Departamento de Eletrónica, Telecomunicações e Informática

Foundations of Machine Learning
(winter semester 2023/2024)

LECTURE 1 : INTRODUCTION

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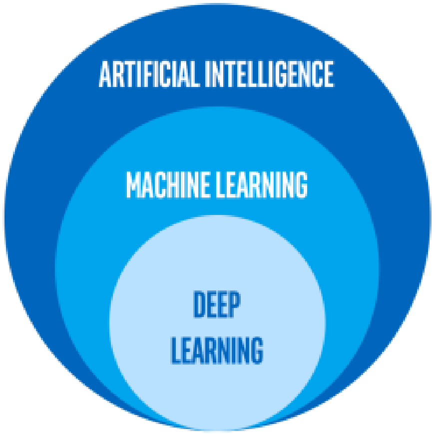
AI - the new Electricity

Artificial Intelligence (AI) will influence every industry .

McKinsey estimated 13 trillion dolars of global GDP value creation by 2030 due to AI.

Software Industry (strongly affected by AI) : Web Search; On-line Advertysing; Languare translation; Social Media

Non-Software Industry (still long way to go): Manifacture, Agriculture, Retail, Transportation, Logistics, etc.



PROGRAM

Supervised learning

Linear (univariate/ multivariate) regression
Logistic regression. Regularization
Artificial Neural Networks (ANN)
Support Vector Machines (SVM)
Decision Tree (DT);
Naive Bayes classifier
k-Nearest Neighbor (k-NN) classifier

Unsupervised learning

K-means clustering
Data dimensionality reduction
Principal components analysis (PCA)
Multivariate Gaussian approach for Anomaly Detection

Deep Learning

Deep Learning architectures :
CNN (Convolutional Neural Networks);
Sequence models : LSTM (Lond Short Term Memory)

Recommender systems

Evaluation

Lectures & labs: 3 hours per week.

<u>Practical component - 50% of the final grade</u>

Practical component consists of 2 projects, developed in a group of two students.

The first project is evaluated based on a submitted report (IEEE format) and a short (10-15 min.) oral presentation.

The second project is evaluated based on a submitted report (IEEE format).

The students are encouraged to use Latex text editor.
Overleaf is a convenient platform for collaborative writing and publishing using Latex (https://www.overleaf.com/) .

<u>Theoretical Component – 50% of the final grade (</u>Final exam).

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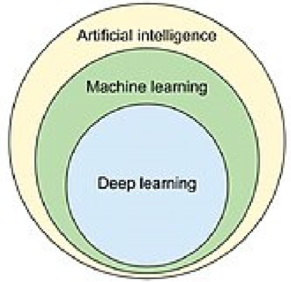
Why ML ?



- Grew out of work in Artificial Intelligence and increasing computational resources.

- Exponential growth of data – need for data mining
  (IoT, medical records, biology, engineering, etc.)

- Applications can't be explicitly programed by hand.

  ✓ Autonomous driving;
  ✓ Computer Vision;
  ✓ Natural Language Processing (Speech recognition, Machine translation)
  ✓ User behaviour monitoring (Sentiment classification, Video activity recognition) .
  ✓ Medical diagnostics

A bit of history

- **1950,** Alan Turing: "Computing Machinery and Intelligence" define the question "Can machines think?“ =>Turing test.

- **1956** –The field of Artificial Inteligente (AI) formally established at the conference in Dartmouth College.

- **1959,** Arthur Samuel: “ Field of study that gives computers the ability to learn without being explicitly programmed ".

- **1998,** Tom M. Mitchell: “ Can the computer program learn from experience ? “.

Machine Learning – "definition"

„A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E.“ **(T. Mitchell 1998)**

- **Given**

  - a task T (e.g. classify spam/regular emails)
  - a performance measure P (weighted sum of mistakes)
  - some experience E with the task (e.g. hand-sorted emails)

- **Goal**

  - generalize the experience in a way that allows to improve the machine performance on the task

Learning to classify documents

Web page:
Company, Personal, University, etc.

Articles:
Sport,Political, History, etc.

