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Introduction

Data Analysis for Networks - NDA (2019-2020)

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Sorbonne-LIP6

September 11, 2019

Course (main) Bibliography

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B.1 Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani. "An introduction to statistical learning: with applications in R". Springer Texts in Statistics.

ISBN 978-1-4614-7137-0 (DOI 10.1007/978-1-4614-7138-7)

B.2 C. Bishop, "Pattern Recognition and Machine Learning", Springer 2006.

ISBN 978-0387-31073-2

B.3 H. Pishro-Nik, "Introduction to probability, statistics, and random processes", available at https://www.probabilitycourse.com, Kappa Research LLC, 2014.

Surveys - Overview

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S.1 Raouf Boutaba et al. - "A comprehensive survey on machine learning for networking: evolution, applications and research opportunities", Journal of Internet Services and Applications, Springer (2018) 9:16
DOI 10.1186/s13174-018-0087-2

Stats VS Machine Learning

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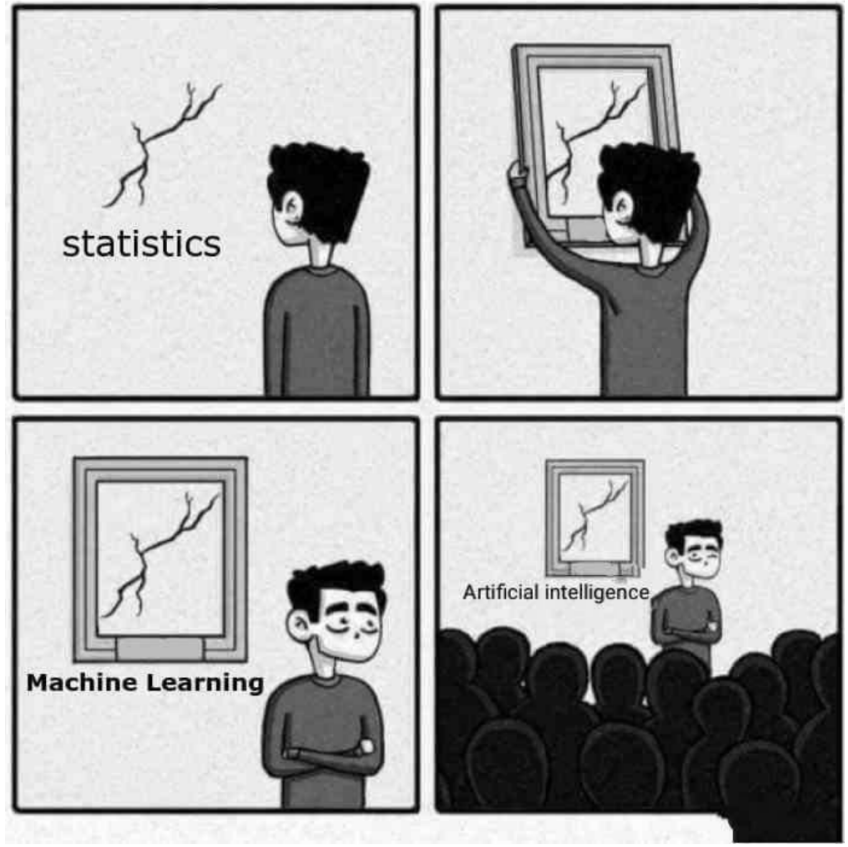

Figure: "When you're fundraising, it's AI. When you're hiring, it's ML. When you're implementing, it's logistic regression."

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Intro

Data Analysis and Machine Learning (ML) revolutionise our world!

- Computer Vision (CV) and Natural Language Processing (NLP): classifying images, facial recognition, automatic translation.
- Recommendation engines: Amazon, Netflix, or Youtube.

Been around since a very long time...

- *Statistics is a branch of mathematics dealing with the collection, analysis, interpretation, and presentation of masses of numerical data.*
- *"Machine Learning, is the field of study that gives computers the ability to learn without being explicitly programmed" (Arthur Samuel, 1959)*

Why now? Sufficient and cheap computational power & lots, lots, lots of (labeled) data available e.g. Facebook and Google photos, WWW...

