

Course Introduction

Machine Learning

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Information



□ Daniele Loiacono (Instructor)

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- ▶ Office: DEIB, room 150

□ Teaching Assistant: Alberto Maria Metelli

□ Exam

- ▶ Written test (closed-book)
 - Questions, exercises, code
 - See examples on WeBeep
 - **Late enrollment is NEVER accepted**
- ▶ Check the remote exam policy on WeBeep



WeBeep page

Information (2)

- ❑ Weekly schedule
 - ▶ Tue, 14.15 – 16.15, T11
 - ▶ Thu, 12.15 – 14.15, T21
- ❑ There is no streaming but lectures will be recorded
- ❑ Check the [syllabus](#) for (tentative) info about the topics of each lecture
- ❑ Practical classes
 - ▶ will cover exam-like exercises and practical examples
 - ▶ will present practical examples using **Python** (bring your laptop!)
- ❑ Interact
 - ▶ Feel free to ask questions
 - ▶ Use the forum of the course

References

- ❑ You will have access to all the materials used in classroom but slides are not an alternative to textbooks!

- ❑ Supervised Learning
 - ▶ Bishop, “Pattern Recognition and Machine Learning”, Springer, 2006.
 - ▶ Hastie, Tibshirani, Friedman, “The Elements of Statistical Learning: Data Mining, Inference, and Prediction”, Springer, 2009.
 - ▶ Mitchell, “Machine Learning”, McGraw Hill, 1997.
 - ▶ Murphy, “Probabilistic Machine Learning: An Introduction”, MIT Press, 2022

- ❑ Reinforcement Learning
 - ▶ Sutton and Barto, “Reinforcement Learning: an Introduction”, MIT Press, 1998. New draft available at:
<http://www.incompleteideas.net/book/the-book-2nd.html>

What will you learn?

Goals

- ❑ Learn to correctly **model** machine learning problems
 - ▶ Can I apply machine learning to this problem?
 - ▶ What type of model is best suited for this task?
 - ▶ How do I define the inputs and outputs effectively?
- ❑ Learn the **principles** and the **main techniques** of ML
 - ▶ What are the main differences between supervised, unsupervised, and reinforcement learning?
 - ▶ How do domain constraints and data availability influence the choice of model?
 - ▶ What are the typical steps involved in an end-to-end machine learning workflow?
 - ▶ How models' parameters are optimized and how does it influence the outcome?

Goals (cont.)

- ❑ Learn how to **assess** the performances of ML models
 - ▶ Which performance metrics are suitable for classification, regression, or clustering tasks?
 - ▶ How do I accurately evaluate the performance of a model?
 - ▶ How do I detect and manage common issues such as overfitting or underfitting?
- ❑ Learn **limitations** of ML techniques and how to **choose** the most appropriate one for your problem
 - ▶ Under what circumstances might a simpler model outperform a more complex one?
 - ▶ How does data availability affect the choice of the model?
- ❑ Provide the basic background to understand the latest developments in this field
 - ▶ How do recent trends in machine learning fit into the broader field and build on existing foundations?
 - ▶ Which core principles drive these new developments, and what limitations or challenges might they face?

Topics

- ❑ Linear Regression
- ❑ Linear Classification
- ❑ Bias-Variance
- ❑ Model Selection
- ❑ PAC-Learning and VC dimension
- ❑ Kernel Methods
- ❑ Support Vector Machines
- ❑ Markov Decision Processes
- ❑ Dynamic Programming
- ❑ RL in finite MDPs
- ❑ Multi-armed bandit

What you will not learn?

Prerequisites

- ❑ Linear Algebra
 - ▶ Operations with matrix and vectors, eigenvalues, eigenvectors, etc.
- ❑ Probability and statistics
 - ▶ Distributions, confidence intervals, hypothesis test, bayesian statistics
- ❑ Optimization (basics)

- ❑ Basics understanding of Python (for practical classes)

- ❑ Where to find this?
 - ▶ Read Chapter 1-2 and Appendix B,C,E of textbook (Bishop, "Pattern Recognition and Machine Learning")
 - ▶ Check the recap lectures on Python, Linear Algebra and Probability
 - ▶ Chapter 1 of "Probabilistic Machine Learning: An Introduction"

Other courses

- ❑ A course of 5 credits is **not enough** to cover Machine Learning
- ❑ Fortunately, there are **other courses** that deal with other machine learning topics not covered in this course:
 - ▶ Data Mining
 - ▶ Uncertainty in Artificial Intelligence
 - ▶ Artificial Neural Networks and Deep Learning
 - ▶ Applied Statistics
 - ▶ Numerical Analysis for Machine Learning
 - ▶ ...

What is Machine Learning?

Why and when to apply it?

