Machine Learning on DESI Data

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Mexican
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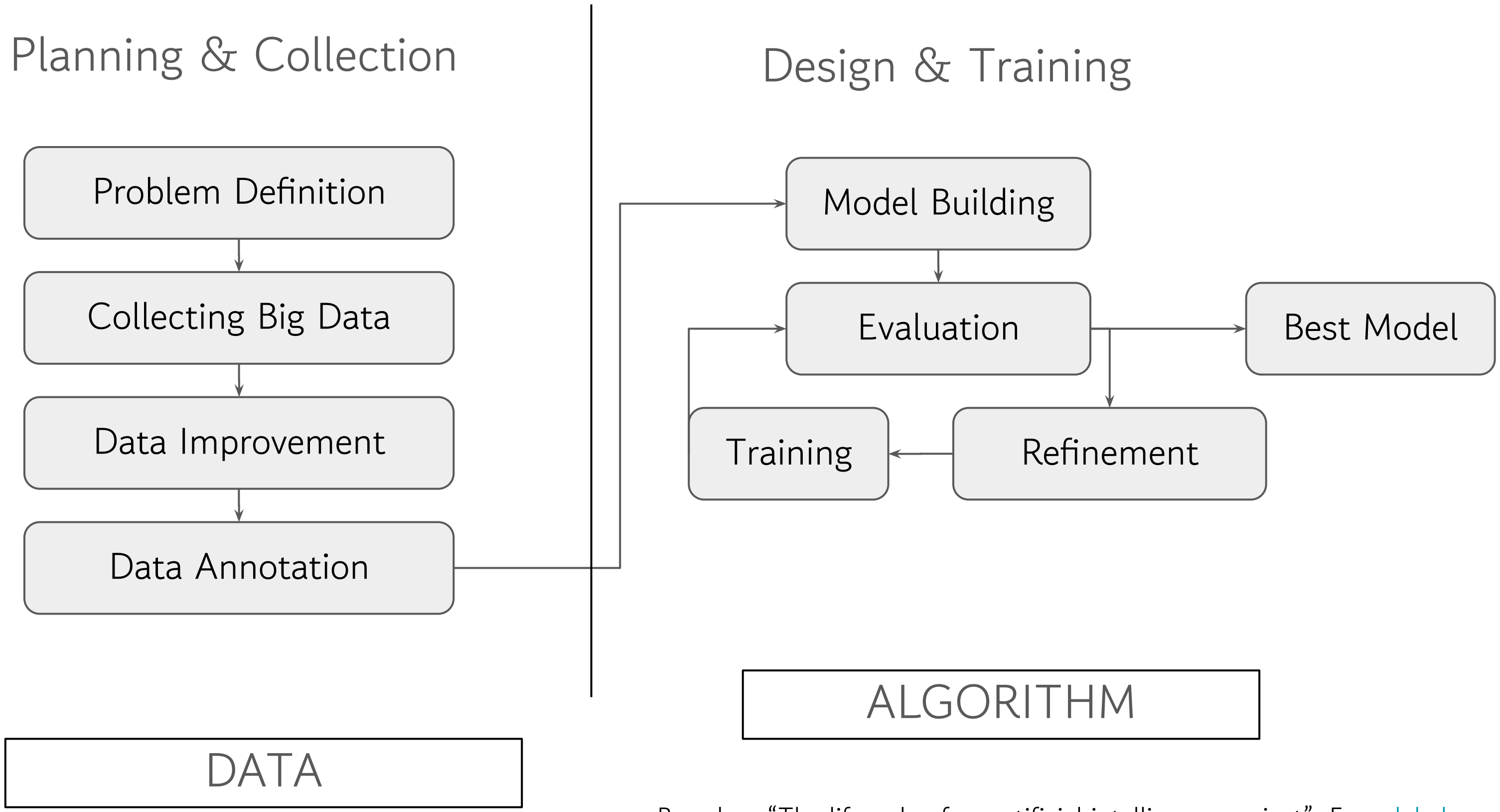
Statistics
School

AI project stages



Planning & Collection

Problem Definition

Collecting Big Data

Data Improvement

Data Annotation

DATA

Design & Training

Model Building

Evaluation

Best Model

Training

Refinement

ALGORITHM

Based on “The lifecycle of an artificial intelligence project”. From labelyourdata.