Computer Vision

Learning to detect & recognize faces

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Computer Vision Tasks

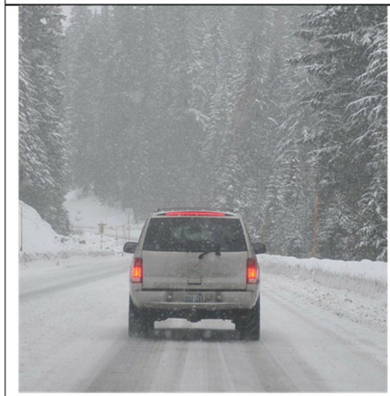
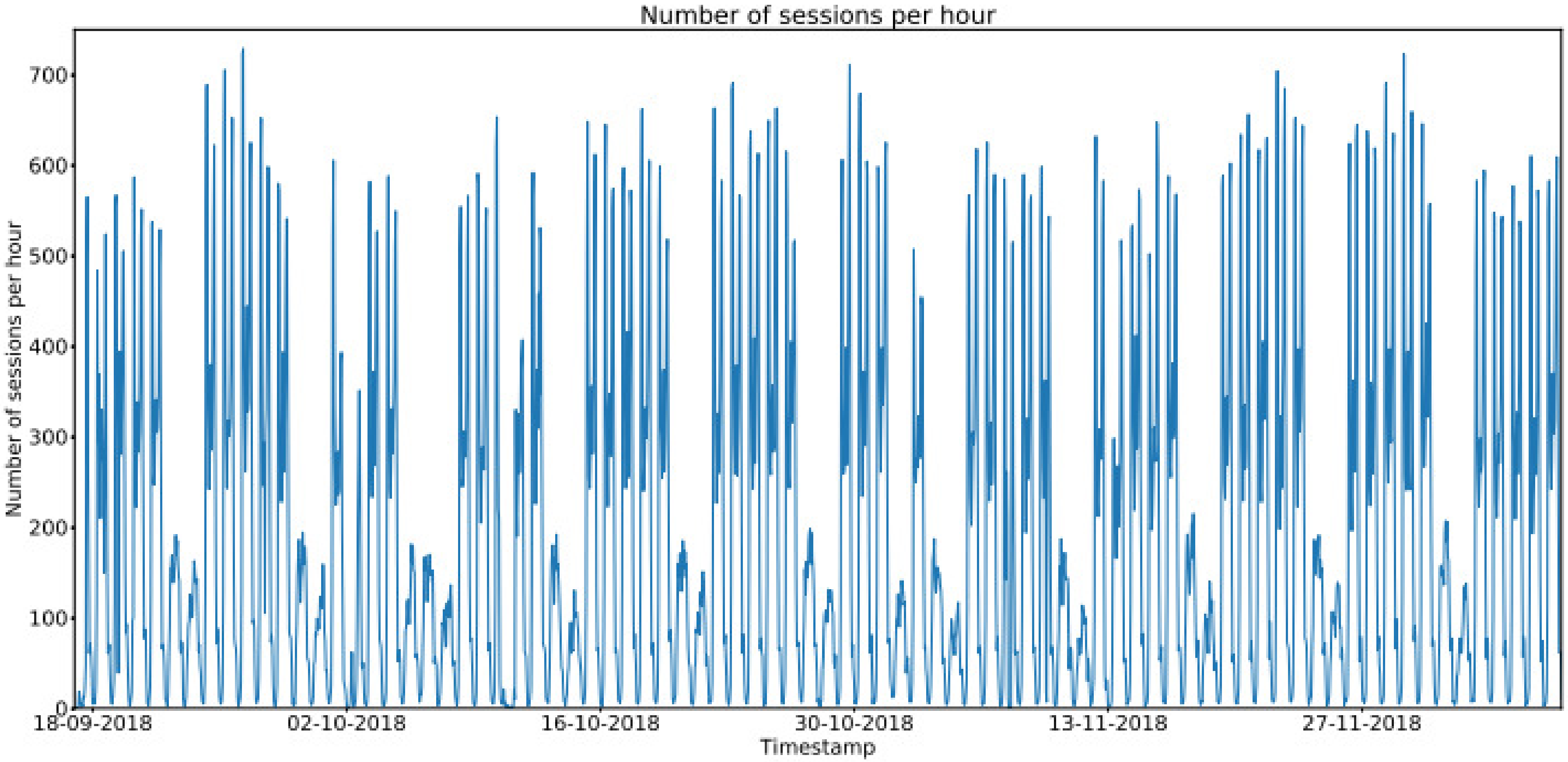
Image classification	Classification & Localization	Detection
	 b_x, b_y, b_h, b_w	

Image classification: input a picture into the model and get the class label (e.g. person, bike, car, background, etc.)