What is Machine Learning

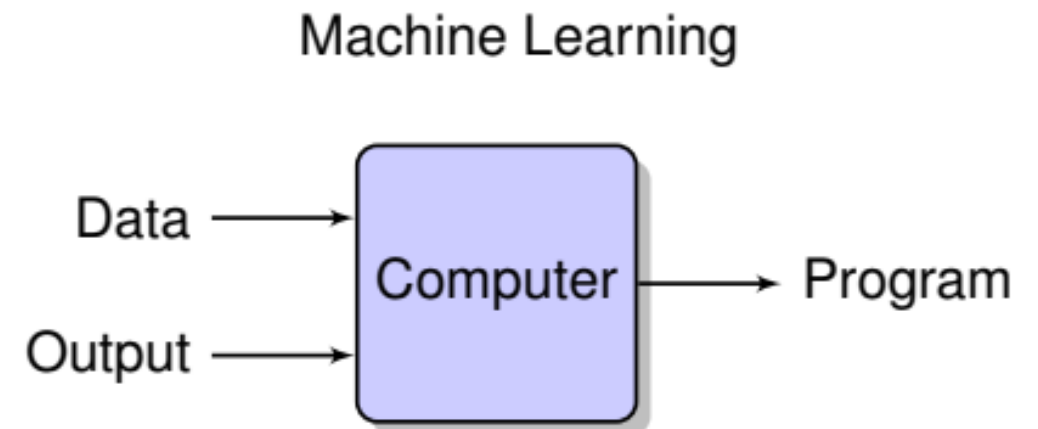
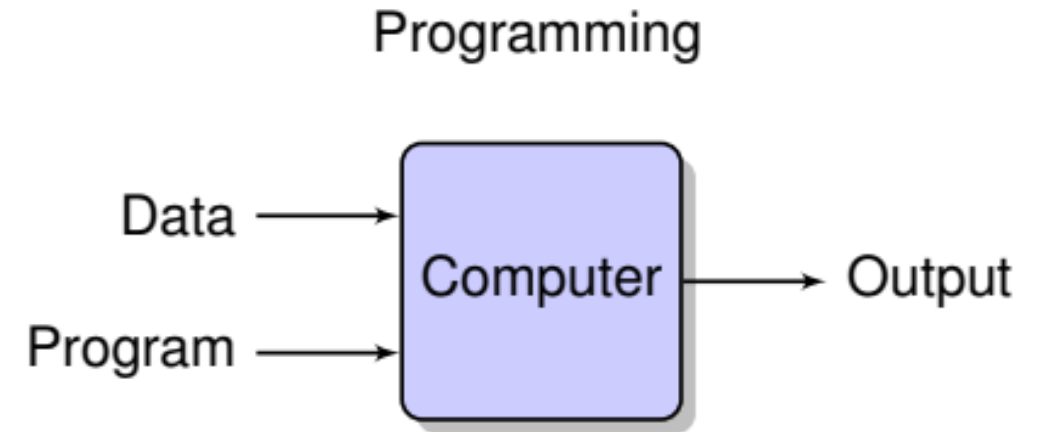
“A computer program is said to learn from **experience E** with respect to some class of **tasks T** and **performance measure P**, improves with experience E” *Mitchell (1997)*

- ❑ ML is the sub-field of AI where the **knowledge** comes from:
 - ▶ Experience
 - ▶ Induction

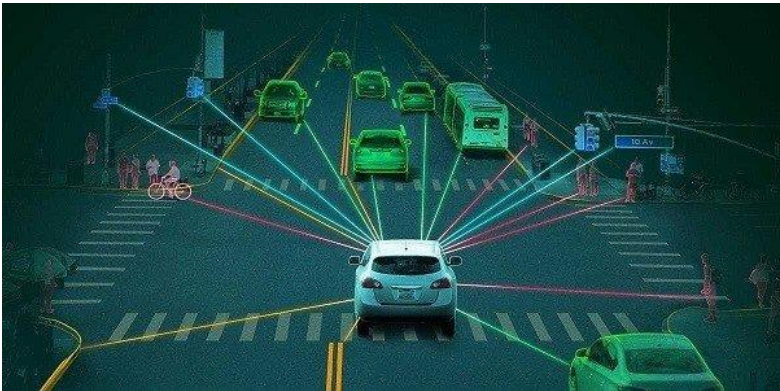
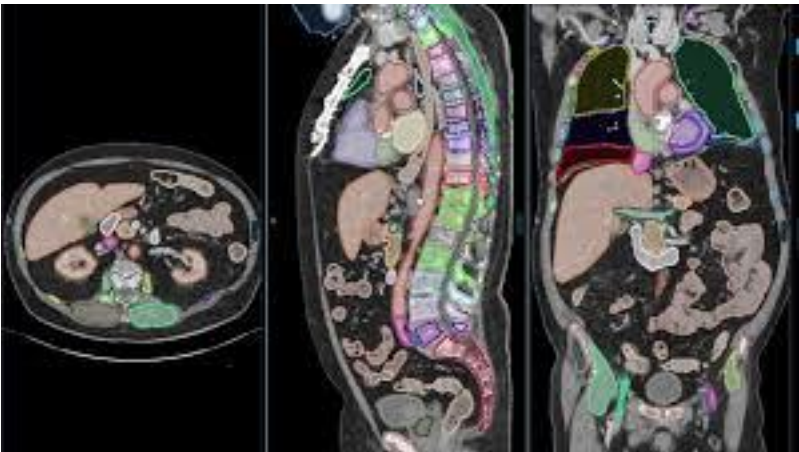
- ❑ However, Machine learning is not magic!
 - ▶ You need to know **how it works**
 - ▶ You need to understand **how to use it**
 - ▶ It can **extract** information from data, **not create** information

Why Machine Learning?

- ❑ We need computers to **make informed decisions** on new, unseen data
 - ▶ Often it is too difficult to design a set of meaningful rules
 - ▶ Machine learning allows to **automatically extract relevant information** from previous data and exploit it on new one
- ❑ Getting computers to **program themselves (automating automation)**
 - ▶ writing software is the **bottleneck**
 - ▶ let the **data** do the work instead




Machine Learning applications



D

Generate a text for advertising a new electric car model



Introducing the future of driving: the all-new electric car model!

👍

👎

With sleek lines and a bold design, this car not only looks great, but it's also packed with cutting-edge technology and features that will make your daily commute an absolute joy.

Say goodbye to gas stations and hello to a new era of sustainable driving. The electric car model is powered by a high-capacity battery that can be charged in the comfort of your own home, at work, or at any public charging station. You'll save money on fuel costs and enjoy a quieter, smoother ride.

But that's not all. The electric car model also comes equipped with advanced safety features such as lane departure warning, blind spot detection, and automatic emergency braking. Plus, its state-of-the-art entertainment and connectivity system ensures that you'll stay connected and entertained on the road.

We've designed this car with the environment in mind, but we've also made sure that it delivers the performance you need. With instant torque and a quick acceleration, you'll feel the power of electric driving the moment you step on the pedal.

Get ready to experience the future of driving. Test drive the electric car model today and see for yourself how it can transform the way you get around.