DESI Spectra Classification

DESI's Current Progress

- 50 million spectra measured (as of Dec 2024) (36.3 M galaxies & quasars. 13.7 M stars.)
- Data Release 1 (DR1): 18 million unique objects.
- Data Release 2 (DR2, March 2025): includes the first 3 years of observations.
- Backup program: ~7 M Milky Way stars observed (1.2 M in DR1).

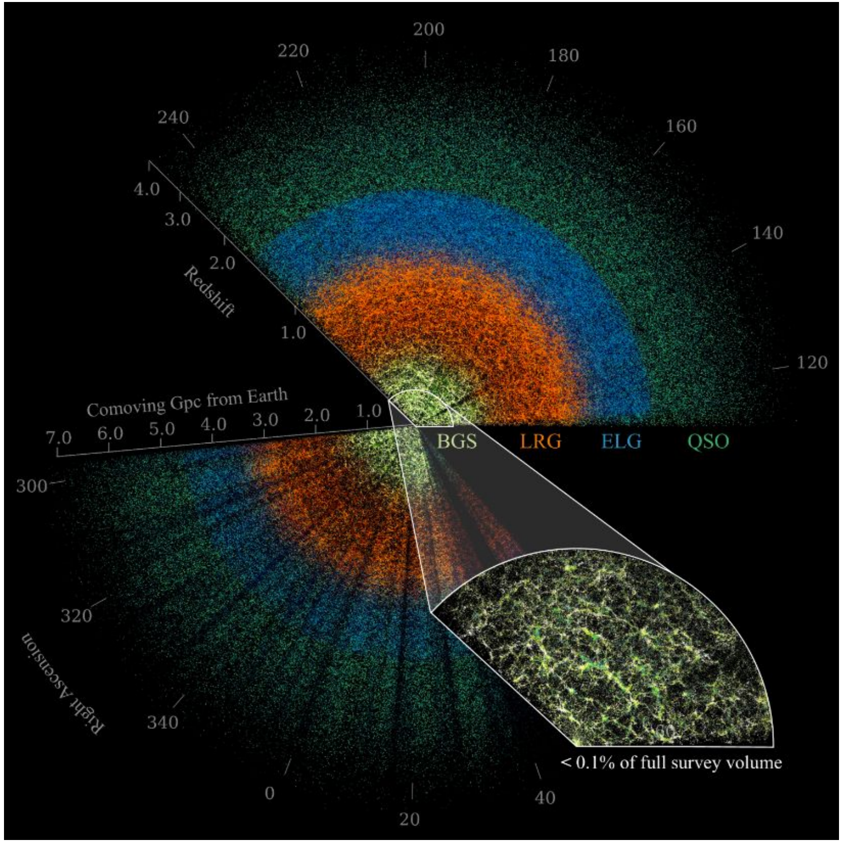
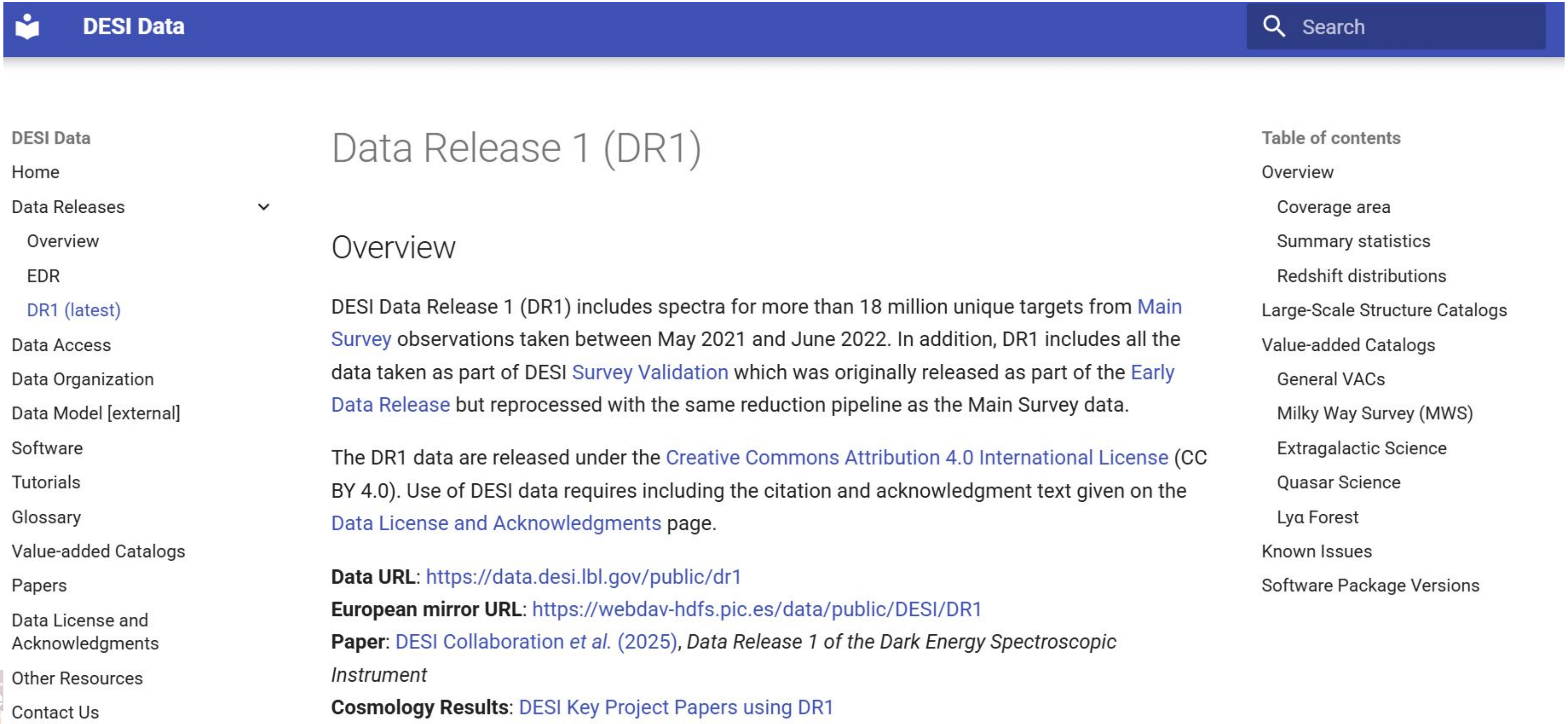