Classification & localization: the model outputs not only the class label of the object but also draws a bounding box (the coordinates) of its position in the image.

Detection: the model detects and outputs the position of several objects.

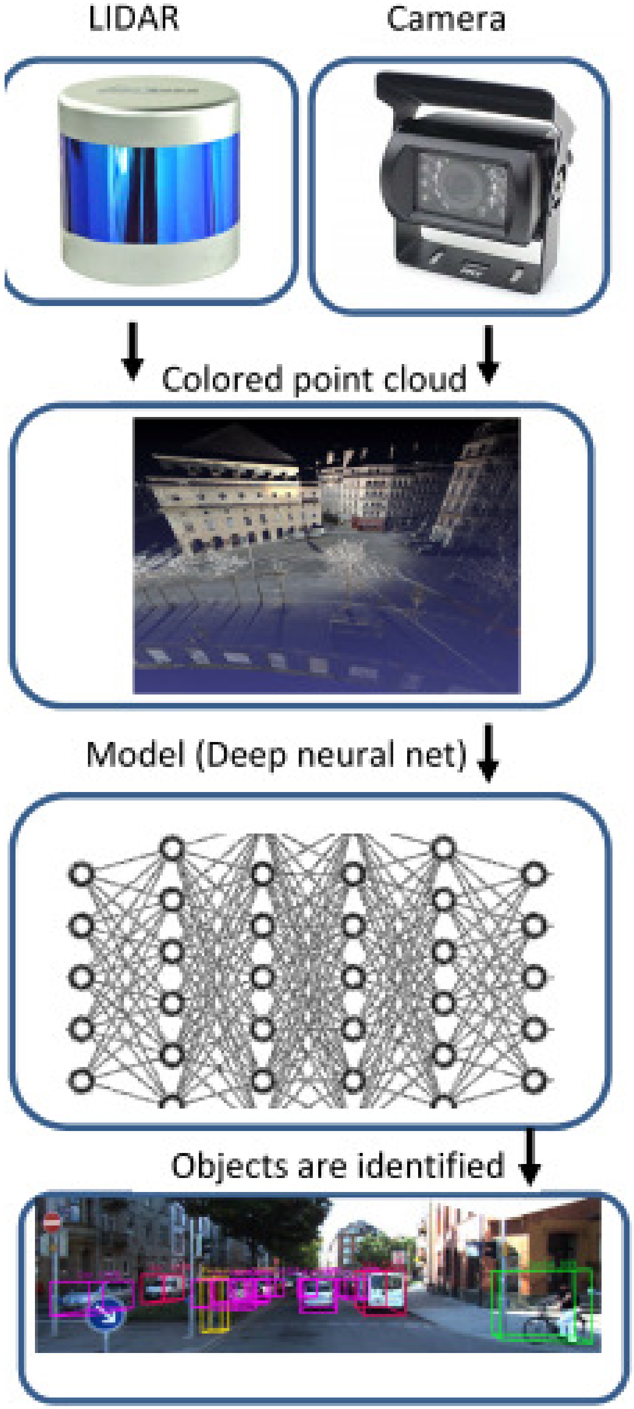
Time Series (TS) Forecasting



Time Series - collection of data points indexed based on the time they were collected . Most often, data are recorded at regular time intervals.