Google Ads

New Performance Max campaign























123-456-7890 Sosa
emailme@gmail.com

Meat, Protein, & Vitamins

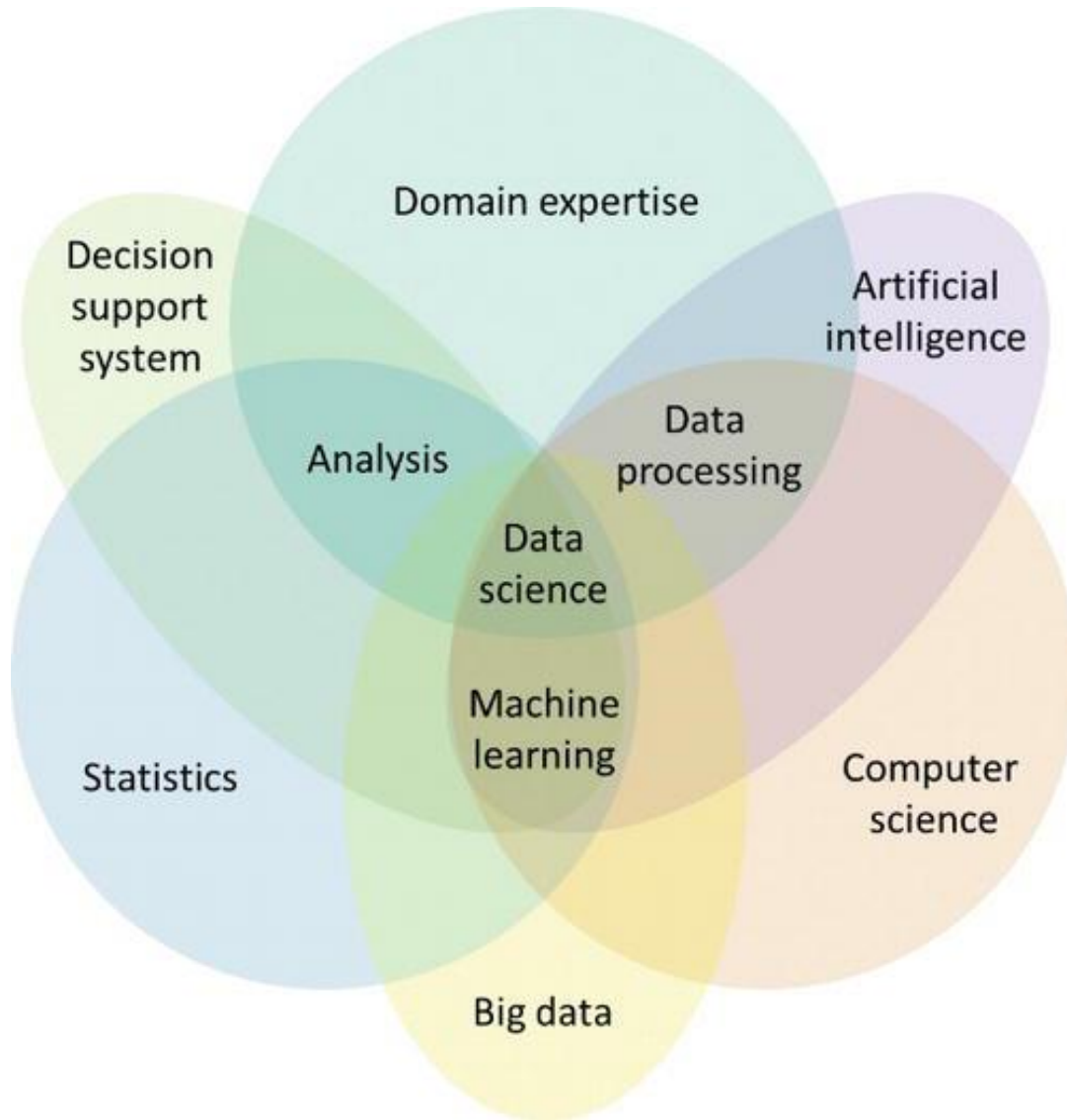
View more

Images (20/20)

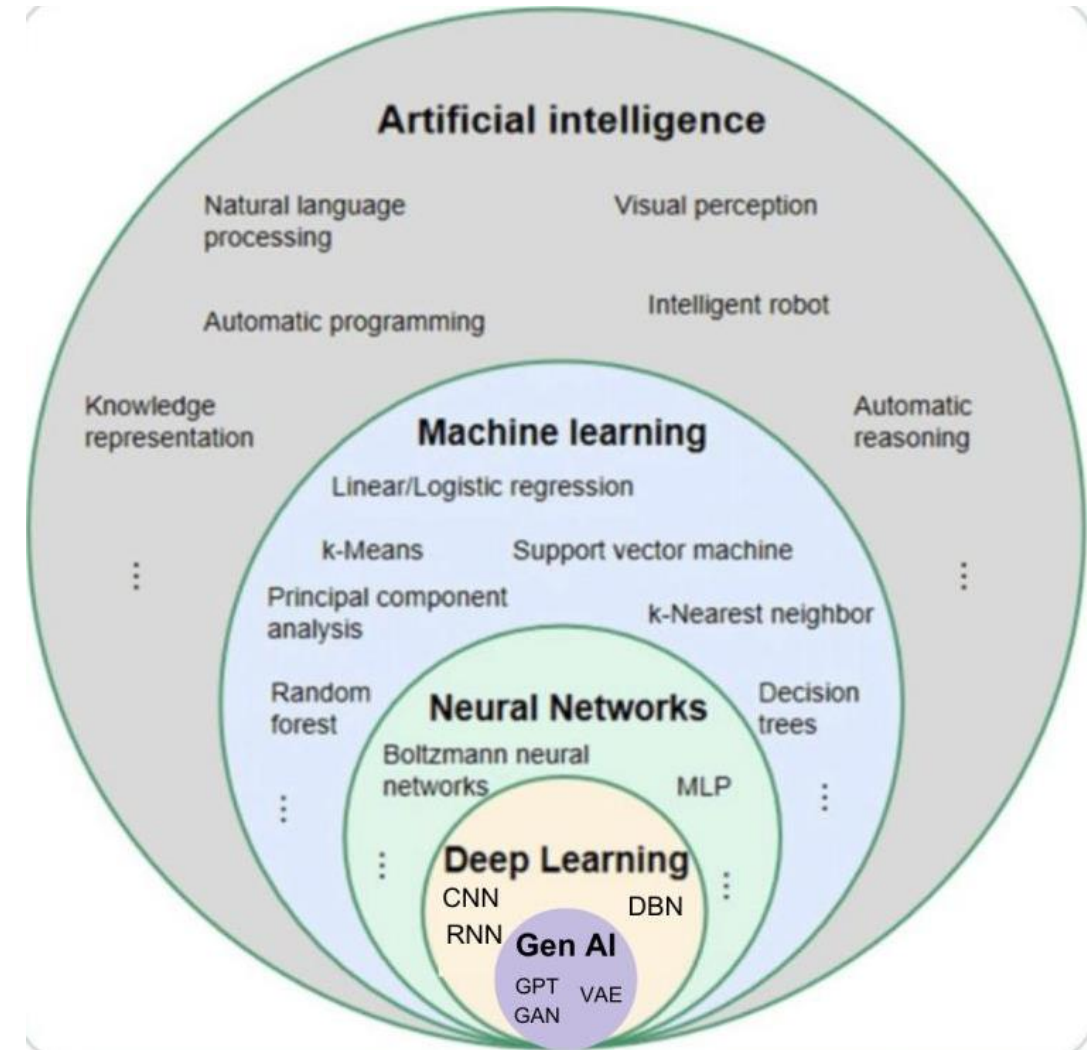
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Machine Learning and other fields