Image from Data Release 1 of the Dark Energy Spectroscopic Instrument paper.

Data Release 1



Data Release 1 (DR1)

Overview

DESI Data Release 1 (DR1) includes spectra for more than 18 million unique targets from Main Survey observations taken between May 2021 and June 2022. In addition, DR1 includes all the data taken as part of DESI Survey Validation which was originally released as part of the Early Data Release but reprocessed with the same reduction pipeline as the Main Survey data.

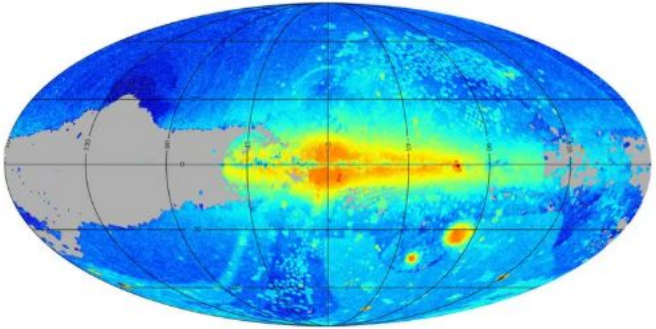
The DR1 data are released under the Creative Commons Attribution 4.0 International License (CC BY 4.0). Use of DESI data requires including the citation and acknowledgment text given on the Data License and Acknowledgments page.

Data URL: https://data.desi.lbl.gov/public/dr1
European mirror URL: https://webdav-hdfs.pic.es/data/public/DESI/DR1
Paper: DESI Collaboration *et al.* (2025), *Data Release 1 of the Dark Energy Spectroscopic Instrument*
Cosmology Results: DESI Key Project Papers using DR1

https://data.desi.lbl.gov/doc/releases/dr1/

Astro Data Lab + SPARCL

Astro Data Lab Science Platform



The Astro Data Lab Science Platform enables efficient exploration and analysis of the large datasets now being generated by instruments on NOIRLab and various other wide-field telescopes.

