sigma(z_n) \end{bmatrix} = \sigma(\boldsymbol{z})$



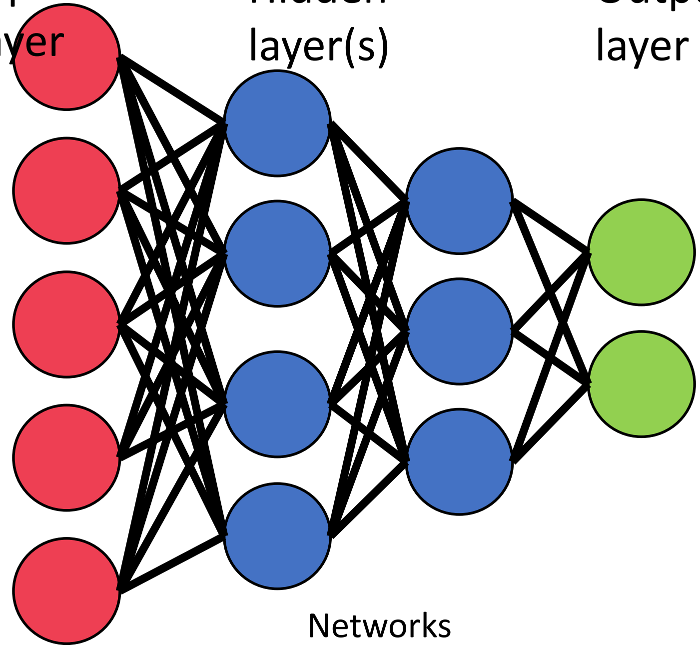
Artificial Neural Networks



Input layer

Hidden layer(s)