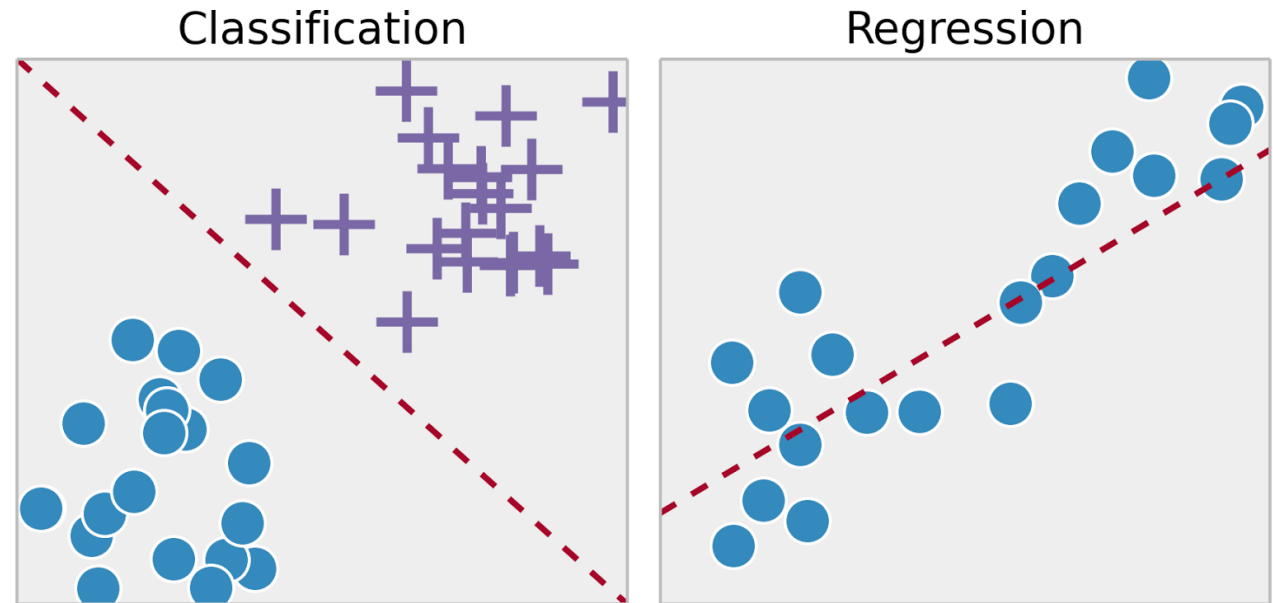
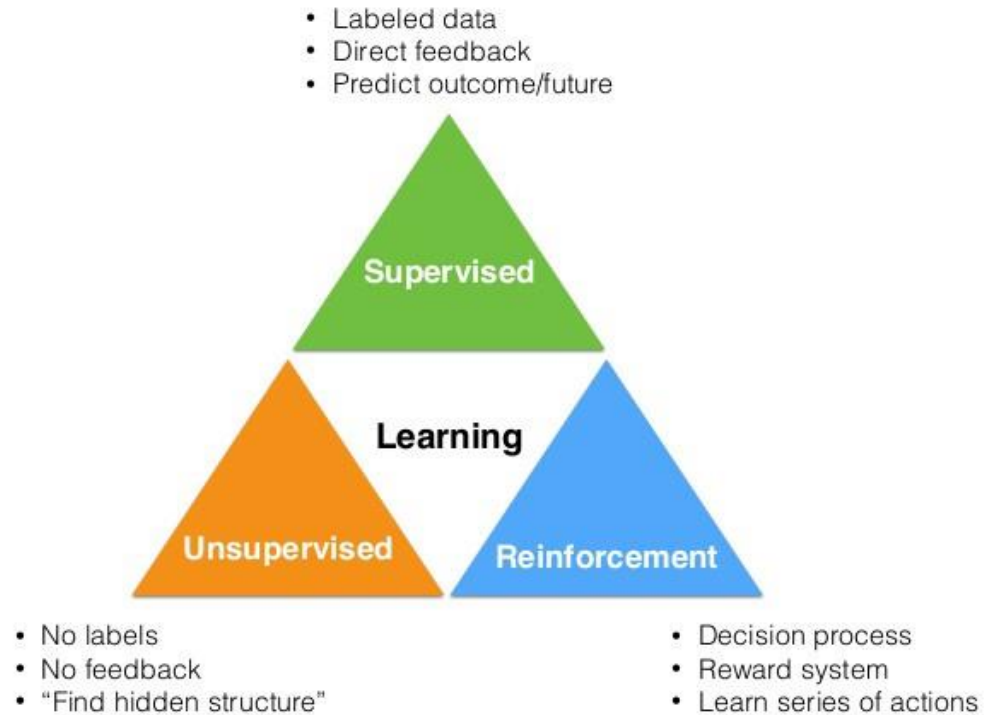
Lee et al., 2018