SPARCL: Spectra Analysis & Retrievable Catalog Lab

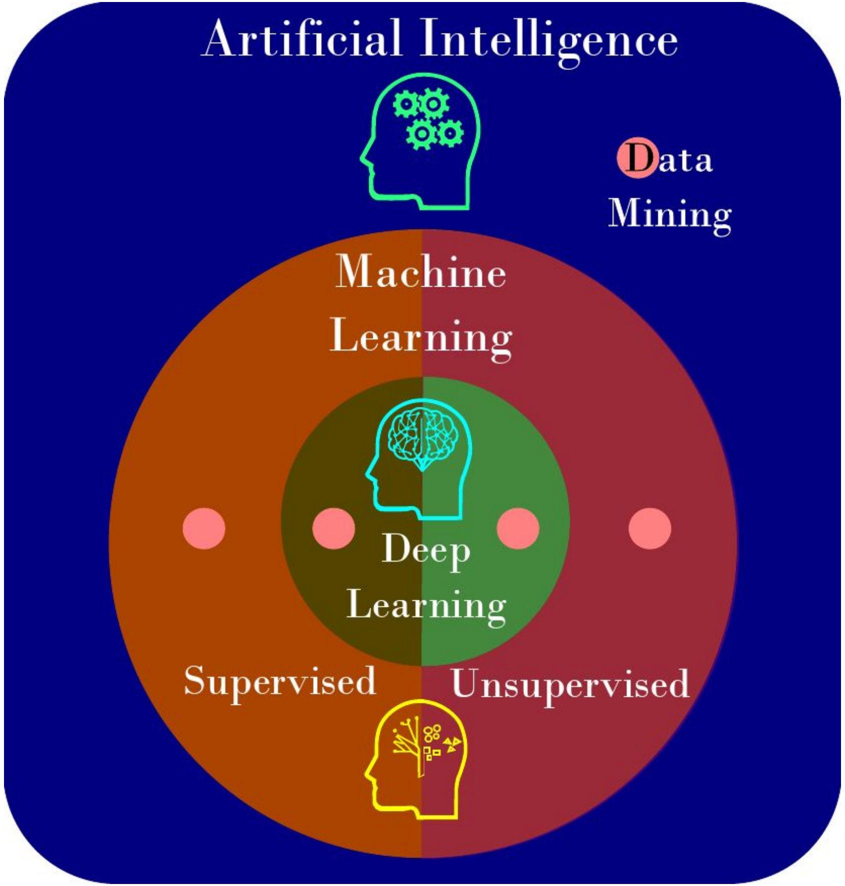
- ❑ Online service for discovery and retrieval of 1D optical/infrared spectra.
- ❑ Currently hosts data from SDSS and BOSS spectrographs.
- ❑ Designed to support DESI spectra, to be included with the first public data release.

What is AI?

❑ Simulating of human intelligence in machines (visual perception, speech recognition, decision-making, language processing).

❑ Algorithms and models that can process large amounts of data, trained with techniques as **Supervised** or **Unsupervised** learning.

❑ Main subfields of AI are Machine & Deep learning. Data Mining cut across both.



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Supervised & Unsupervised Learning

Supervised

- Used for classification or regression tasks.

- Requires to use labels to make predictions.

ML Algorithms

* Support Vector Machines
* K-nearest neighbors
* Decision Trees
* Random Forest.

DL Algorithms

* Multi-Layer Perceptron
* Convolutional Neural Network
* Recurrent Neural Network
* Transformers

Unsupervised

- Used for clustering or dimensionality reduction tasks.

- Doesn't require to use labels. Used to find patterns.