Highlights I

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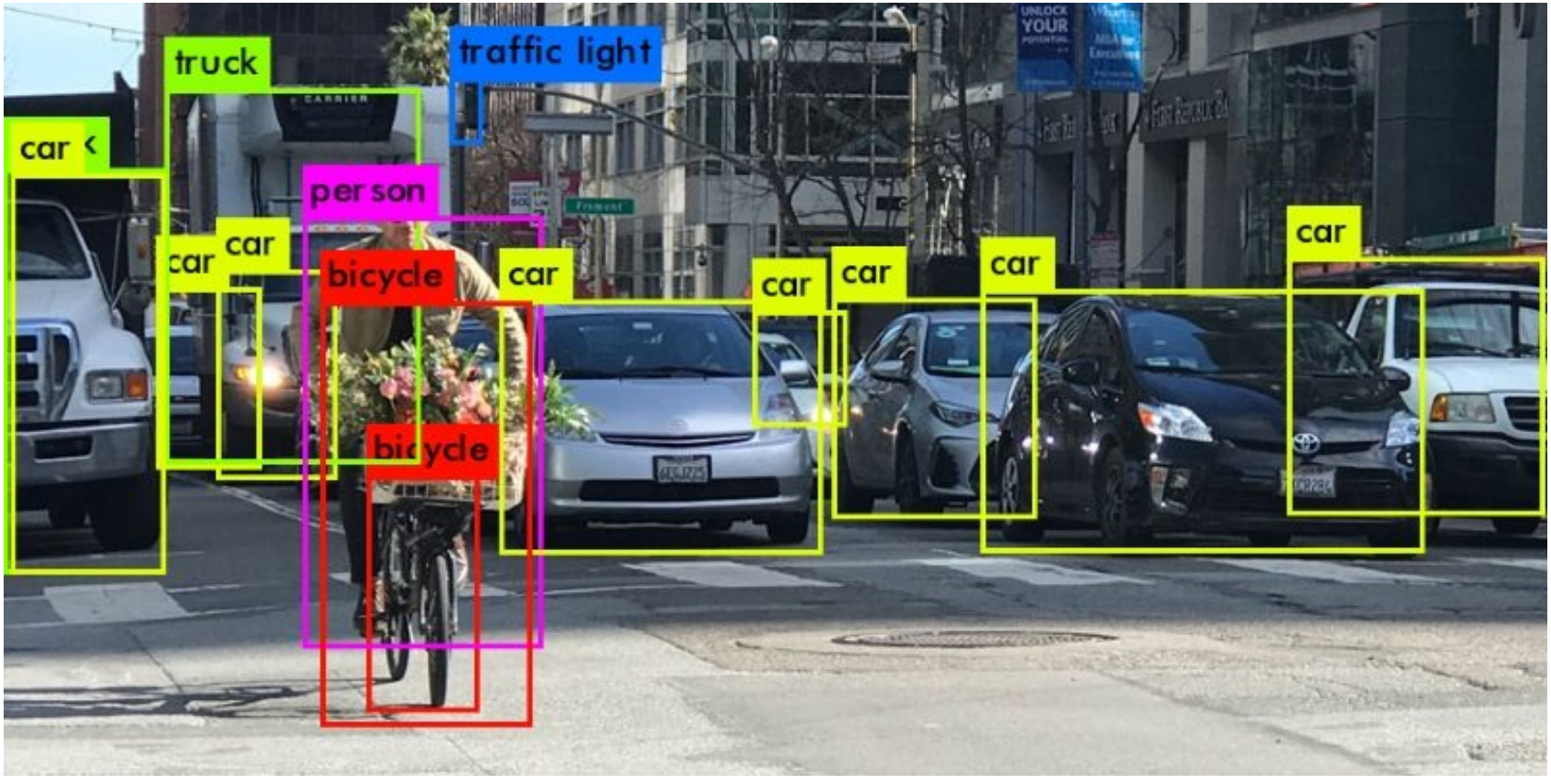

Figure: Object detection and recognition for driverless cars.