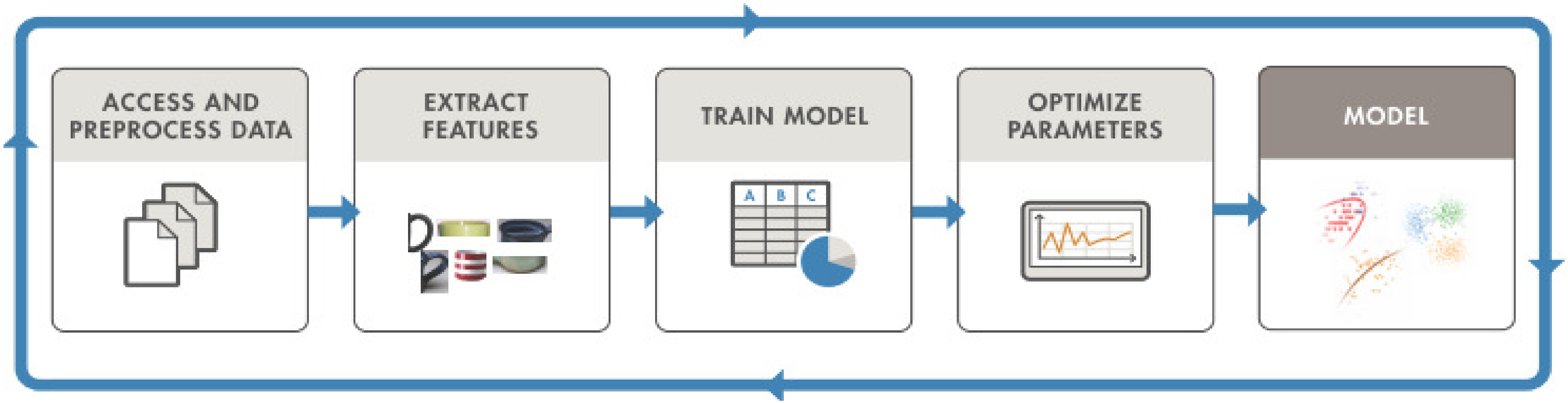
Based on past data, predict future trends, seasonality, anomalies, etc.

Object Detection (sensor fusion)

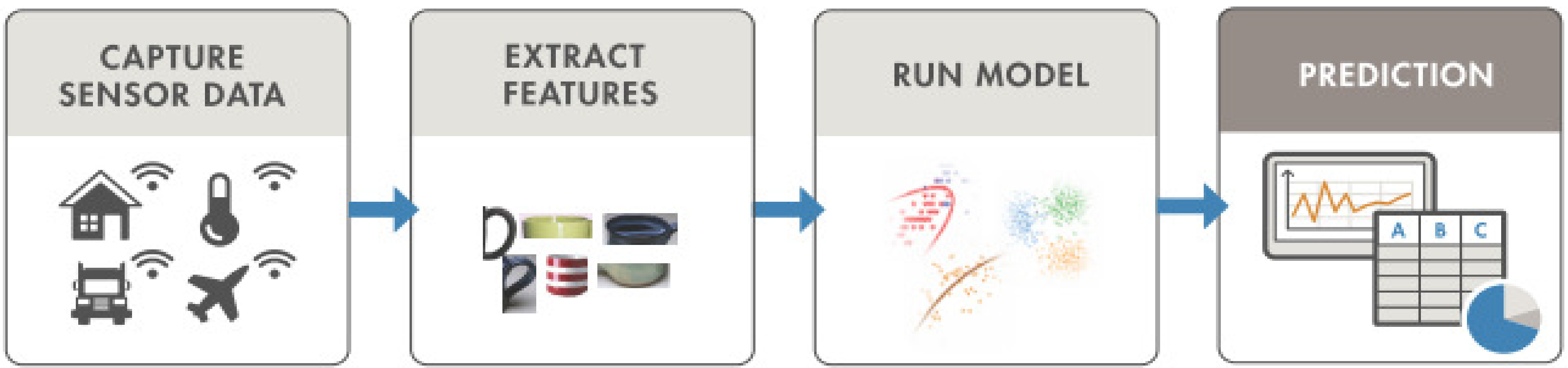


ML workflow

Train: Iterate until achieve satisfactory performance (**usually off-line**)



Predict: Integrate trained models into applications **(on-line)**



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Machine Learning Approaches

Supervised Learning

Given examples with “correct answer” (labeled examples)

(e.g. given dataset with spam/not-spam labeled emails)

Unsupervised Learning

Given examples without answers (no labels).

Deep Learning

Automatically extract hidden features (in contrast to hand-crafted features). Need a lot of data (Big data) . Need for very high computational resources (GPUs).

Reinforcement Learning

On-line (on the fly) learning, by trial and error.

Supervised Learning

Requires labeled data (examples with “correct answer”).

Regression: The Labels are real numbers.

Ex. Predict the house price (output) based on data for the house area and number of bedrooms (features).

Living area (feet^2)	#bedrooms	Price (1000$s)
2104	3	400
1600	3	330
2400	3	369
1416	2	232
3000	4	540
⋮	⋮	⋮

Classification: The Labels are integer numbers (class 1, class 2, etc.)