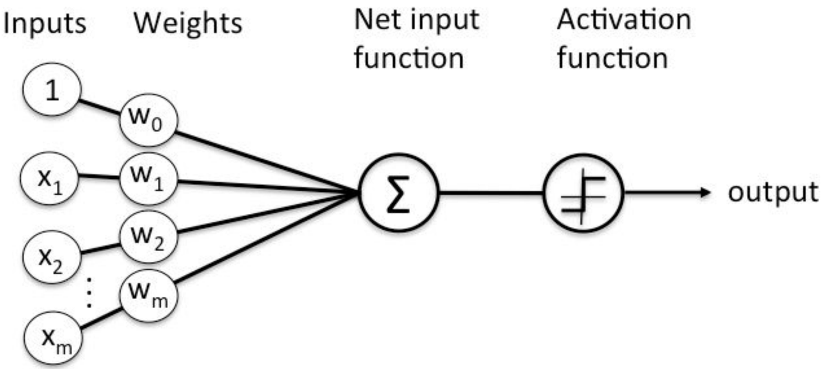
Output layer

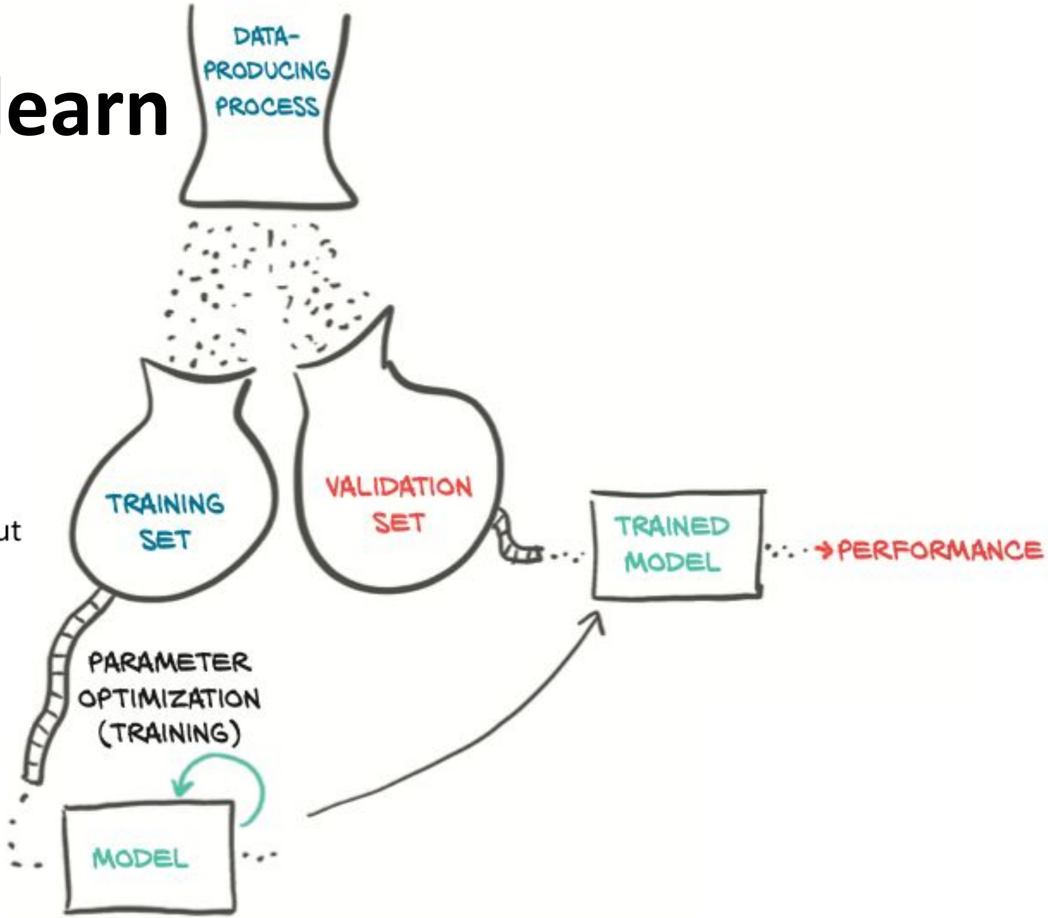


Neural

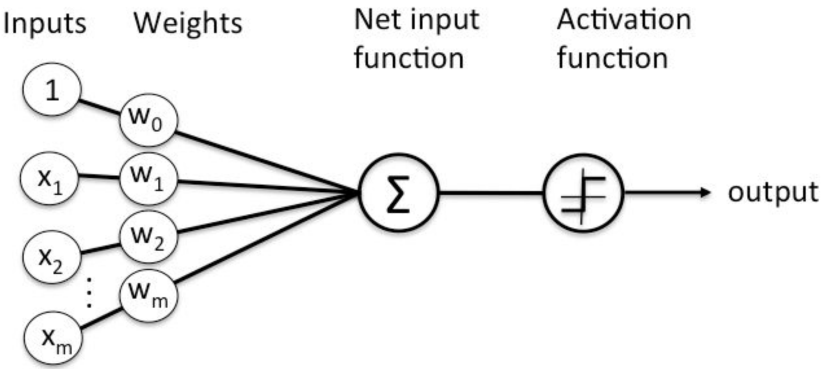
Networks

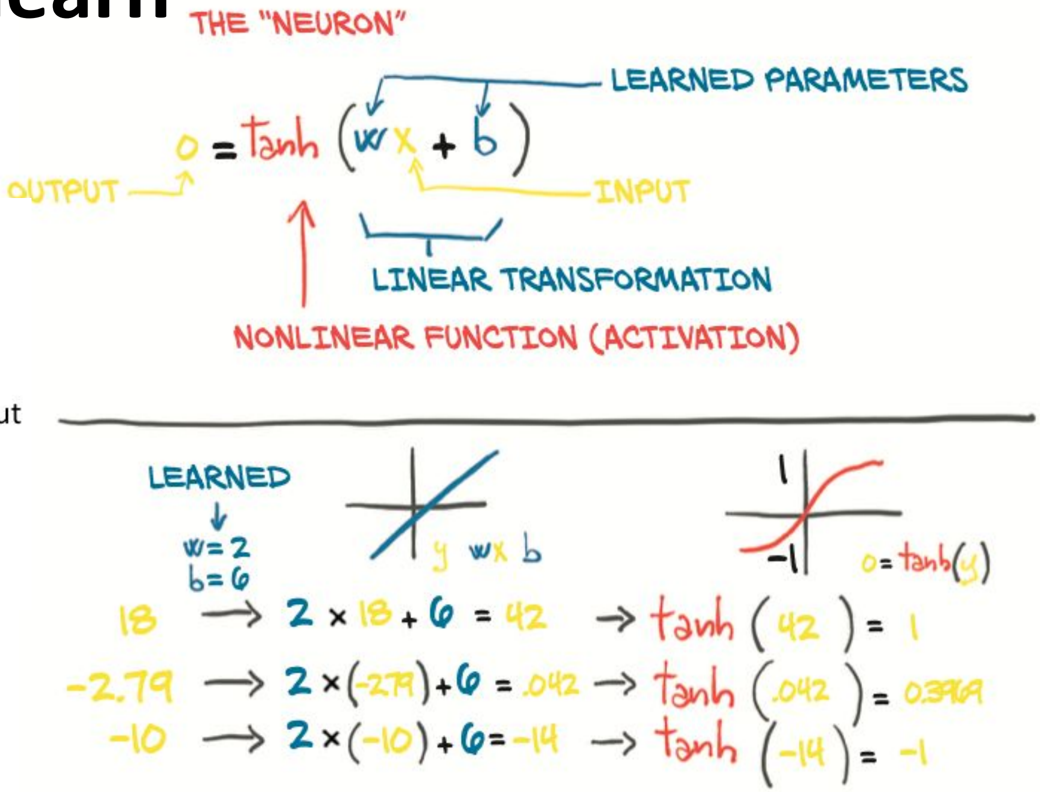