DL Algorithms

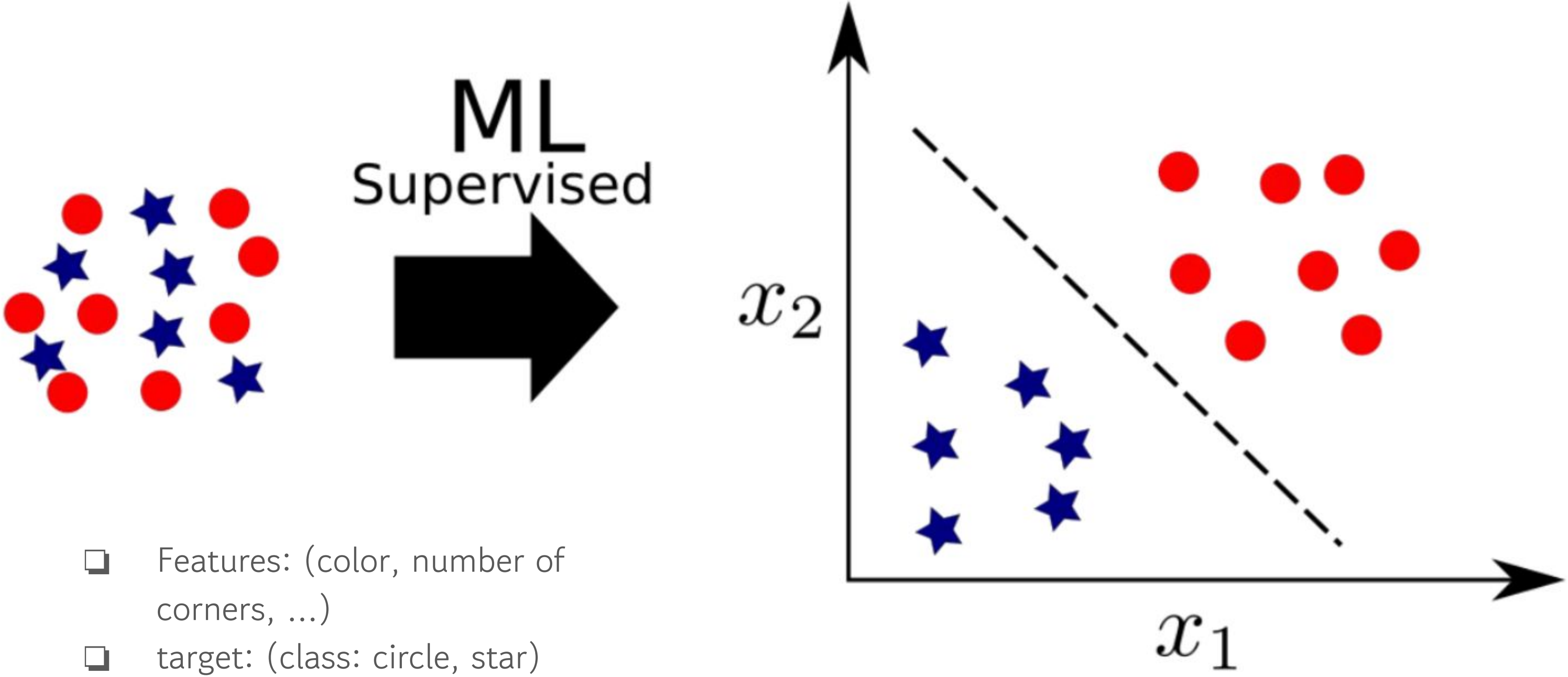
* Autoencoders

ML Algorithms

Clustering:
* K-means clustering
* DBScan
* Gaussian Mixture Models

Dimensionality Reduction:
* PCA
* Isometric Map
* T-SNE
* UMAP

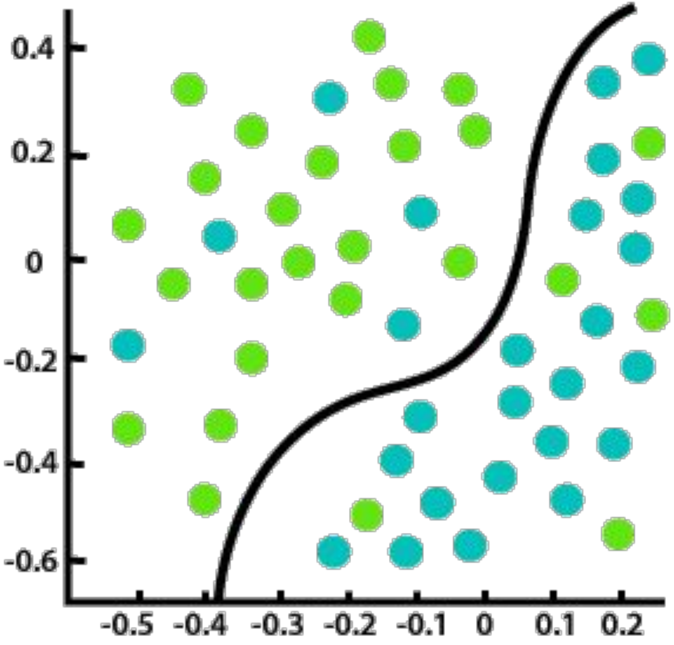
Supervised Learning



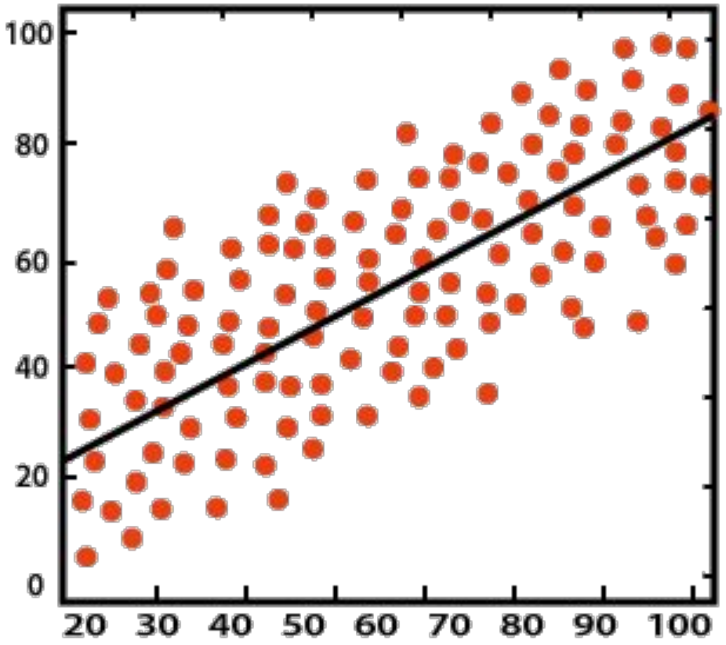
- Features: (color, number of corners, ...)
- target: (class: circle, star) (mass,...)