[source](#)

Learning Paradigms in ML

□ Supervised Learning

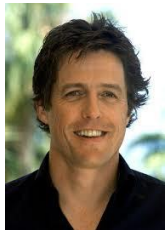


An example of classification

Training Set



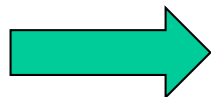
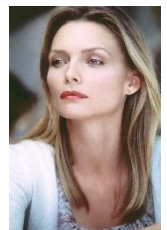
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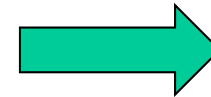
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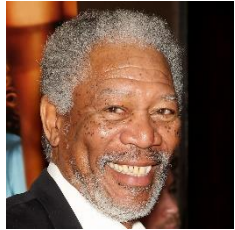
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An example of regression

Training Set



78



34



25

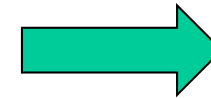
Testing



78



81



41

Supervised Learning

□ Goal

- ▶ Learn from **data** a **model** that maps **known inputs** to **known outputs**
- ▶ Training set: $\mathcal{D} = \{\langle x, t \rangle\} \Rightarrow t = f(x)$

□ Tasks

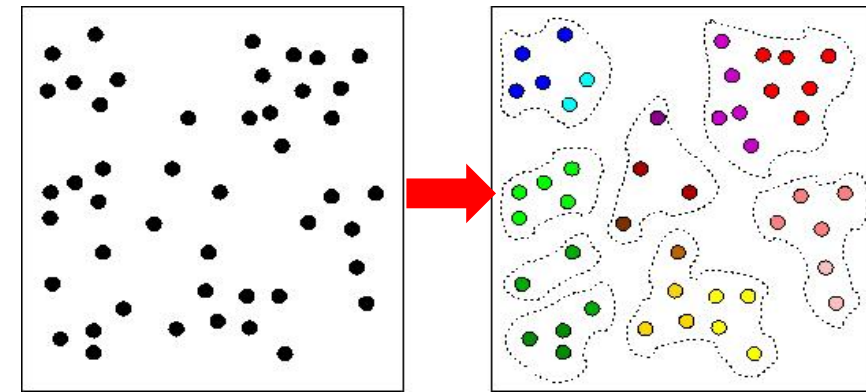
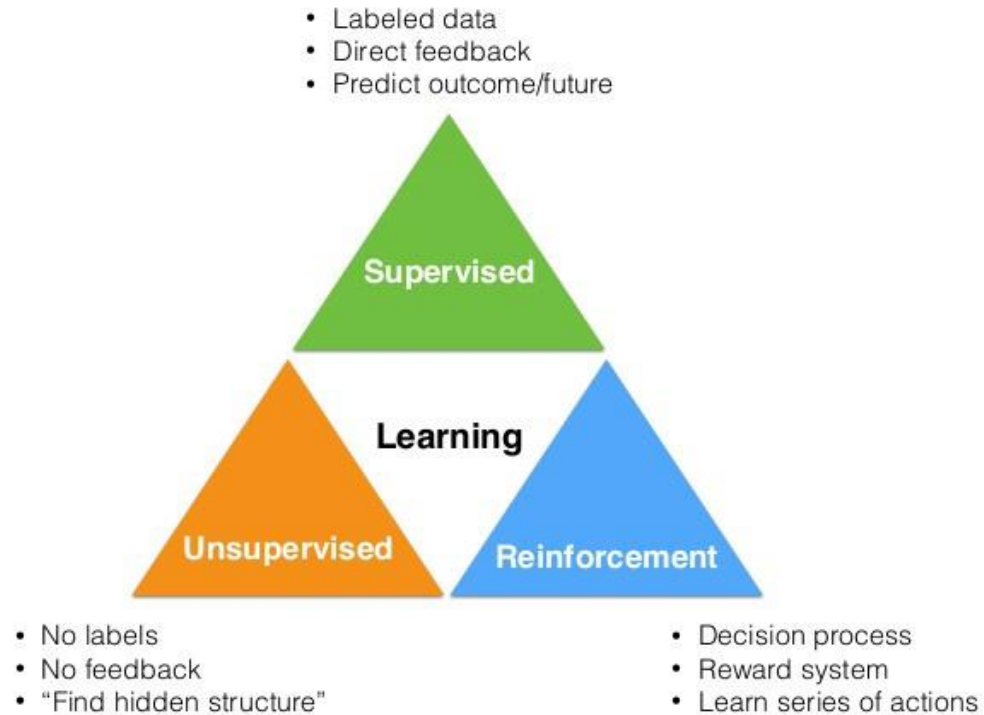
- ▶ Classification
- ▶ Regression
- ▶ Probability estimation

□ Techniques

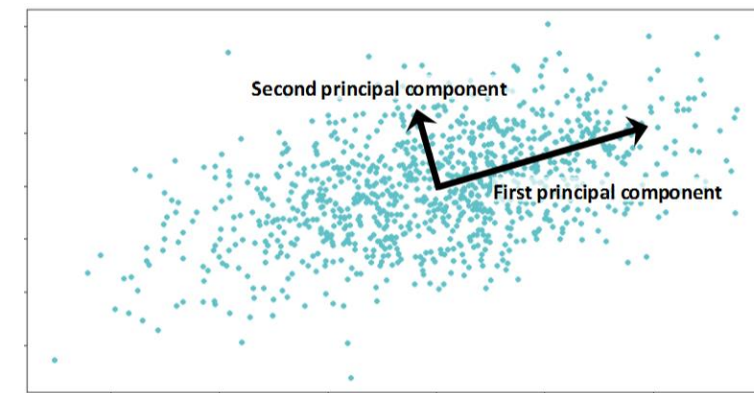
- ▶ Linear Models
- ▶ Artificial Neural Networks
- ▶ Support Vector Machines
- ▶ Decision trees
- ▶ etc.