How the networks learn

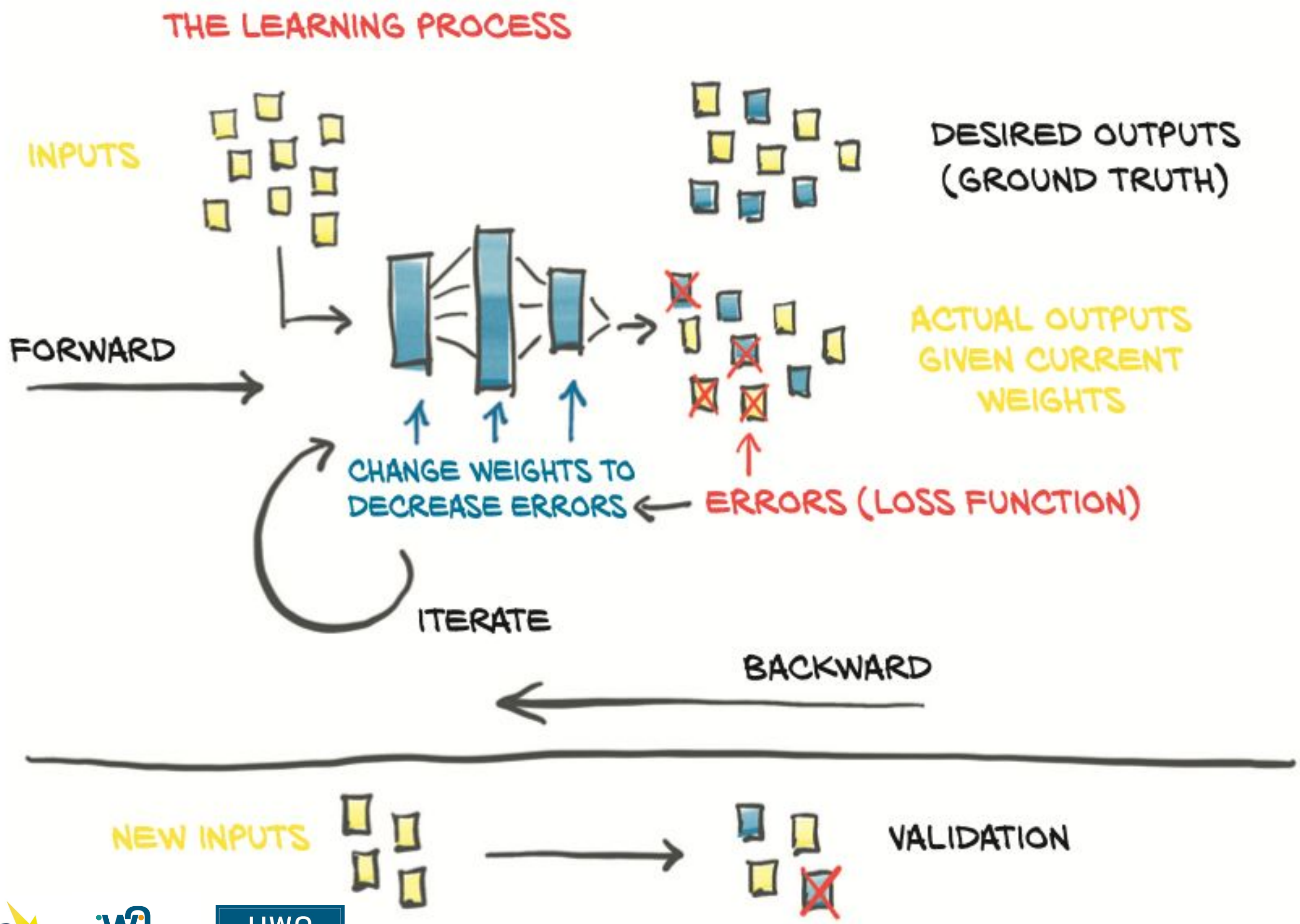


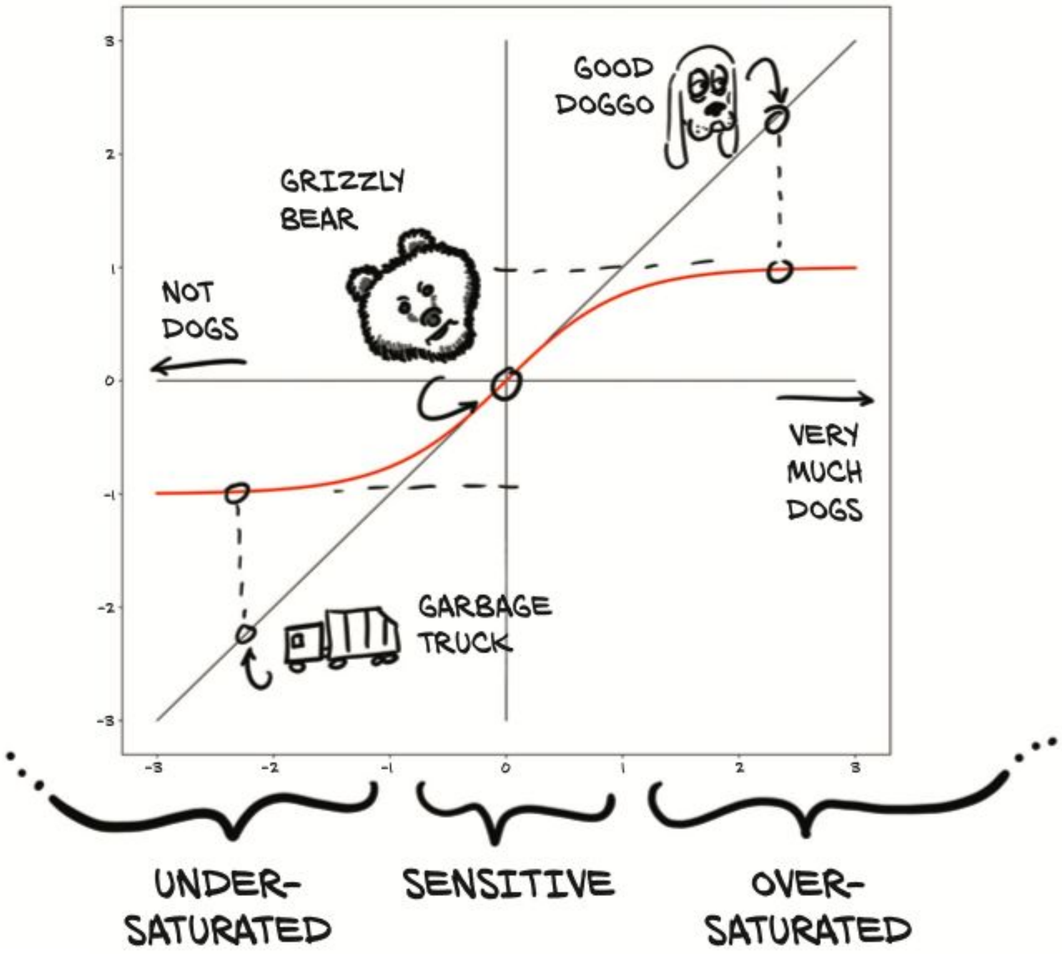


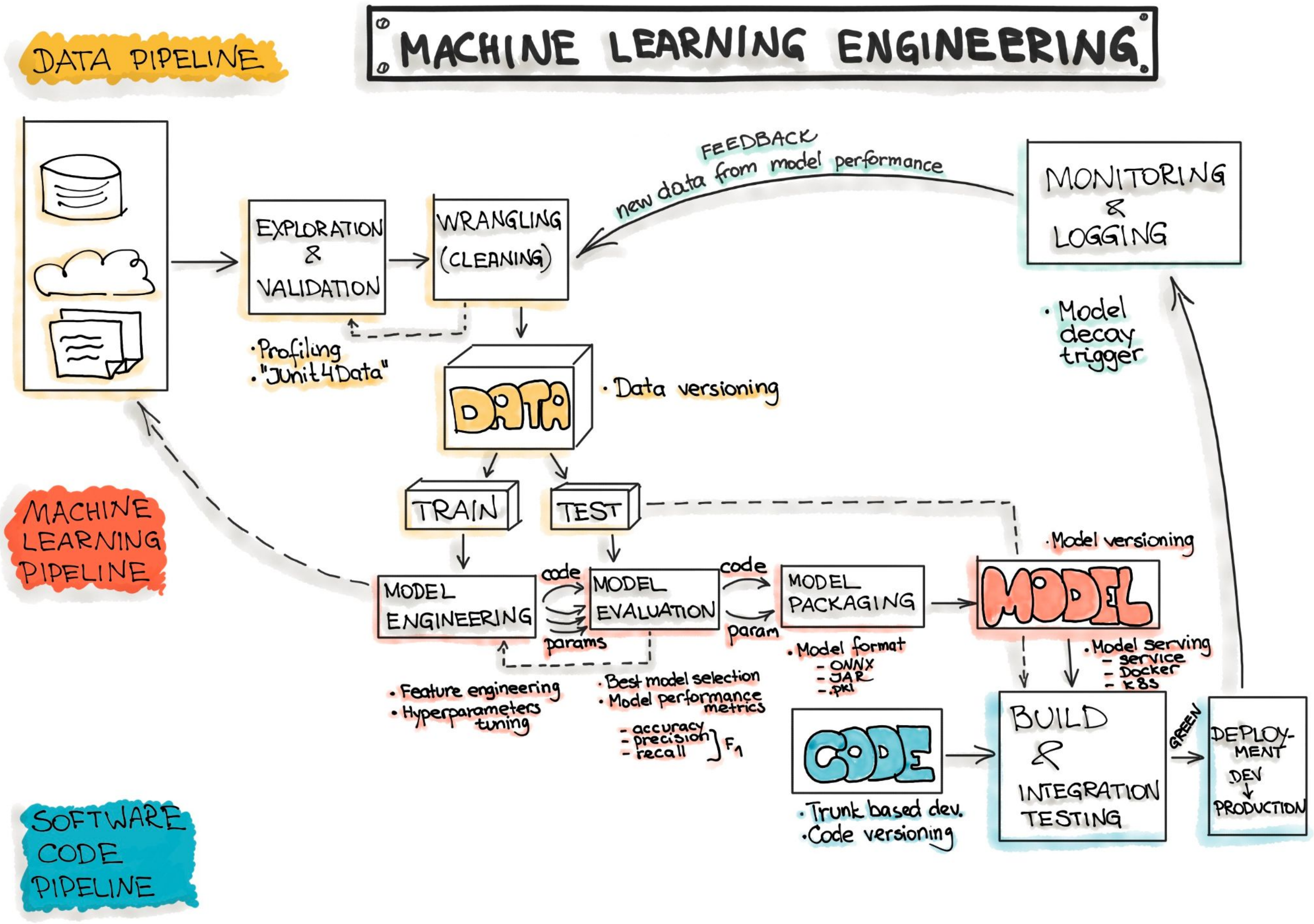
How the networks learn





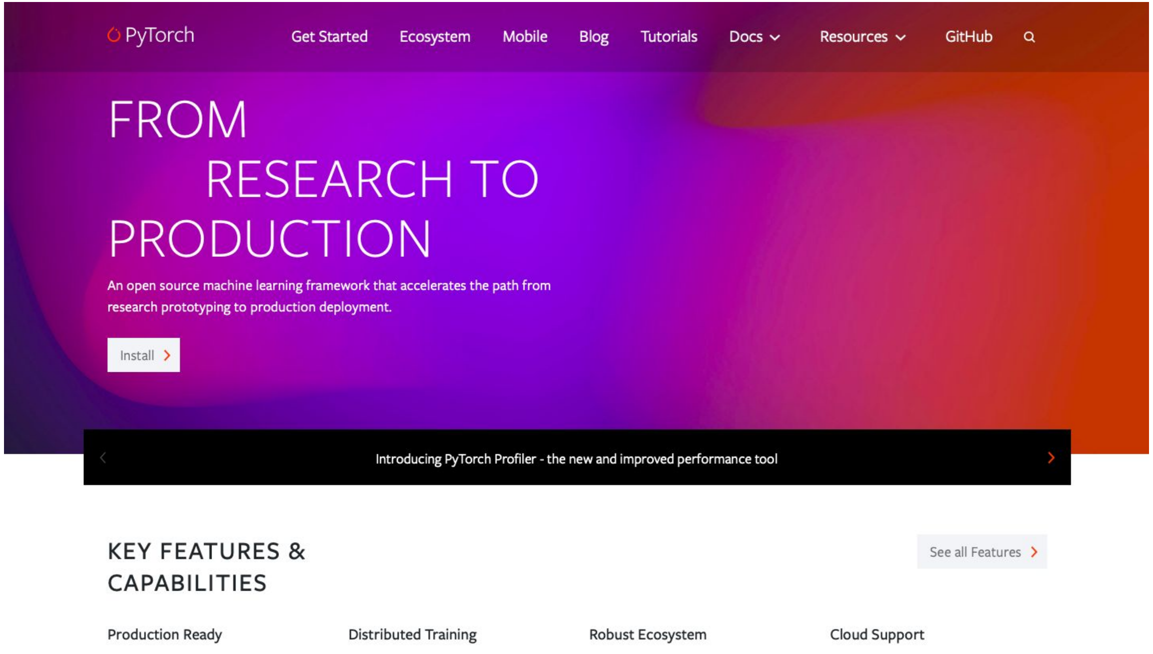

THE LEARNING PROCESS
INPUTS
DESIRED OUTPUTS (GROUND TRUTH)
FORWARD
ACTUAL OUTPUTS GIVEN CURRENT WEIGHTS
CHANGE WEIGHTS TO DECREASE ERRORS
ERRORS (LOSS FUNCTION)
ITERATE
BACKWARD
NEW INPUTS
VALIDATION