Supervised Learning

Classification



Regression

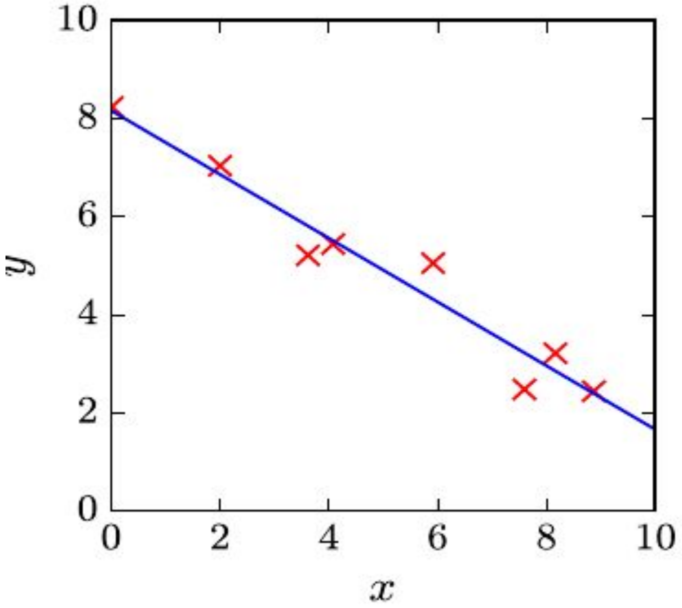


Linear Regression

$$f(x, \vec{\beta}) = \beta_o + \beta_1 x$$

$$MSE : L(x, y, \vec{\beta}) = \frac{1}{N} \sum_{i=1}^{N} (f(x, \vec{\beta}) - y_i))^2$$

$$\beta_{best} = \beta \; when \; \left(\left. \frac{\partial L(x,y,\vec{\beta})}{\partial \vec{\beta}} \right|_{x,y} = 0 \right)$$



