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Deep Learning: a hands-on introduction

A course offered in the PhD program in Computer Science and Systems Engineering

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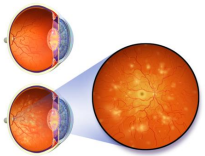
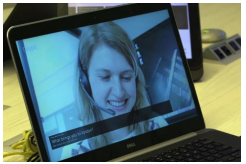
OpenSEARCH

What is deep learning

- Deep learning models have revolutionized many areas of machine intelligence, with particular impact on image understanding tasks

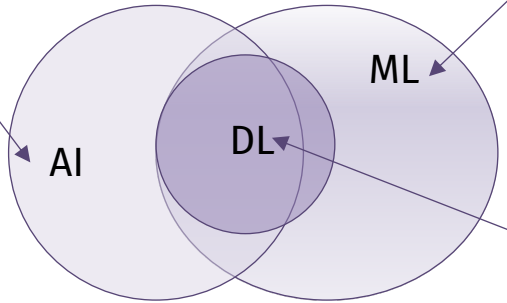





- They are particularly effective for unstructured data, to learn a good representation together with a “model”

What is deep learning

A non-biological system that mimics human behaviour and intelligence

Algorithms that learn models automatically from data



Algorithms that learn from data models that have multiple layers of abstraction

Inspired from https://github.com/rasbt/stat479-deep-learning-ss19/blob/master/L01-intro/L01-intro_slides.pdf

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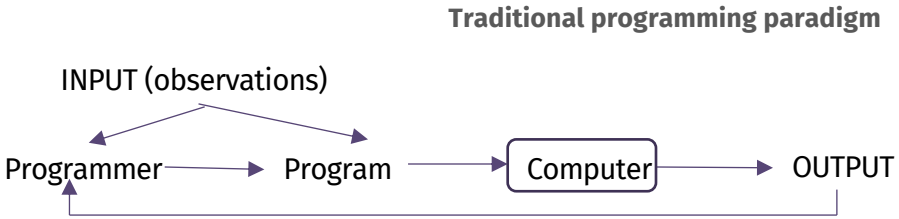
A step back: Machine Learning

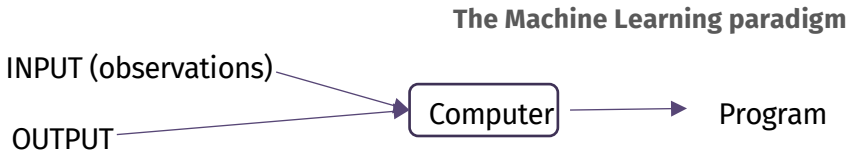
Machine Learning

"It is the field of study that gives computers the ability to learn without being explicitly programmed"

- Arthur L. Samuel, AI pioneer, 1959

Machine Learning





Machine Learning basics

- Supervised learning

- Unsupervised learning

Machine Learning basics

- **Supervised learning**

- Unsupervised learning

Machine Learning basics

The goal of supervised learning is to find an underlying input-output relation

$$f(x_{new}) \sim y$$

given a training set *S*, i.e. a set of *n* input-output pairs (the examples)