GOOD DOGGO
GRIZZLY BEAR
NOT DOGS
VERY MUCH DOGS
GARBAGE TRUCK
UNDER-SATURATED
SENSITIVE
OVER-SATURATED


MACHINE LEARNING ENGINEERING
DATA PIPELINE
MACHINE LEARNING PIPELINE
SOFTWARE CODE PIPELINE
EXPLORATION & VALIDATION
WRANGLING (CLEANING)
·Profiling
·"Junit4Data"
FEEDBACK
new data from model performance
MONITORING & LOGGING
·Model decay trigger
DATA
·Data versioning
TRAIN
TEST
MODEL ENGINEERING
code
params
MODEL EVALUATION
code
param
MODEL PACKAGING
MODEL
·Model versioning
·Feature engineering
·Hyperparameters tuning
·Best model selection
·Model performance metrics
- accuracy
- precision
- recall
F1
·Model format
- ONNX
- JAR
- .pkl
·Model serving
- service
- Docker
- K8S
CODE
·Trunk based dev.
·Code versioning
BUILD & INTEGRATION TESTING
GREEN
DEPLOYMENT
DEV
PRODUCTION

Introduction to PyTorch

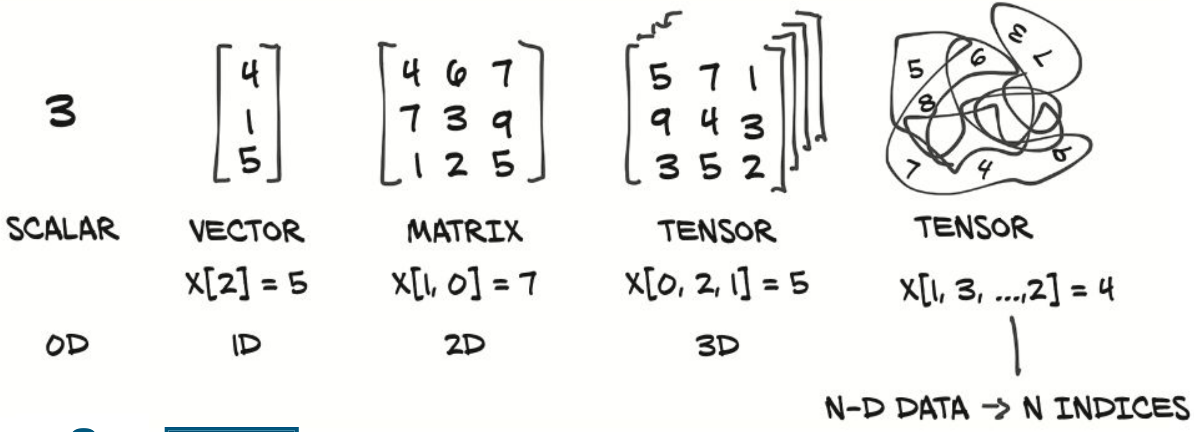
- torch.tensor
- torch.autograd
- torch.nn
- torch.optim