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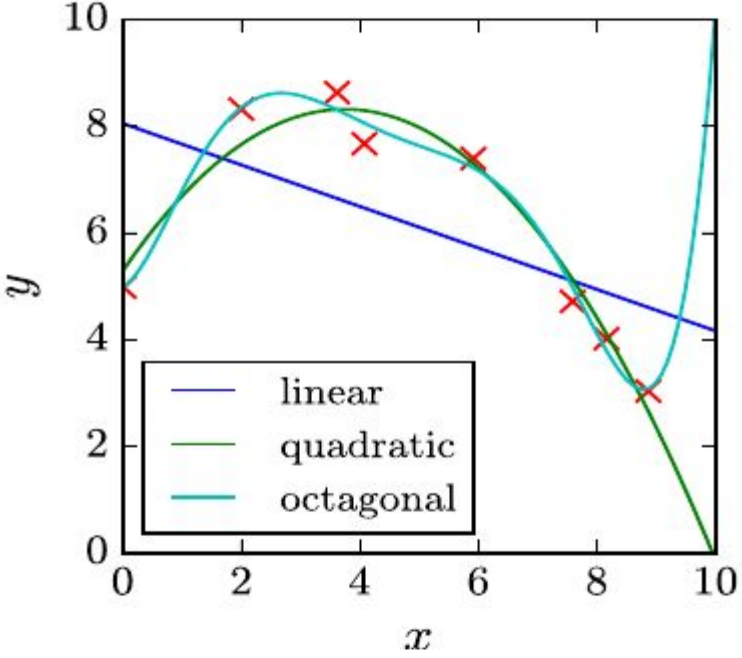
Non-Linear Regression

$$f(x,\vec{\beta}) = \beta_o + \beta_1 x + \beta_2 x^2$$

$$MSE : L(x,y,\vec{\beta}) = \frac{1}{N}\sum_{i=1}^{N}(f(x,\vec{\beta}) - y_i))^2$$

$$\beta_{best} = \beta \ when \ \left(\left.\frac{\partial L(x,y,\vec{\beta})}{\partial \vec{\beta}}\right|_{x,y} = 0 \right)$$



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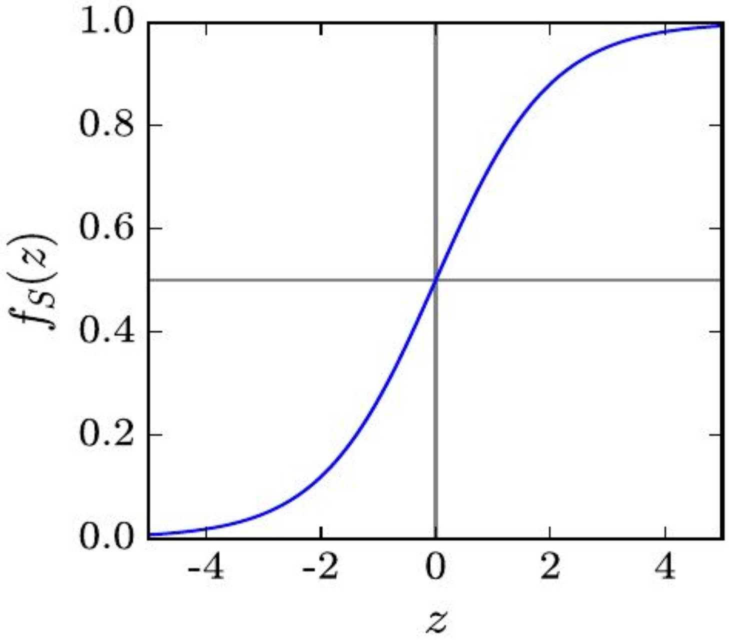
Classification



$$f_s(z) = \frac{1}{1+e^{-z}}$$

$$z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_1^2 + \beta_4 x_2^2 + \beta_5 x_1 x_2$$

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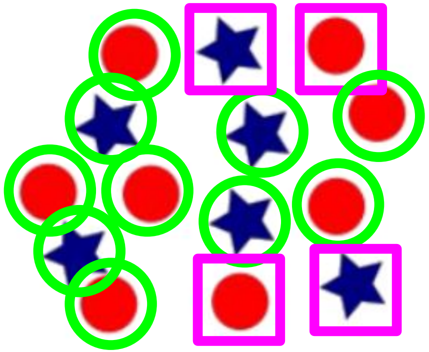
Train/Test Split