Highlights II

Behind Hey Siri: How Apple's AI-Powered Personal Assistant Uses DNN

ABHISHEK SHARMA - FEB 16, 2018

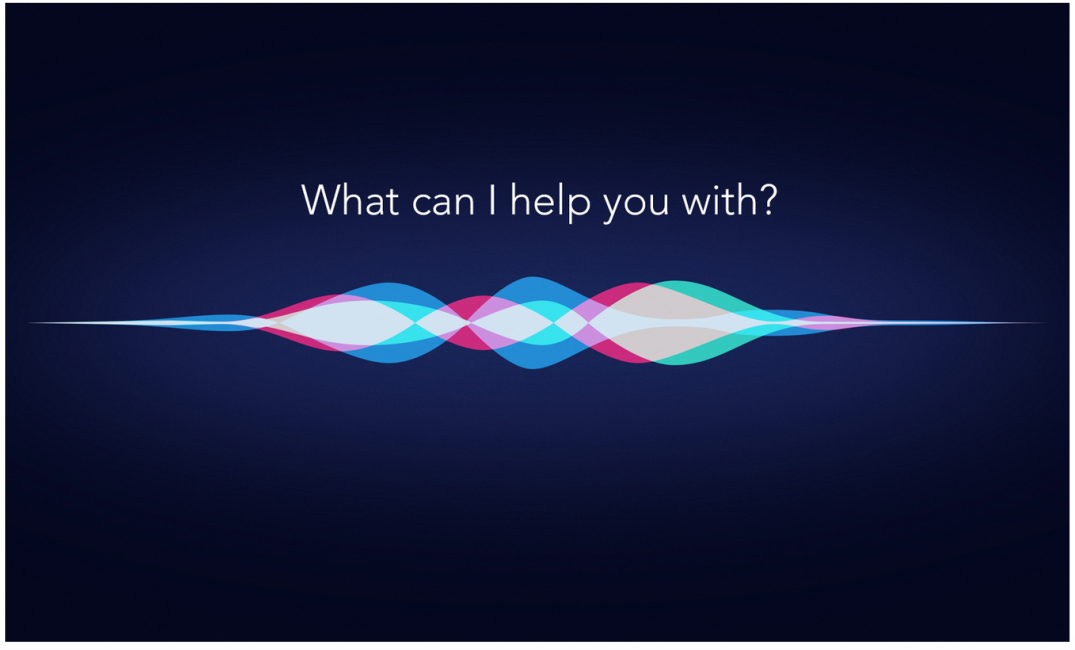

Figure: Speech recognition.

Highlights III

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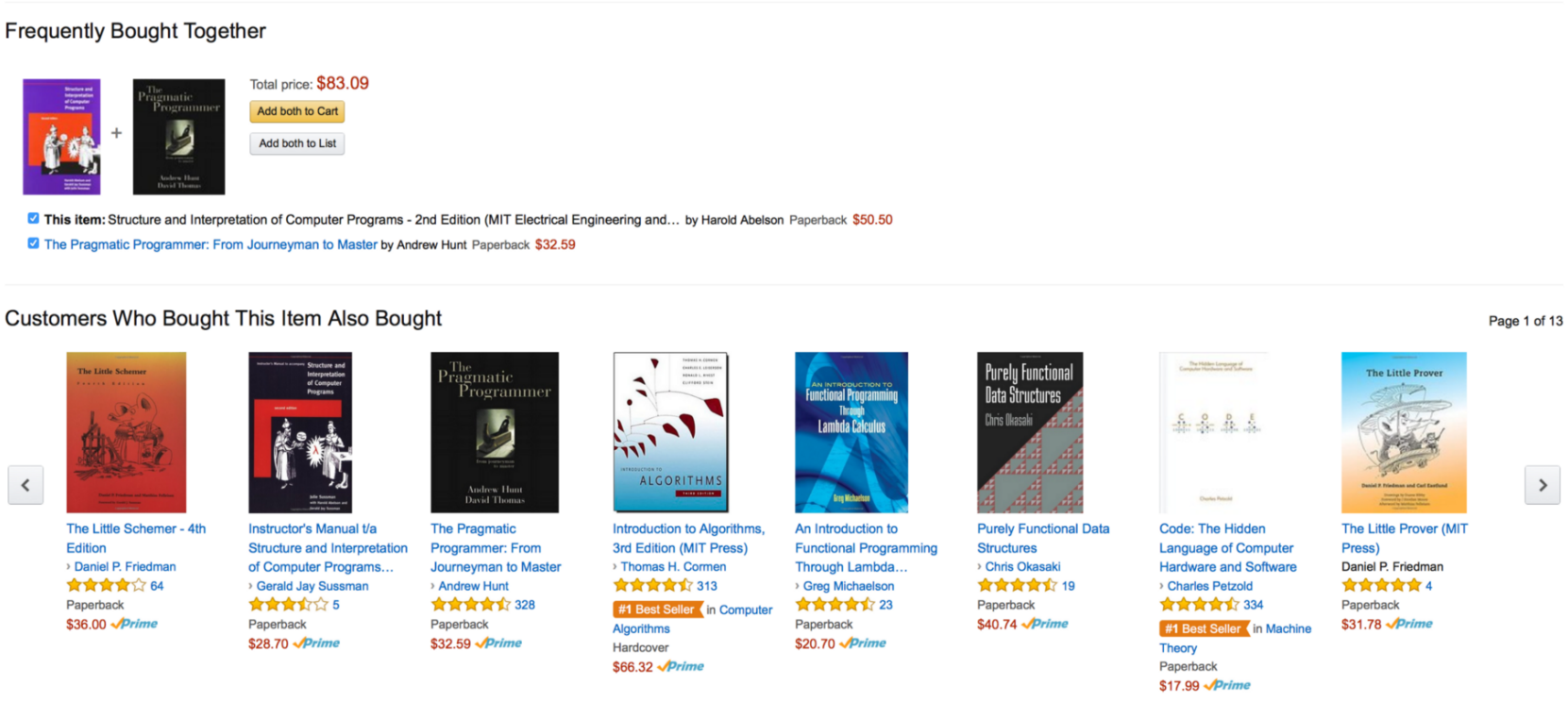

Figure: Useful recommendations.