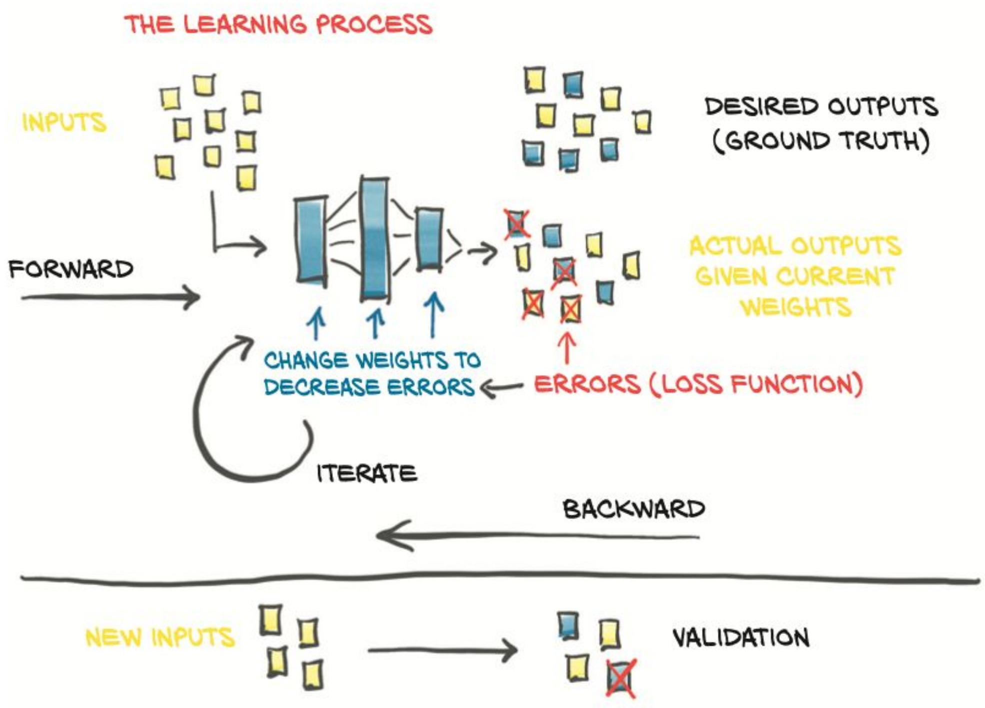
https://pytorch.org

torch.tensor

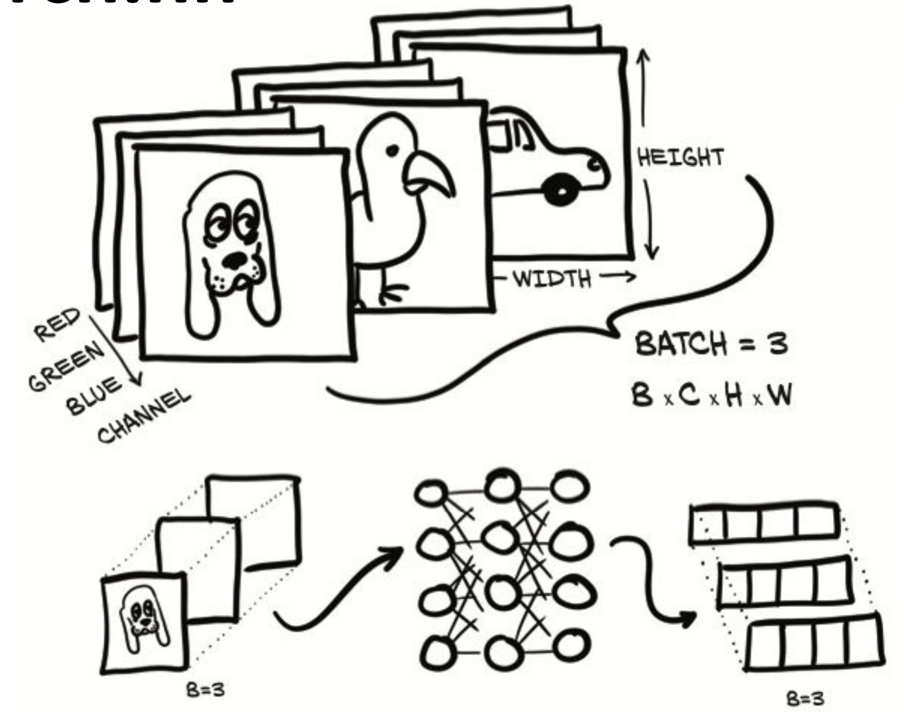
- A torch.tensor is a multi-dimensional matrix containing elements of a single data type.
- Tensors are similar to NumPy's ndattarys, with the addition being that Tensors can also be used on a GPU to accelerate computing.