Ex. Predict normal (0) or abnormal (1) state of data center computers:

Features: memory use of computer ; number of disc accesses /sec; CPU load ; network traffic; silence

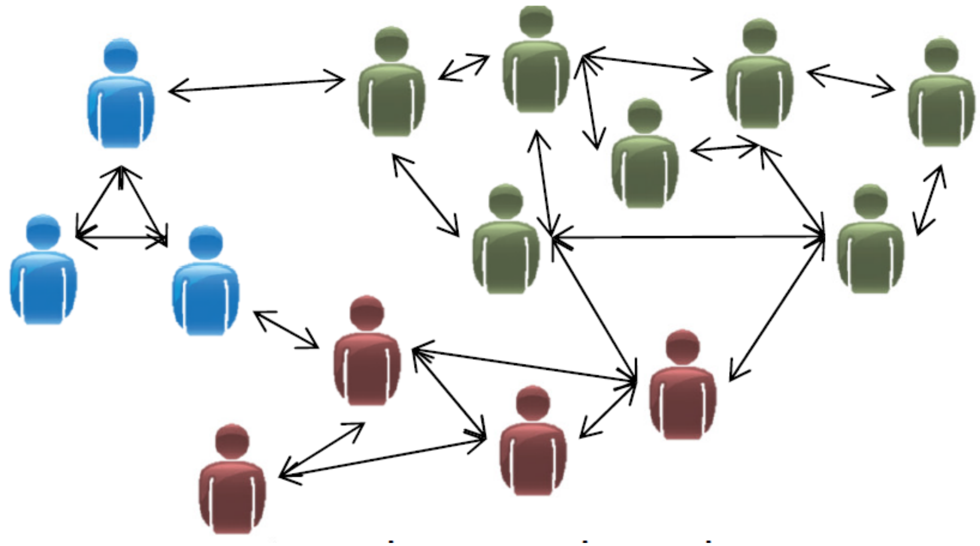
Unsupervised Learning

Given unlabeled data (NO answers)

Features: education, job, age, marital status, etc.

Market segmentation

Social network analysis



Clustering: Given a collection of examples (e.g. user profiles with a number of features). Each example is a point in the multidimensional space of features. Find a similarity measure that separates the points into clusters.

-K-means clustering

Why Deep Learning ?

Hardware get smaller.
Sensors get cheaper, widely available IoT devices with high sample-rate.
Data sources: sound, vibration, image, electrical signals, accelerometer, temperature, pressure, LIDAR, etc.

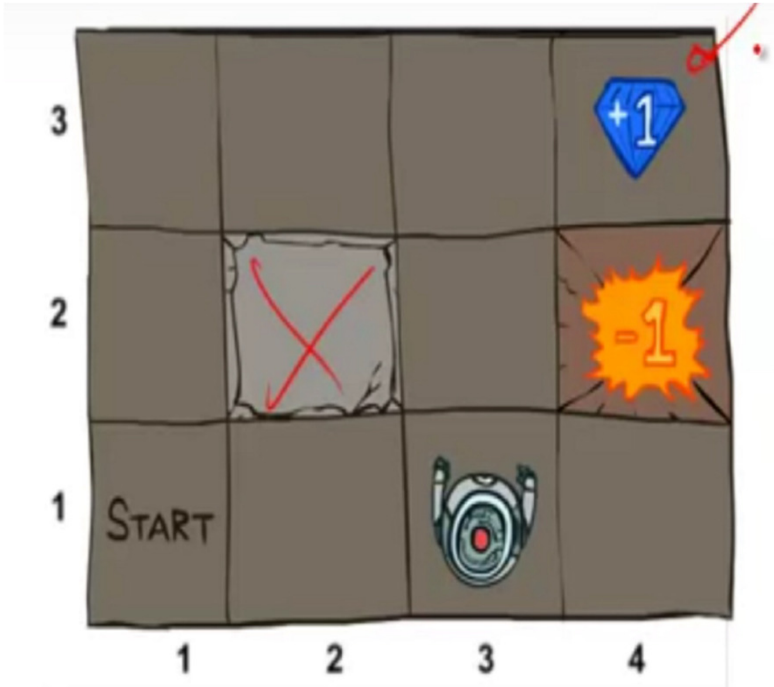
Big Data: Exponential growth of data, (IoT, medical records, biology, engineering, etc.)