$$S = \{(x_1, y_1), \ldots, (x_n, y_n)\}$$

where

$$x_i \in X \subseteq \mathbb{R}^D \qquad y_i \in Y \subseteq \mathbb{R}$$

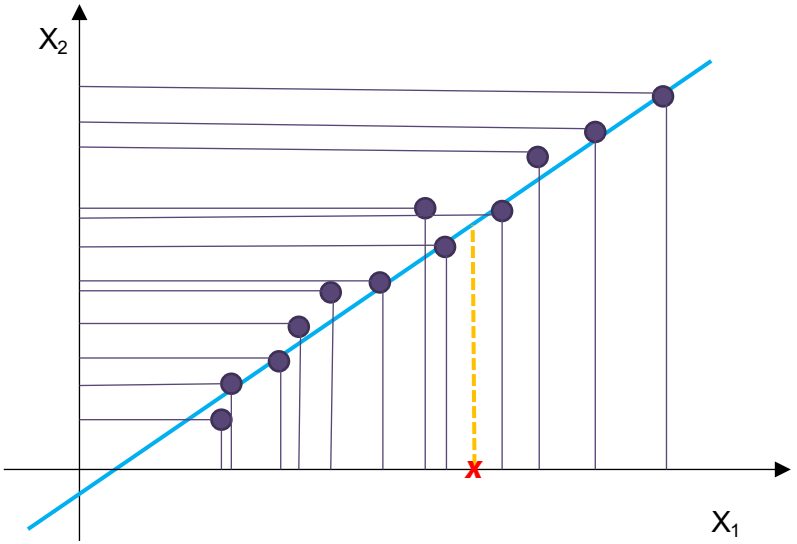
From http://lcsl.mit.edu/courses/mlcc/mlcc2019/slides/MLCC_SLT.pdf

Machine Learning basics

- The problem may take different shapes
  - Regression: $Y \subseteq \mathbb{R}$
  - Binary classification: $Y = \{-1, 1\}$
  - Multi-class classification: $Y = \{1, 2, \ldots, T\}$
  - ...

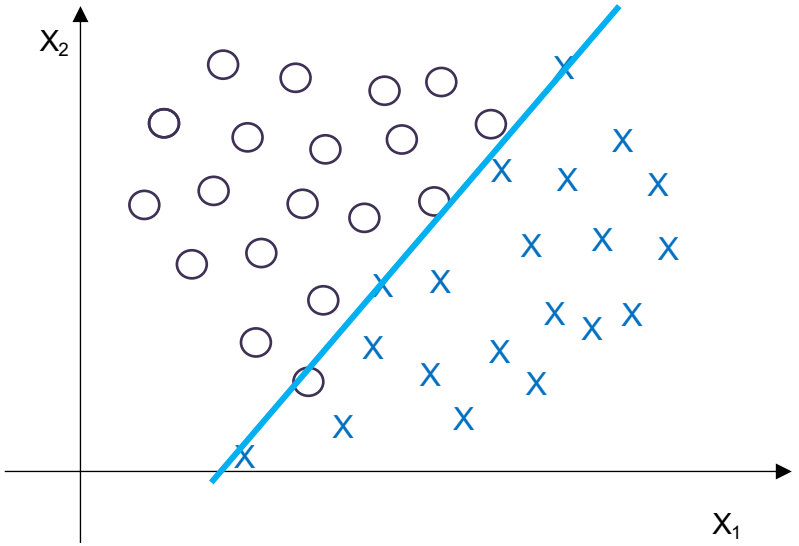
Machine Learning basics

Regression



Machine Learning basics

Classification



Machine Learning basics

Goal: estimating the best I/O relation given “certain assumptions on the data population”

$$f^* : X \rightarrow Y$$

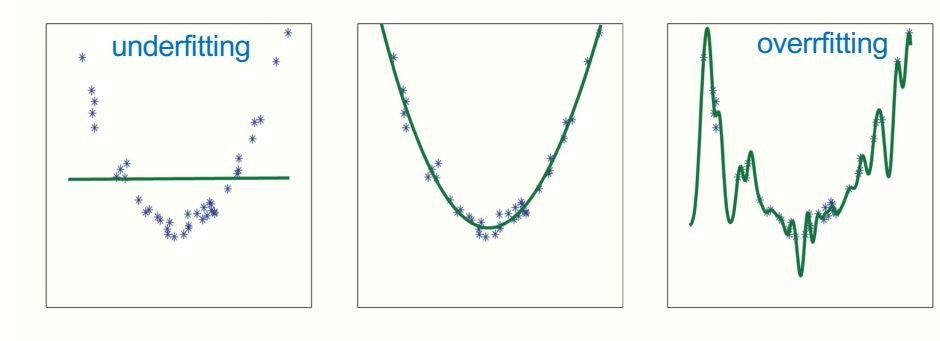
that minimizes a loss function, i.e. a point-wise error measure that estimates the cost of predicting *f(x)* in place of the true *y*

$$\mathcal{L} : Y \times Y \rightarrow [0, \inf)$$

We can only find an estimator of the target function from the available data

Machine Learning basics

- Two desired properties for the estimator are
  - Capability of fitting the available data
  - Capability of generalizing to new, unseen data