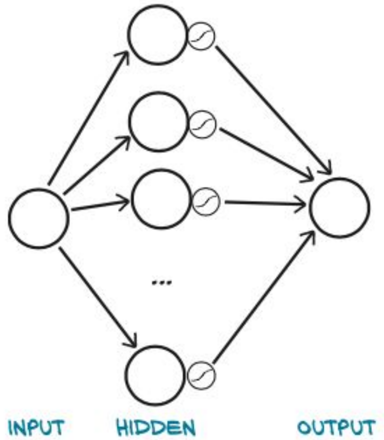


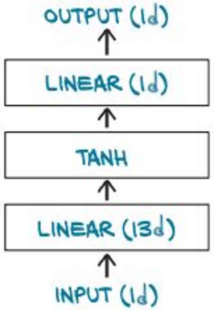
torch.autograd



torch.nn


HEIGHT
WIDTH
RED
GREEN
BLUE
CHANNEL
BATCH = 3
B x C x H x W
B=3
B=3

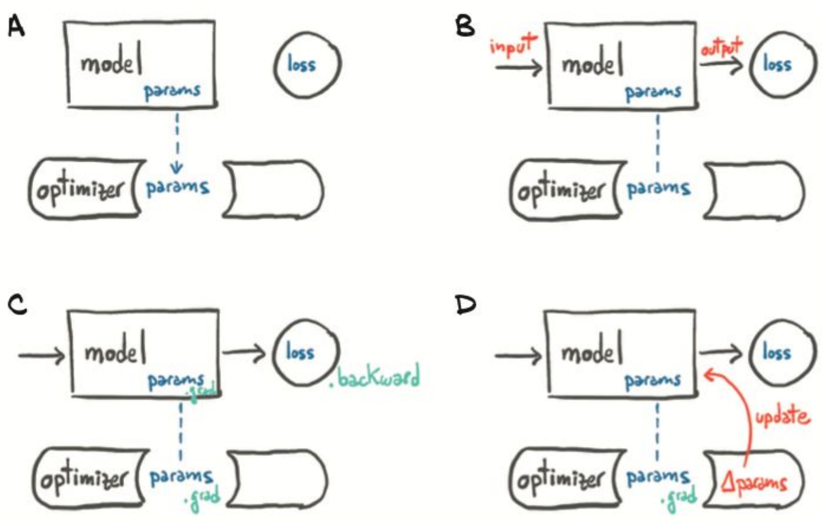

...
INPUT
HIDDEN
OUTPUT

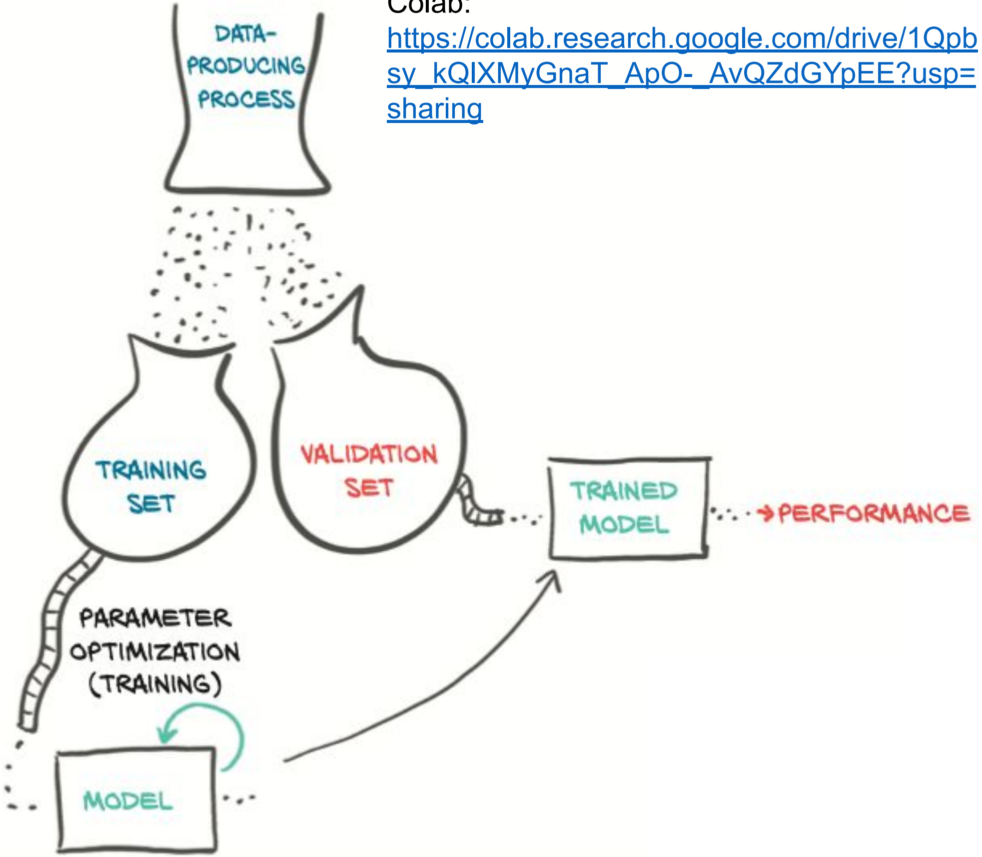

OUTPUT (1d)
LINEAR (1d)
TANH
LINEAR (13d)
INPUT (1d)

[Review] Gradient Descent

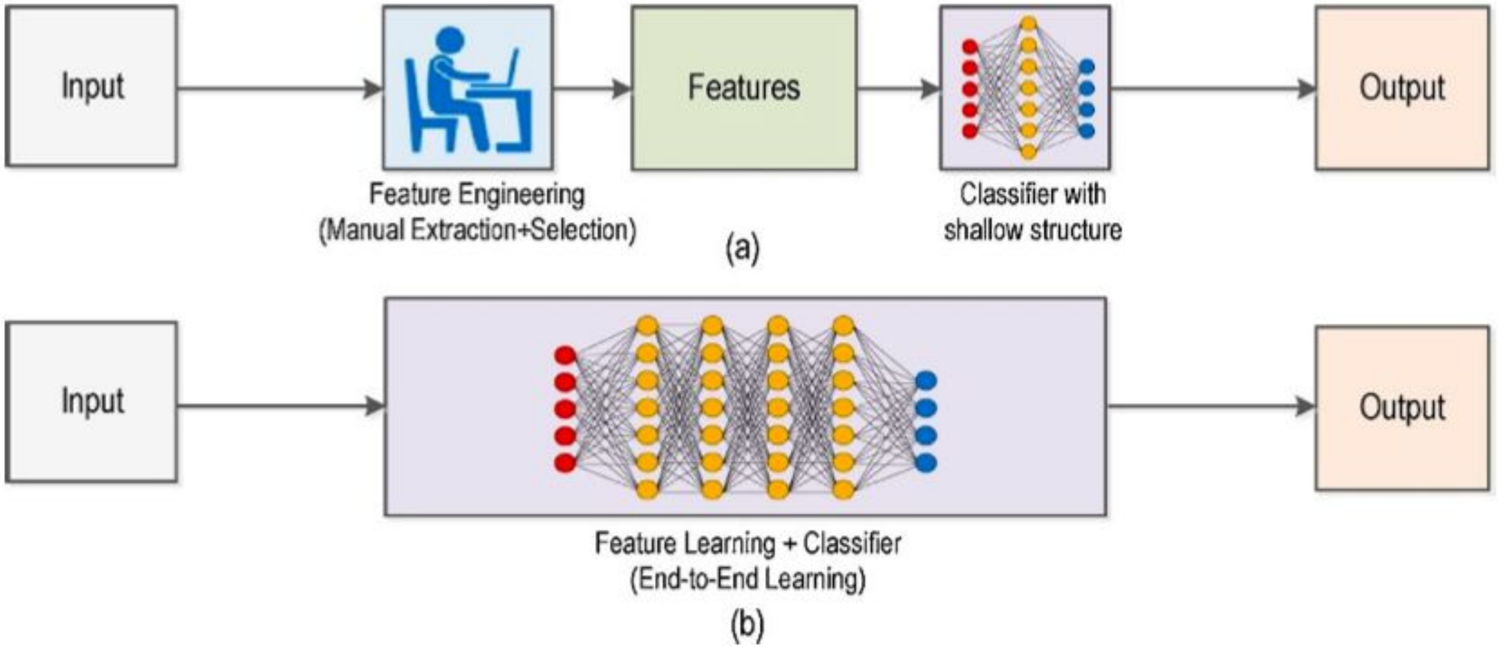
Colab: https://colab.research.google.com/drive/1Qpbsy_kQIXMyGnaT_ApO-_AvQZdGYpEE?usp=sharing

torch.optim





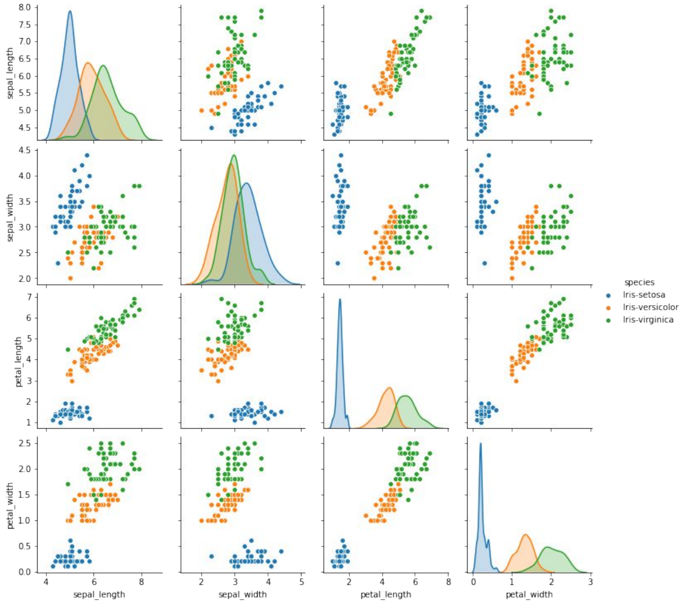
Traditional computer vision workflow vs Deep learning workflow