How to deals with **unstructured data** (image, voice, text, EEG, ECG, etc.) => What are the best feature ?

Deep Neural Networks: first extract (automatically) the hidden features, then solve ML tasks (classification, regression)

Reinforcement Learning

On-line learning by taking actions and getting rewards/penalties.
intelligent robotics =>



Little vs. Lots of Data

Most ML applications lay somewhere in this spectrum:

Little data <--> Lots of data

We have lots of data for speech recognition;
Reasonable large data for image recognition (cats or dogs) ;
and much less data for object detection (bounding boxes) .

If Lots of data: the best way to get good performance is to build deep models (several layers), playing with network architectures, but less hand-engineering.

If Little data: the best way to get good performance is hand-engineering – very difficult and skilful task that requires a lot of inside (expert) knowledge.

Data Types

1. **Numeric (Quantitative) features**
   - Integer numbers
   - Floats (decimals) **-** temperature, height, weight, humidity, etc.

2. **Boolean** – True/False

3. **Categorical features -** gender, days of the week, seasons, country of birth, colors, etc.

   How to deal with categorical features ? - One-hot encoding (1,0) transforms n categories into n features

Color
Red
Red
Yellow
Green
Yellow

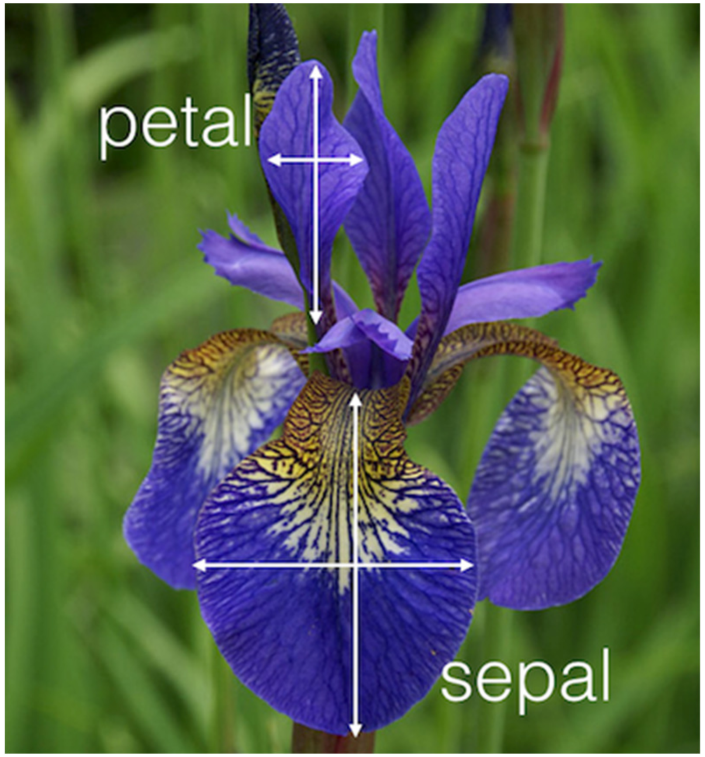
Red	Yellow	Green
1	0	0
1	0	0
0	1	0
0	0	1

Iris Plant data

- Iris Plant data – benchmark dataset for illustration of ML methods.
  - UCI Machine Learning Repository
    http://www.ics.uci.edu/~mlearn/MLRepository.html

  - 3 flower types (classes):
    - Setosa
    - Virginica
    - Versicolour

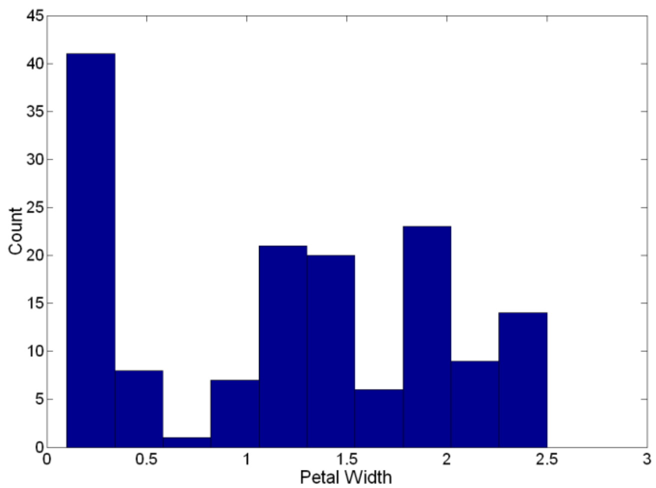
  - 4 attributes (features)
    - Sepal width and length
    - Petal width and length