Learning Paradigms in ML

□ Unsupervised Learning

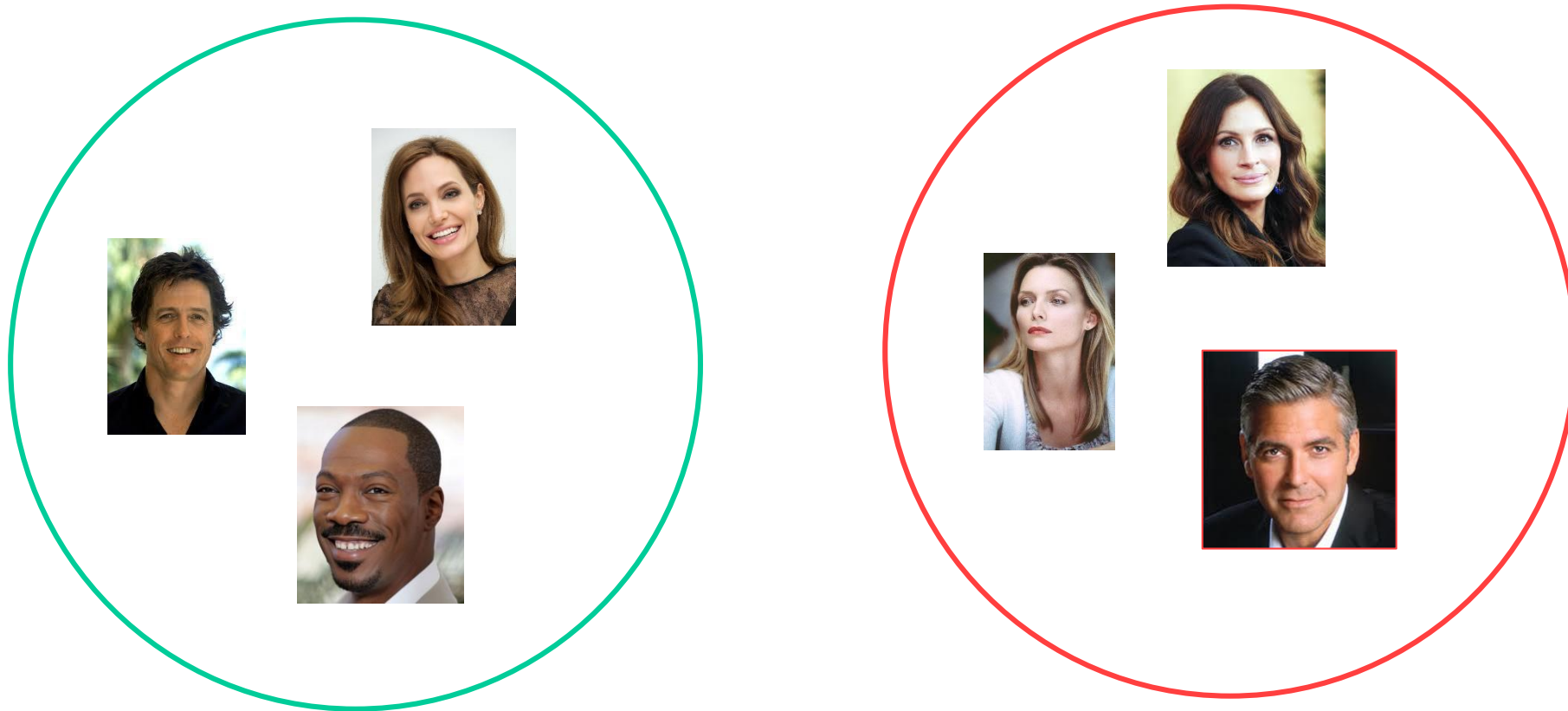


Clustering

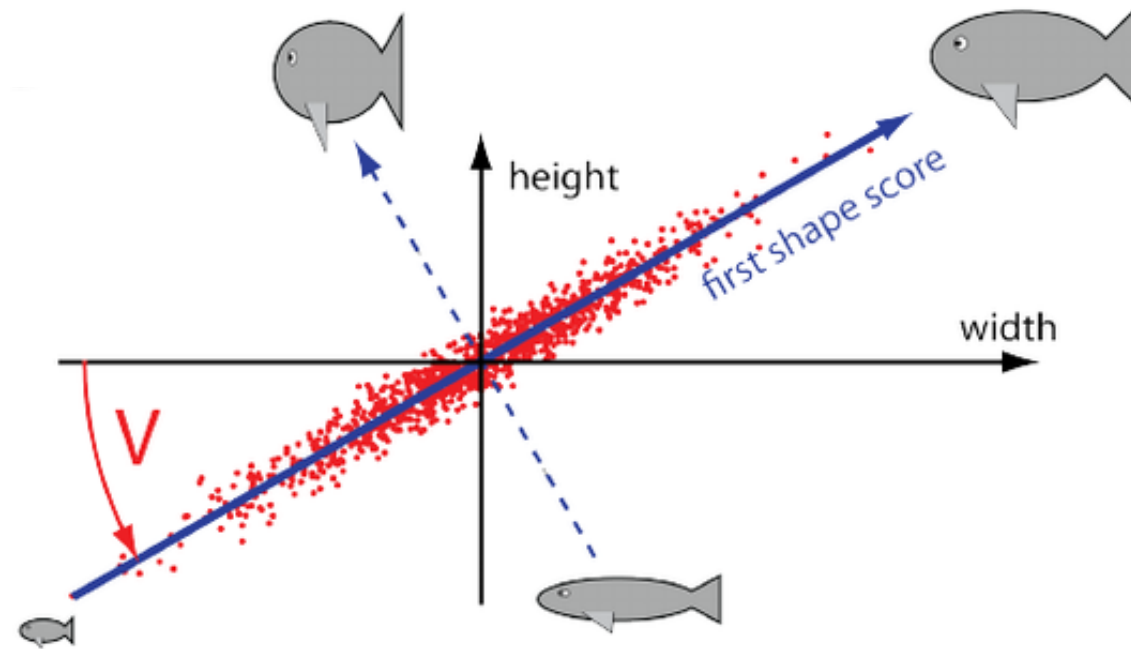
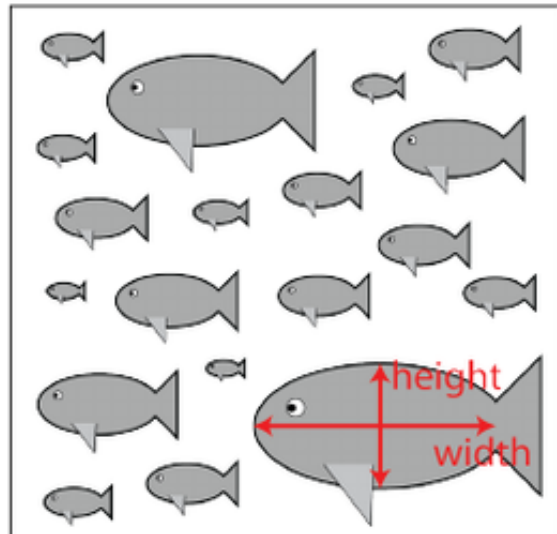