Paper source : https://arxiv.org/pdf/1910.13796.pdf

Iris dataset

Iris Versicolor **Iris Setosa** **Iris Virginica**

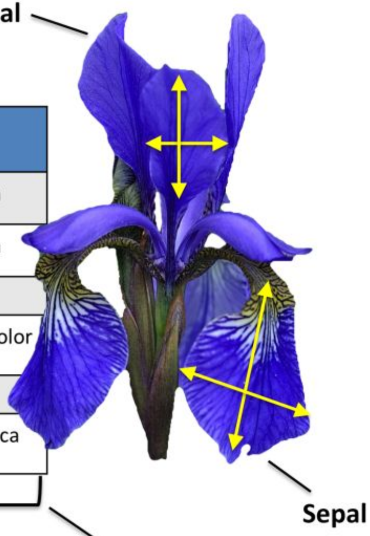


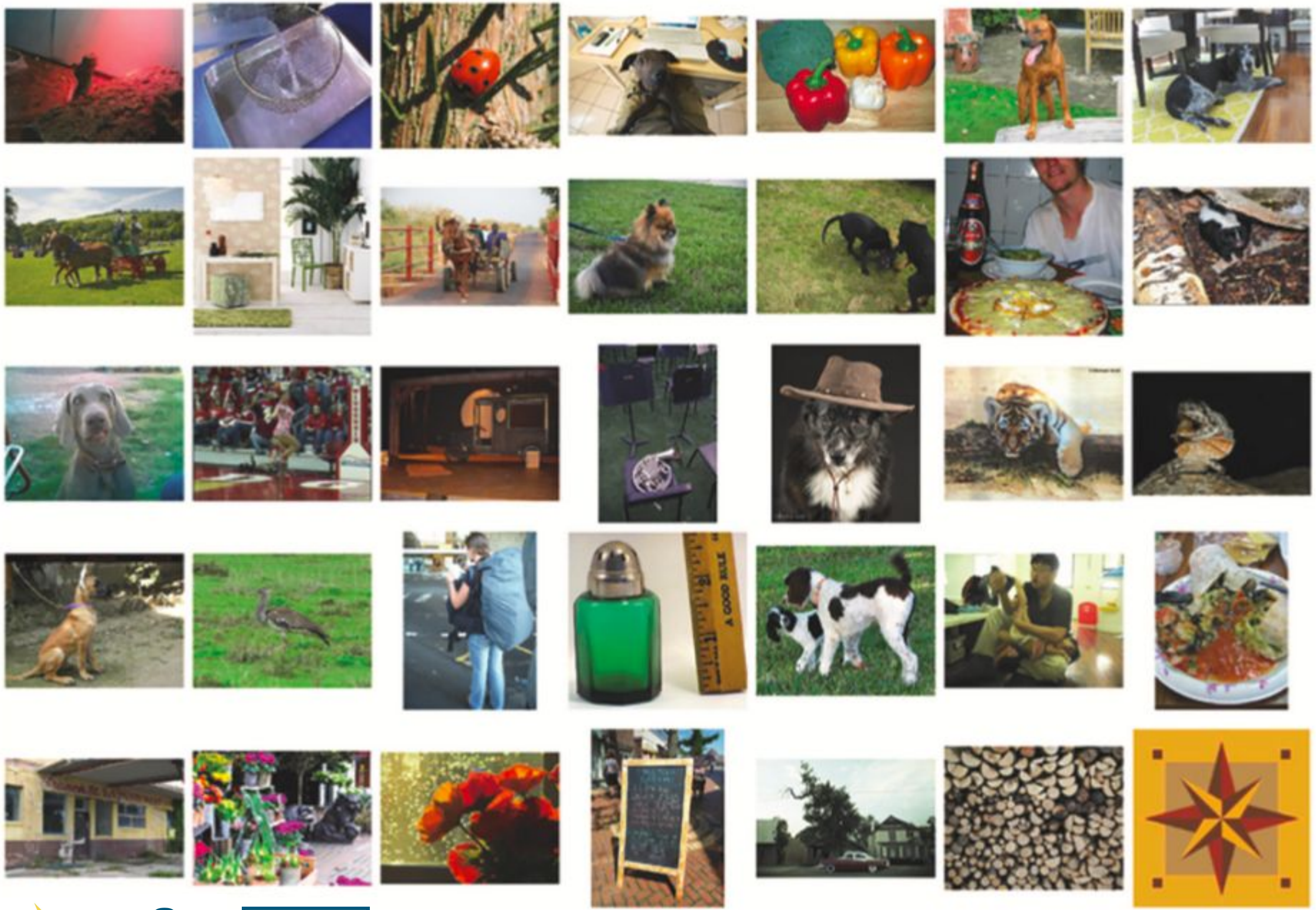
Samples
(instances, observations)

	Sepal length	Sepal width	Petal length	Petal width	Class label
1	5.1	3.5	1.4	0.2	Setosa
2	4.9	3.0	1.4	0.2	Setosa
...					
50	6.4	3.5	4.5	1.2	Versicolor
...					
150	5.9	3.0	5.0	1.8	Virginica

Features
(attributes, measurements, dimensions)

Class labels
(targets)





Machines try to see a dog as...