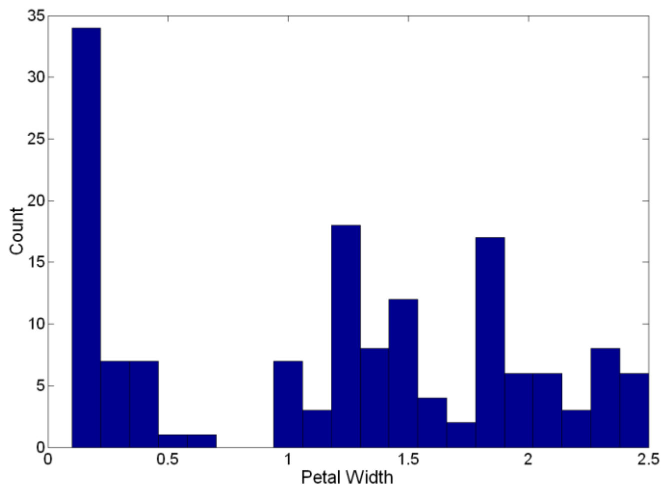


Data Visualization (1)

- **Histograms**
  - Show the distribution of values of a single feature
  - Divide the range of values of a single feature into bins and show bar plots of the number of examples in each bin.
  - Histogram shape depends on the number of bins

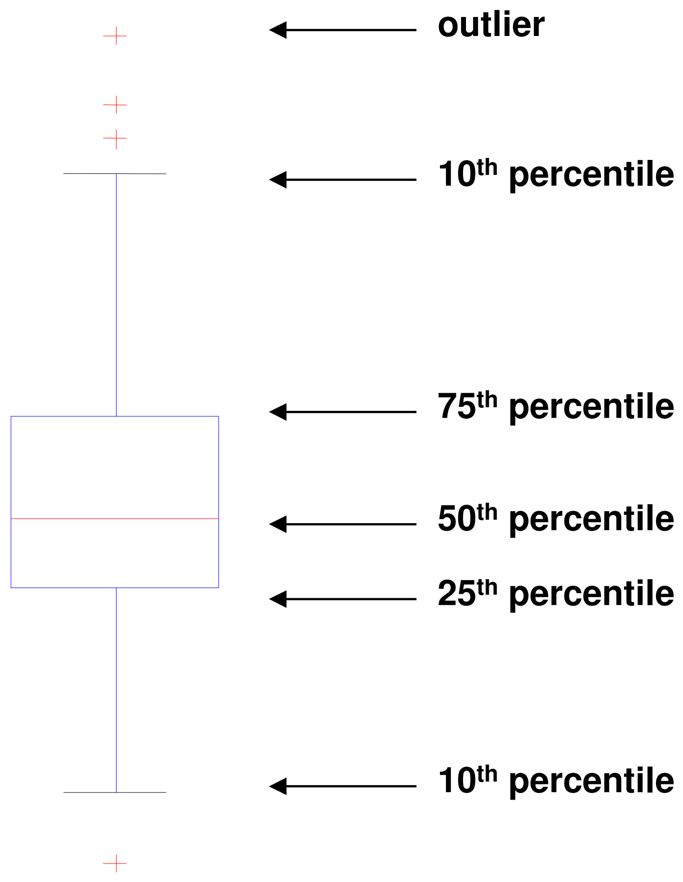
- Example: Petal Width (10 and 20 bins, respectively)