Taxonomy of ML methods

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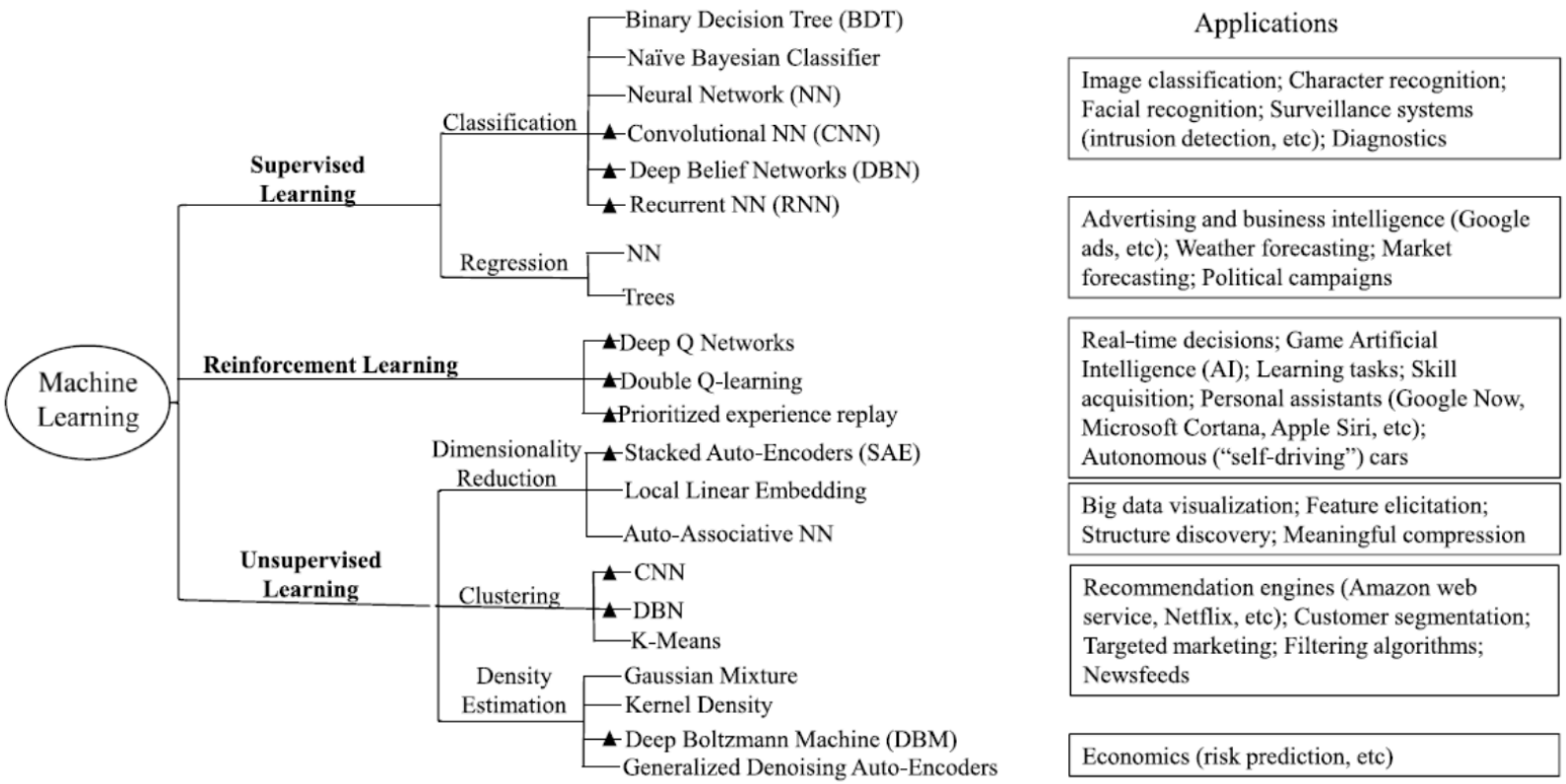

Figure: Taxonomy and applications (Fadlullah, et al (IEEE, 2017)).

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Method differences

All three methods require a common element to work:

DATA!!!