– From http://lcsl.mit.edu/courses/mlcc/mlcc2019/slides/MLCC_SLT.pdf

Machine Learning basics

- Supervised learning

- **Unsupervised learning**

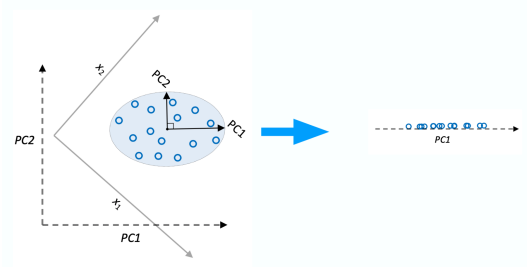
Machine Learning basics

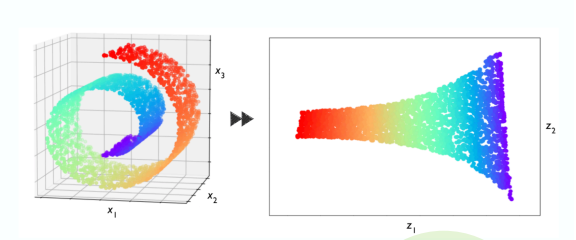
- The goal of unsupervised learning is to find hidden structure in the sample data, for which no label is available

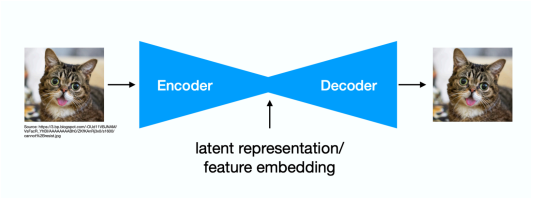
$$S = \{(x_1, \square), \ldots, (x_n, \square)\}$$