Dimensionality Reduction

An example of clustering



An example of dimensionality reduction



Unsupervised Learning

□ Goal

- ▶ Learn **previously unknown patterns** and **efficient data representation**
- ▶ Training set: $\mathcal{D} = \{x\} \Rightarrow f(x)$

□ Tasks

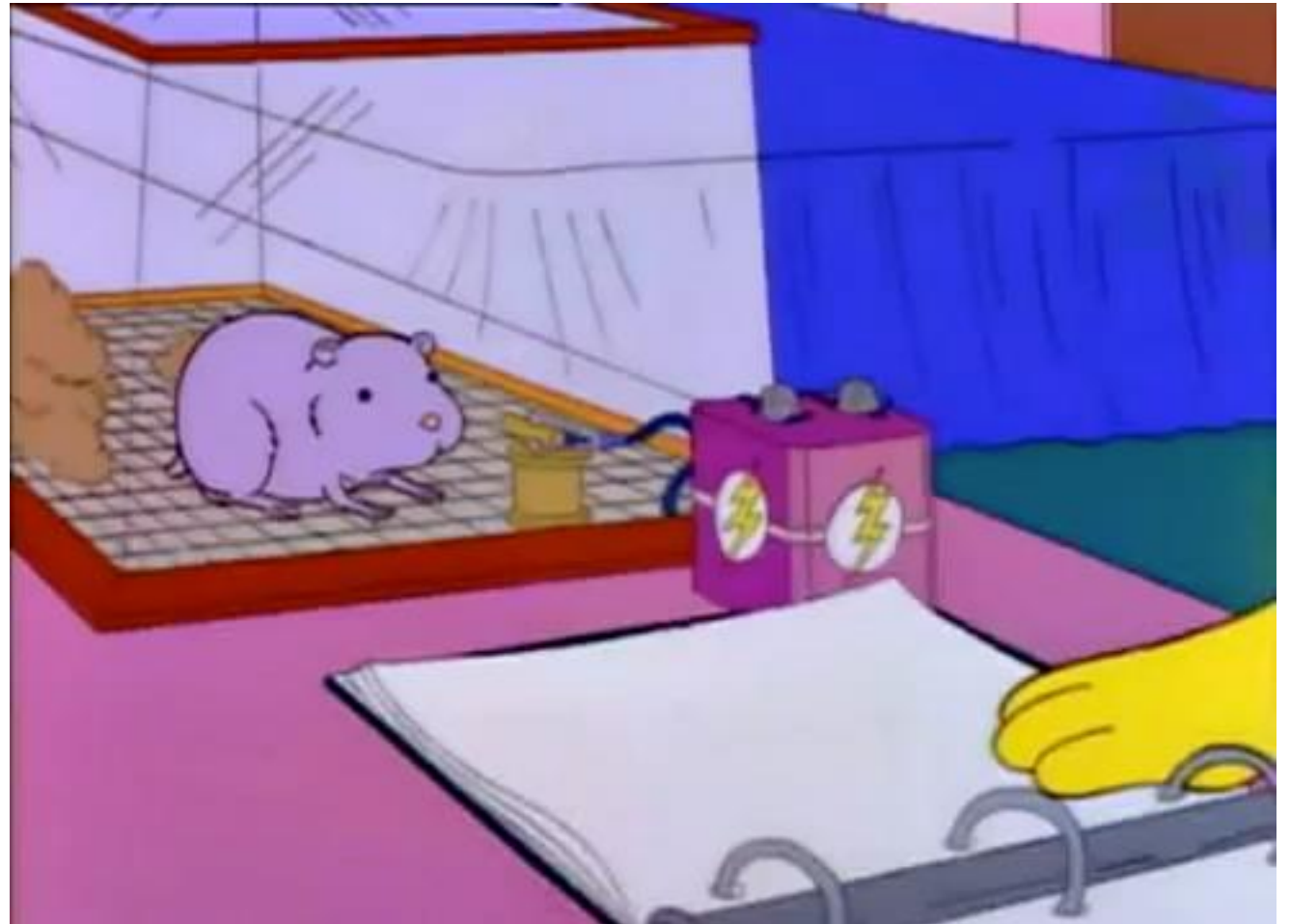
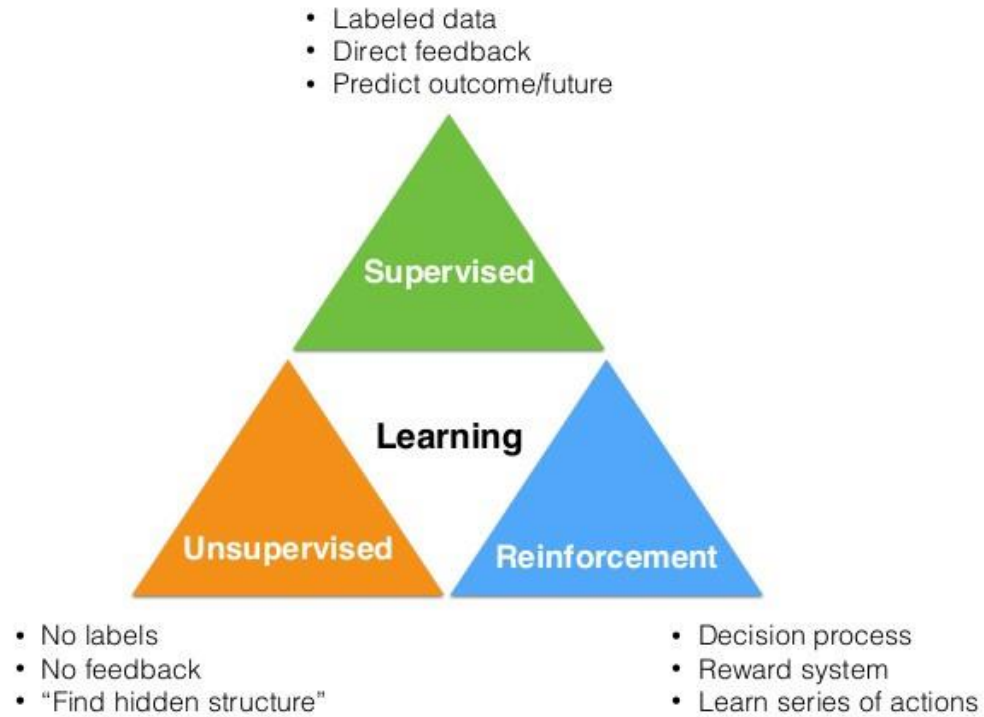
- ▶ Dimensionality Reduction
- ▶ Clustering