The difference is the type of data available or collected:

- Supervised: Labelled data, model learning.
- Unsupervised: Unlabelled data (majority of telecom data).
- Reinforcement: Exploration-exploitation. Data is the rewards collected by application of an action.

Labeling is a non-trivial process to establish the ground-truth. Often hand-made by experts.

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☞ Make a distinction between static and dynamic environments: Data from the first are n-dimensional points, from the second **time-series**.

History of Data Analysis and ML methods

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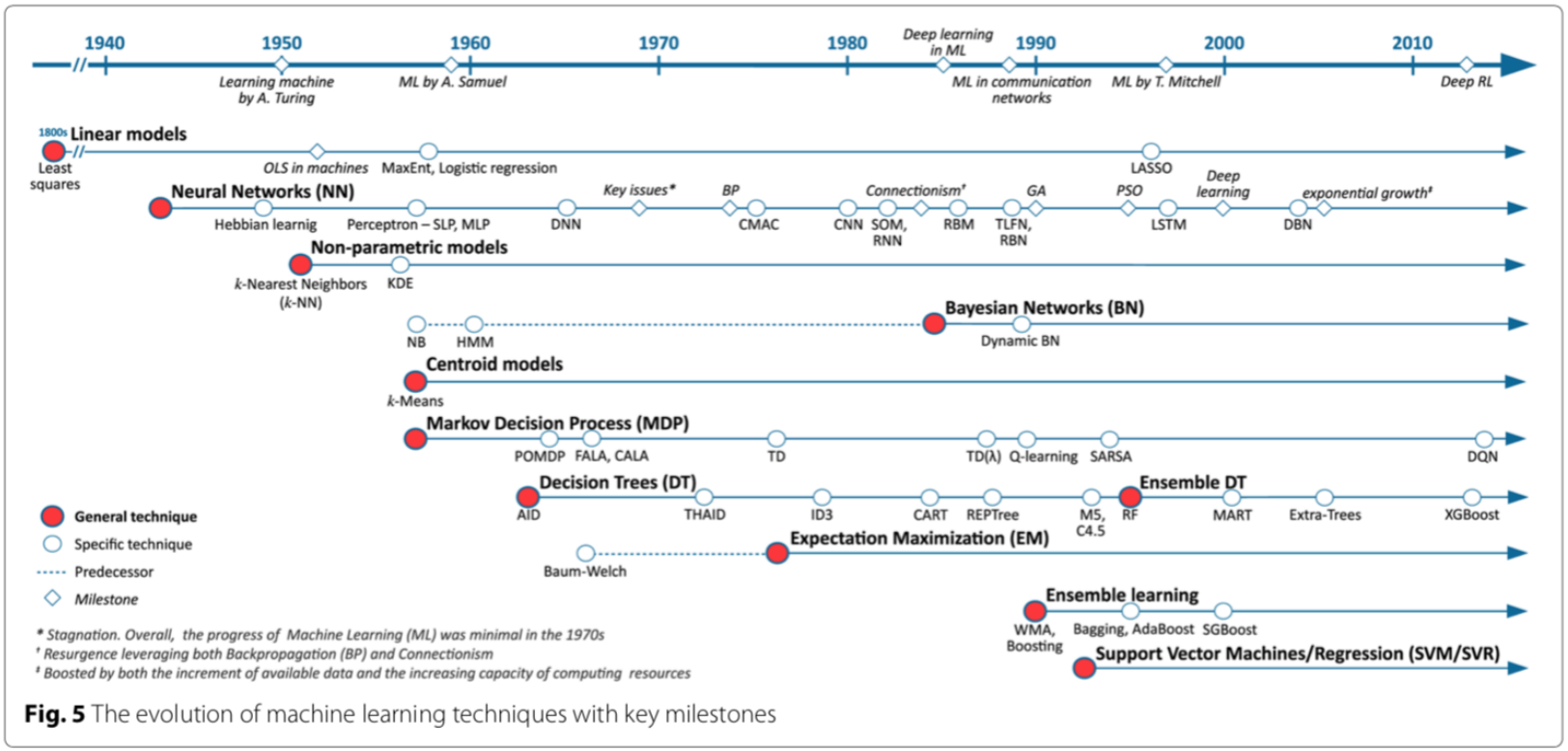

Fig. 5 The evolution of machine learning techniques with key milestones

Figure: ML historical evolution (from [S.1]).

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Main tasks to perform

What can we do with all these methods?

- Estimation: quantify unknown parameters from observations.
- Inference: guess the unknown underlying statistics.
- Regression: guess an underlying model and predict possible outcomes of an experiment.
- Classification: decide on the class of an object.
- Dimensionality Reduction: compress the information contained in several features to easier describe an object.
- Clustering: group objects based on affinity.