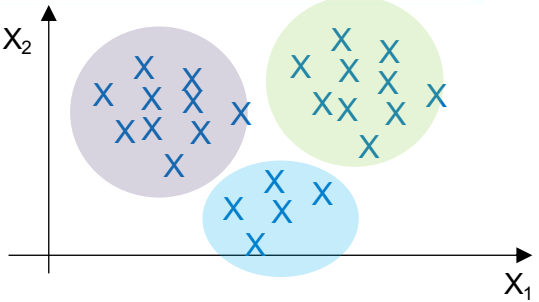
$$x_i \in X \subseteq \mathbb{R}^D$$

Machine Learning basics



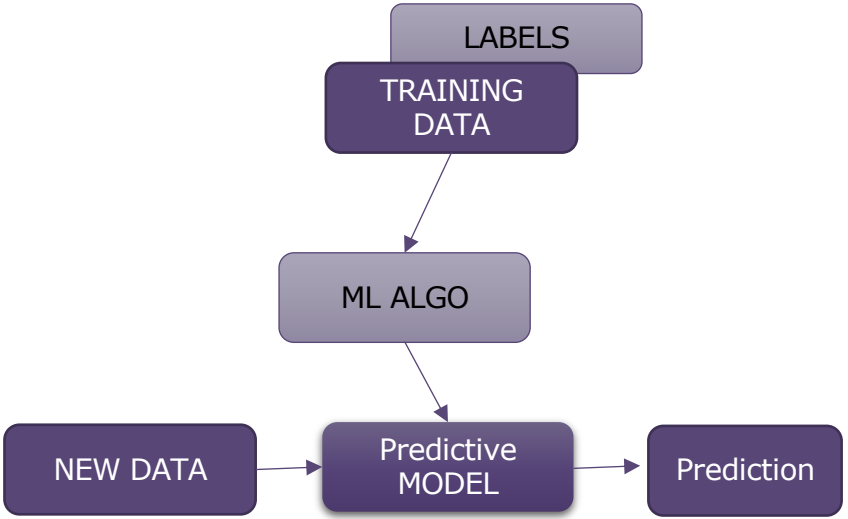






– Partially from https://github.com/rasbt/stat479-deep-learning-ss19/blob/master/L01-intro/L01-intro_slides.pdf

Machine Learning basics



STEPS:

- Define the problem
- Collect [labelled] data
- Pick an algorithm
- Choose an optimization strategy
- Choose a metric for evaluating the model

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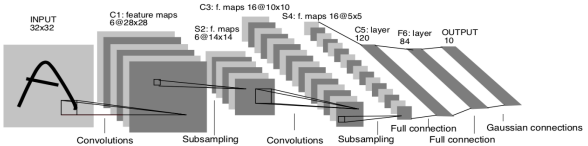
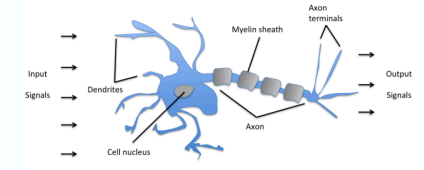
This course

The subject of this course



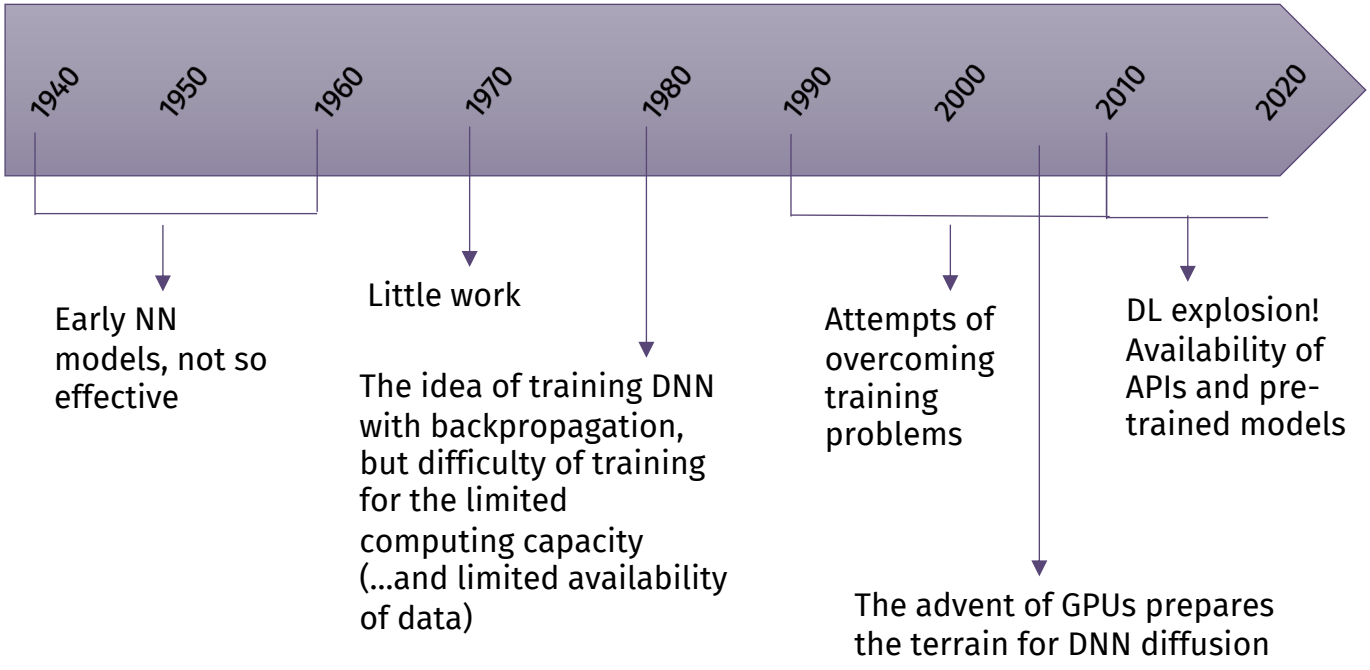
- **Deep learning** is a family of machine learning methods based on artificial neural networks (ANNs) that use multiple layers to **progressively extract higher level features from raw input**