□ Techniques

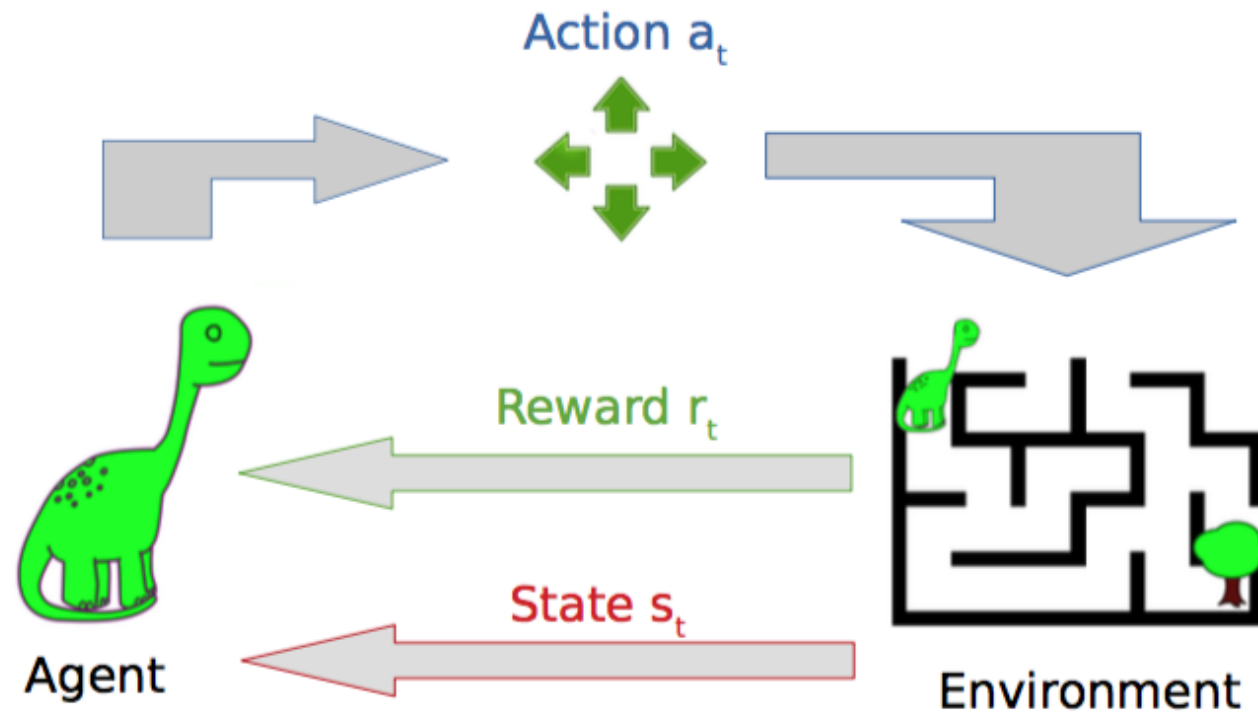
- ▶ K-means
- ▶ Self-organizing maps
- ▶ Principal Component Analysis
- ▶ etc.

Learning Paradigms in ML

□ Reinforcement Learning



An example of reinforcement learning



Reinforcement Learning

□ Goal

- ▶ Learning the **optimal policy**

- ▶ Training set: $\mathcal{D} = \{\langle x, u, x', r \rangle\} \Rightarrow \pi^*(x) = \arg \max_u \{Q^*(x, u)\}$

□ Problems

- ▶ Markov Decision Process (MDP)

- ▶ Partially Observable MDP (POMDP)

- ▶ Stochastic Games (SG)

to estimate

□ Techniques

- ▶ Q-learning

- ▶ SARSA

- ▶ Fitted Q-iteration

- ▶ etc.