Some Tasks

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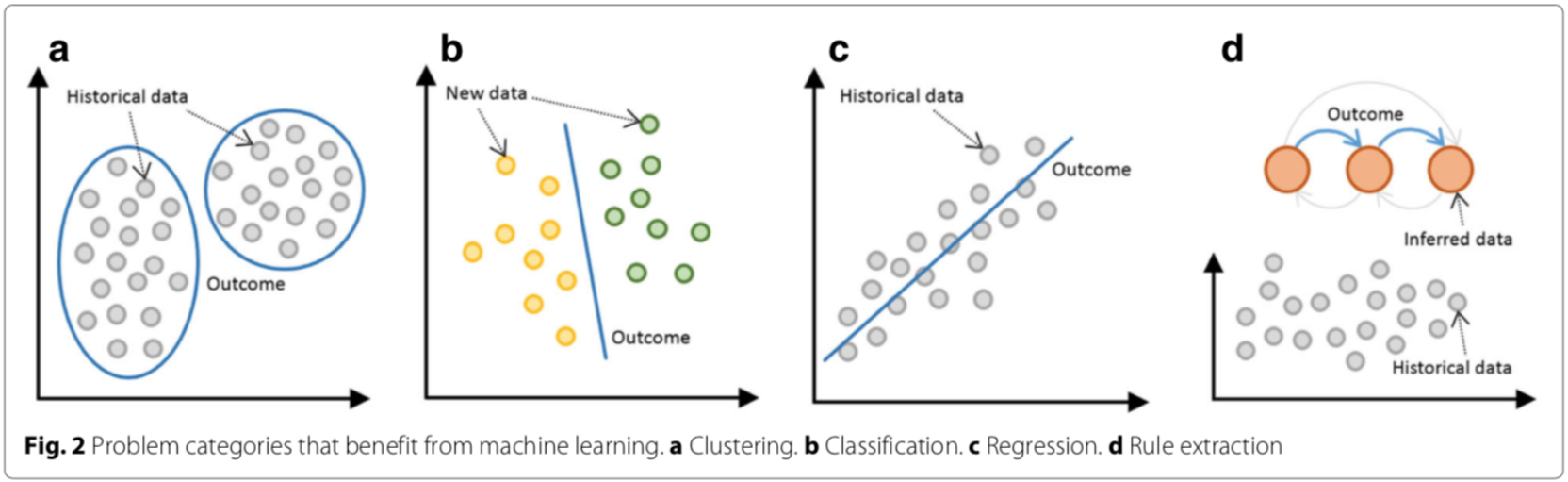

Fig. 2 Problem categories that benefit from machine learning. **a** Clustering. **b** Classification. **c** Regression. **d** Rule extraction

Figure: Task examples (from [S.1]).

General methodology

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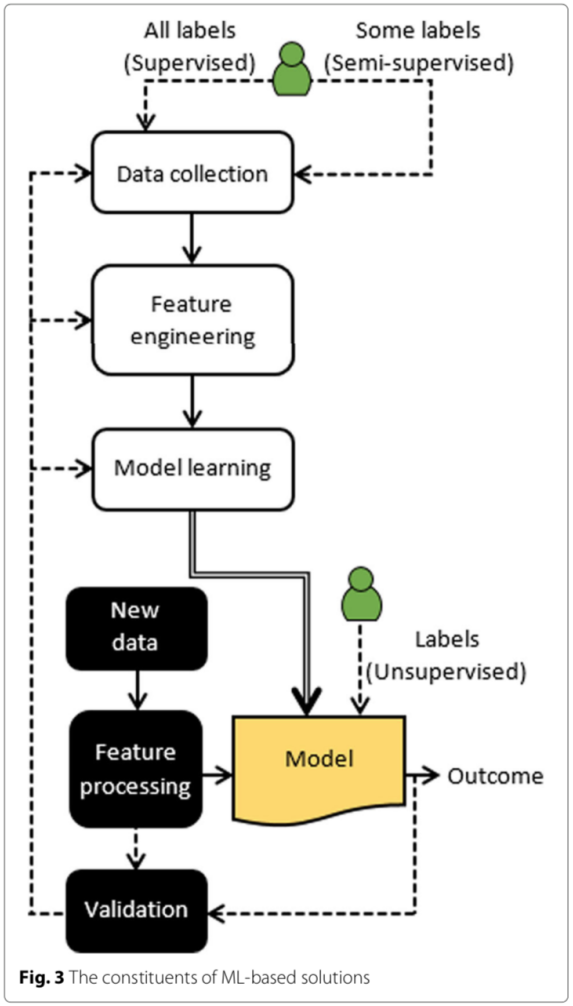

Figure: ML historical evolution (from [S.1]).