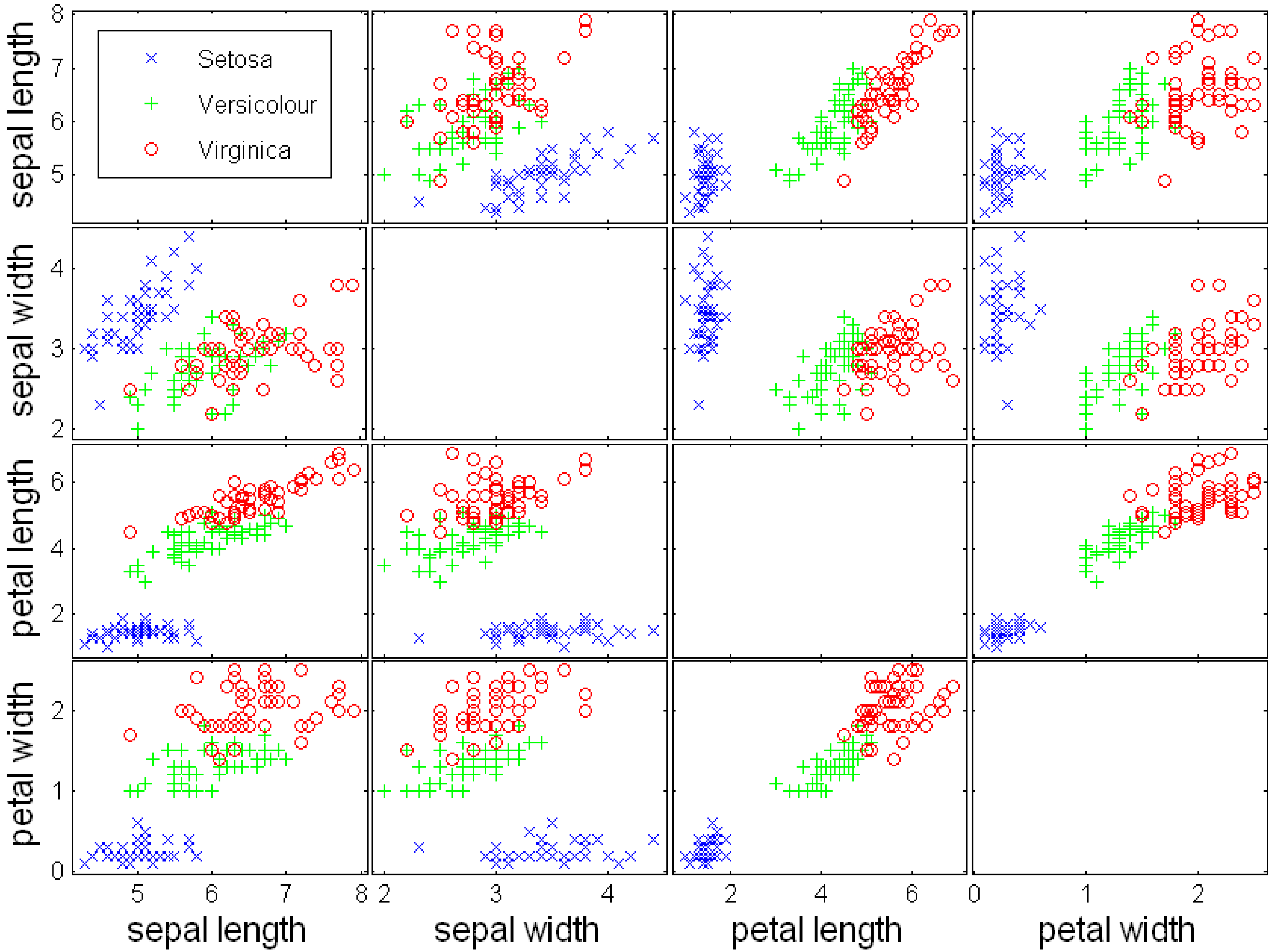
Data Visualization (2)

- **Box Plots**
  - Another way of displaying the distribution of data



Data Visualization (3)

Scatter Plot Array



RECOMMENDED BIBLIOGRAPHY

- Tom Mitchell, Machine Learning. McGraw-Hill, 1997.

- Christopher Bishop, Pattern Recognition and Machine Learning. Springer, 2006.

- David Barber, Bayesian Reasoning and Machine Learning, Cambridge University Press , 2012, (available on-line *http://web4.cs.ucl.ac.uk/staff/D.Barber/textbook/091117.pdf*).

- http://cs229.stanford.edu/ (project ideas)

- MOOC (Massive Open Online Courses)
  e.g. https://www.coursera.org/

ANACONDA 3

1) Install Anaconda 3 for Python 3:

https://www.anaconda.com/distribution/

2) Learn how to use Jupyter Notebook (part of Anaconda)

https://www.dataquest.io/blog/jupyter-notebook-tutorial/