- **ANNs** are computing systems inspired by the **biological neural networks**, based on a collection of units/nodes, the artificial neurons, loosely modelling the neurons in a biological brain



- <u>But also</u>: Deep learning methods are representation-learning methods with multiple levels of representation

A little bit of history

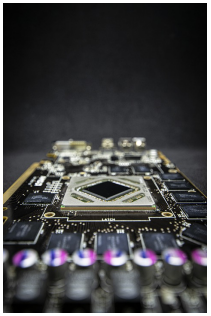


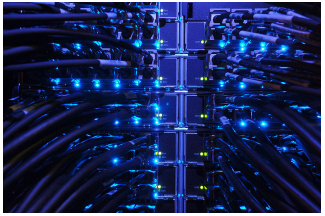
A synergy for a resurgence

Data availability

IMAGENET

Technological advances





Goal of this course

- Providing the background to **understand deep learning principles**

- Gaining **hands-on experience** of a variety of problems with state-of-art frameworks

Schedule

	Day-time	Class/Lab	People
Day 1	Monday, July 13th 9:30am	Introduction to the course From Neural Networks to Deep Neural Networks	Nicoletta Noceti
	Monday, July 13th 11:15am	Lab #1 - Deep Neural Networks	Issa Mouawad Elena Nicora Nicoletta Noceti
Day 2	Tuesday, July 14th 9:30am	Dealing with images: Convolutional Neural Networks	Nicoletta Noceti
	Tuesday, July 14th 11:15am	Lab #2 - Convolutional Neural Networks	Issa Mouawad Paolo Didier Alfano Nicoletta Noceti
Day 3	Wednesday, July 15th 9:30am	Dealing with time: Recurrent Neural Networks and Long-Short Term Memory	Nicoletta Noceti
	Wednesday, July 15th 11:15am	Lab #3 - Recurrent Neural Networks & Long-Short Term Memory	Vito Paolo Pastore Tilani Gunawardena Nicoletta Noceti
Day 4	Thursday, July 16th 9:30am	Autoencoders and GANs	Nicoletta Noceti
	Thursday, July 16th 11:15am	Lab #4 - GANs	Giorgio Cantarini Luca Garello Nicoletta Noceti
Day 5	Friday, July 17th 9:30am	Limitations and new frontiers	Nicoletta Noceti
	Friday, July 17th 10:00am	Starting with your own data: a case study	Gaurvi Goyal
	Friday, July 17th 10:30am	Applications: An industrial take	Vito Paolo Pastore
	Friday, July 17th 11:15am	Applications: Human Motion Understanding in the Rehab Field	Matteo Moro
	Friday, July 17th 11:45am	Applications: Visual perception for autonomous agents	Issa Mouawad

People helping me (a lot!)

Paolo Didier Alfano

Giorgio Cantarini

Luca Garello

Gaurvi Goyal

Tilani Gunawardena

Matteo Moro

Issa Mouawad

Elena Nicora

Vito Paolo Pastore

If you want to know moewabout us have a look at **https://ml.unige.it**

Material

- Sources of inspiration
  - https://www.deeplearningbook.org
  - https://github.com/rasbt/stat479-deep-learning-ss19
  - http://introtodeeplearning.com

- These slides are in a draft state, corrections and comments are welcome!

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