Telecom Network science and Data

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☞ Telecommunication networks offer the infrastructure for ML.

But! Their design and functionality can profit from data analysis and ML, through Telemetry: massive data availability about QoS, QoE, KPIs...

Main possibilities:

1. Traffic: prediction, classification, routing.
2. Performance: congestion control, resource management, fault management, QoS/QoE management.
3. Anomaly detection: hardware/software failure.
4. Security: Intrusion detection, DoS or DDoS Attacks.

Traffic IP

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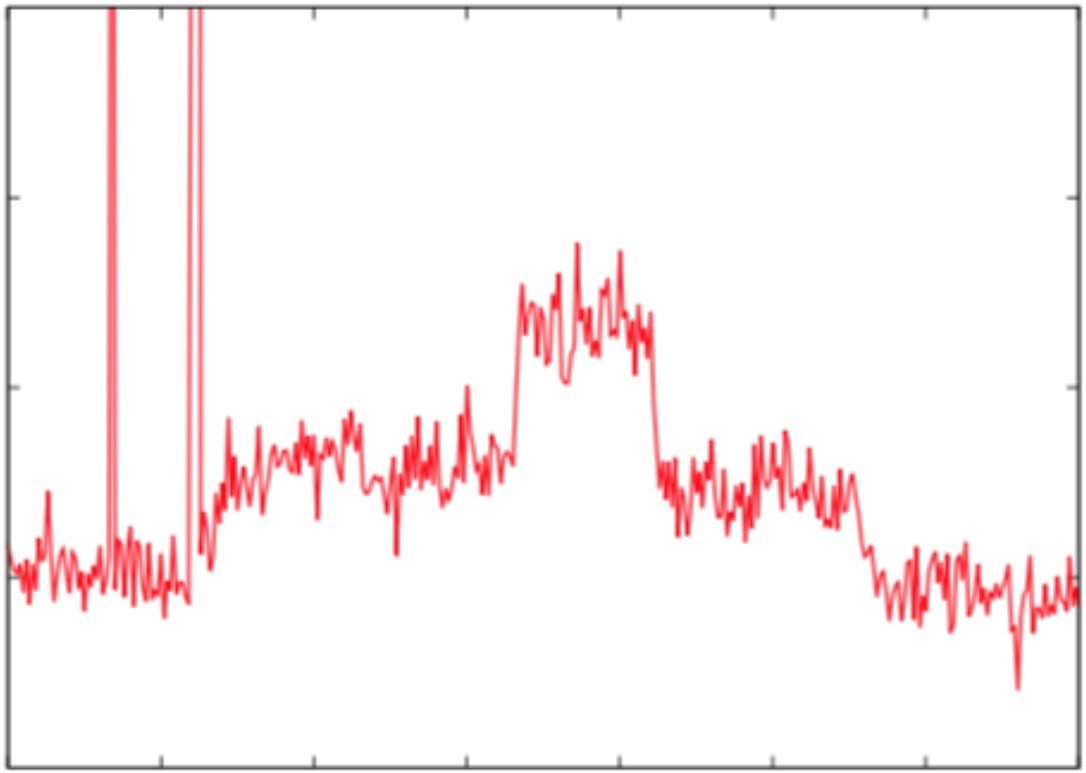

Figure: *image from thesis Audrey Wilmet*.

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Traffic

- **Prediction**
  Forecast future traffic from previously observed data: Time series forecasting through ARMA models (auto-regressive moving average)
- **Classification**
  Associate network traffic to pre-defined classes, e.g. HTTP, FTP, WWW, DNS, P2P
  or applications, e.g. Skype, YouTube, Netflix...
  Features: port number, packet payload, host behaviour, flow features, QoS requirements.
  Traffic can be encrypted! Rely on stochastic characteristics.
- **Routing**
  Select a path for packet transmission with an objective: cost minimisation, link utilisation, QoS provisioning, etc.

  Use of Reinforcement Learning techniques, to explore the environment without supervision (trial-and-error learning).

TCP

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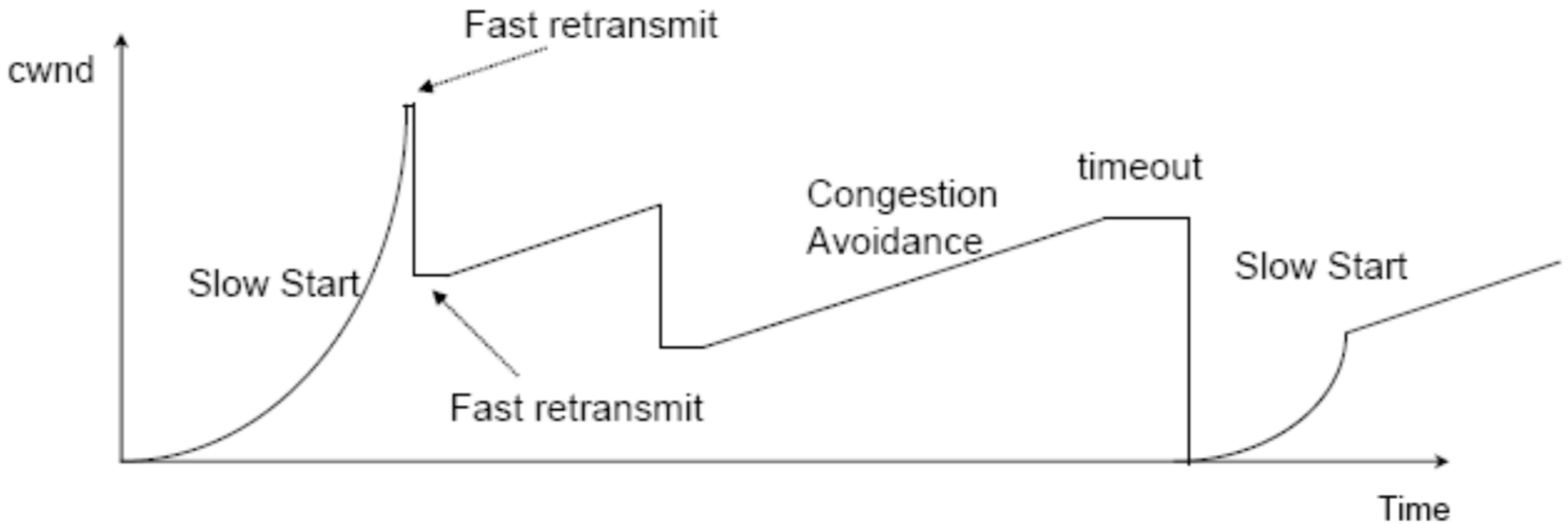

TCP congestion control

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TCP protocol limits the packet sending rate when congestion is detected.

But! TCP recognizes and handles all packet losses as network congestion (buffer overflow).
A packet loss can be due to other reasons:

- Packet reordering.
- Fading and shadowing in wireless.
- Wavelength contention in optical.

Solution: Classify the cause of packet loss and reduce TCP transmission rate only when congestion.

Features: inter-arrival time, round-trip time, one-way delay.

☞ Also, learn the appropriate window reduction per congestion event!

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Network security

Protect the network against cyber-threats.
Attacks can compromise the network's availability and resources.

☞ Businesses are under security threats → cost billions in damage and recovery, may have impact on their reputation.

Current Security measures include :

- Encryption of network traffic, Anti-viruses, Firewalls, etc.

☞ Extra protection:

- Intrusion Detection/Prevention: phishing, DoS, DDoS, ...

Monitor the network for malicious / anomalous activities, find patterns (=attack signatures) in big datasets that deviate from normal behaviour.

What is normal? Unsupervised learning, clustering methods.

Structure of the course I

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☞ Methods from statistics, machine-learning and stochastic processes.

Each course on Wednesdays: 2 hours Theory + 2 hours Python Lab

Part I: Statistics

- C1. Intro to NDA / Probability basics (18 September 2019)
- C2. Frequentist Estimation (25 September 2019)
- C3. Hypothesis Tests (02 October 2019)
- C4. Bayes Rule (09 October 2019)

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Structure of the course II

Part II: Machine Learning

a. Supervised

- C5. Regression (16 October 2019)
- C6. Mode Selection / Validation (23 October 2019)
- C7. Classification (06 November 2019)
- C8. Feature Selection / Regularisation (27 November 2019)
- C9. Tree-based methods (04 December 2019)

b. Unsupervised

- C10. Clustering (11 December 2019)
- C11. Anomaly Detection / PCA (18 December 2019)

Structure of the course III

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Part III: Time-series

- C12. Principles of Time-Series (08 January 2020)
- C13. Modelling with Time-Series (15 January 2020)
- C14. Forecasting using Time-Series (22 January 2020)

☞ End January / begin February 2020 final exam.

Final Note:
40% Python code from all TPs
60% Final exam.

Teaching material

Course Material (slides):
https://github.com/yokaiAG/DataNets-Course

People:

- Anastasios Giovanidis (responsible)
- Maximilien Danisch, Lionel Tabourier.

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END