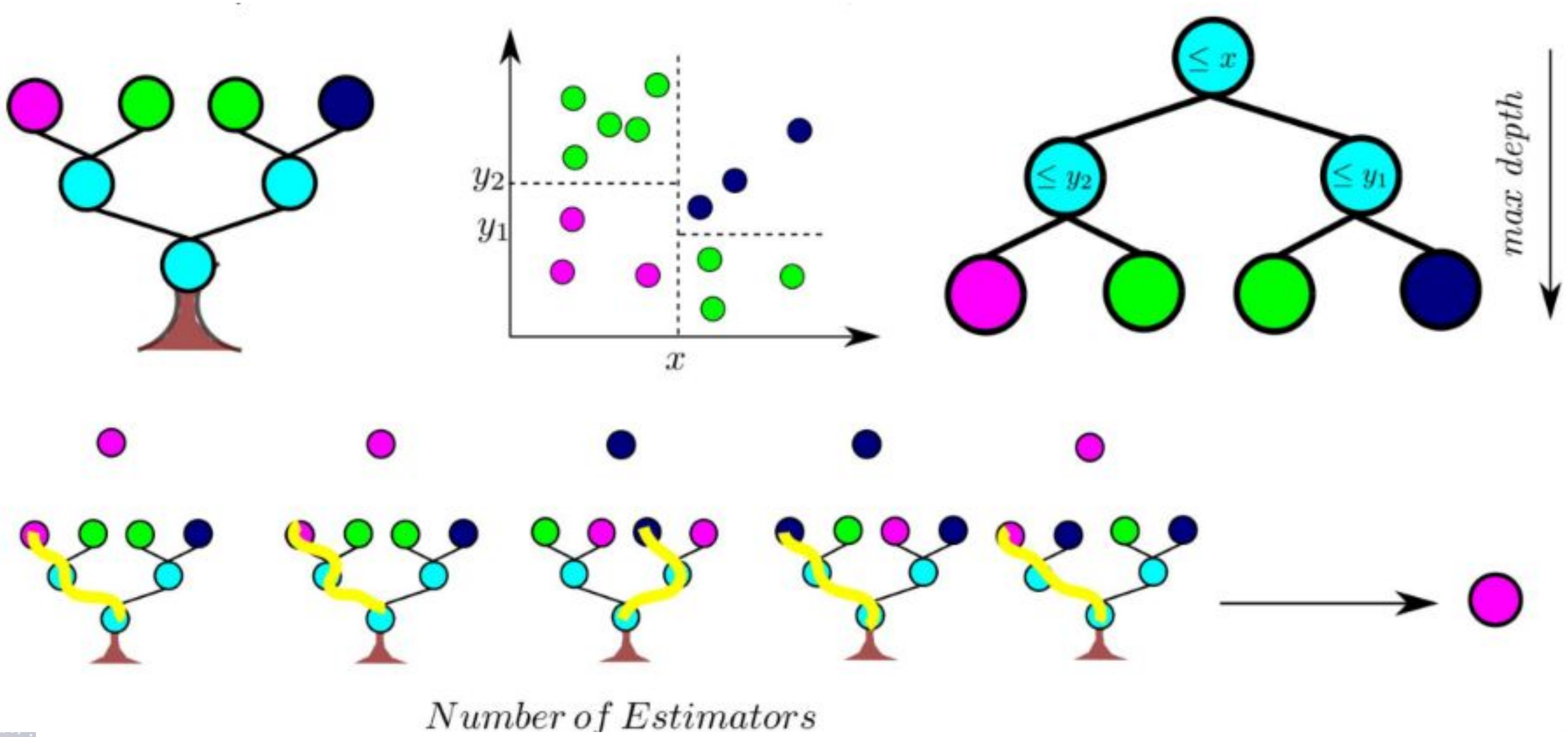
- ❑ Must **train** the model with a fraction of the data (**train data**) and **evaluate** its performance with the remaining fraction (**test data**).
- ❑ To **avoid overfitting** and to **assess the quality** of the fit/prediction.

○ *train data (70%)*

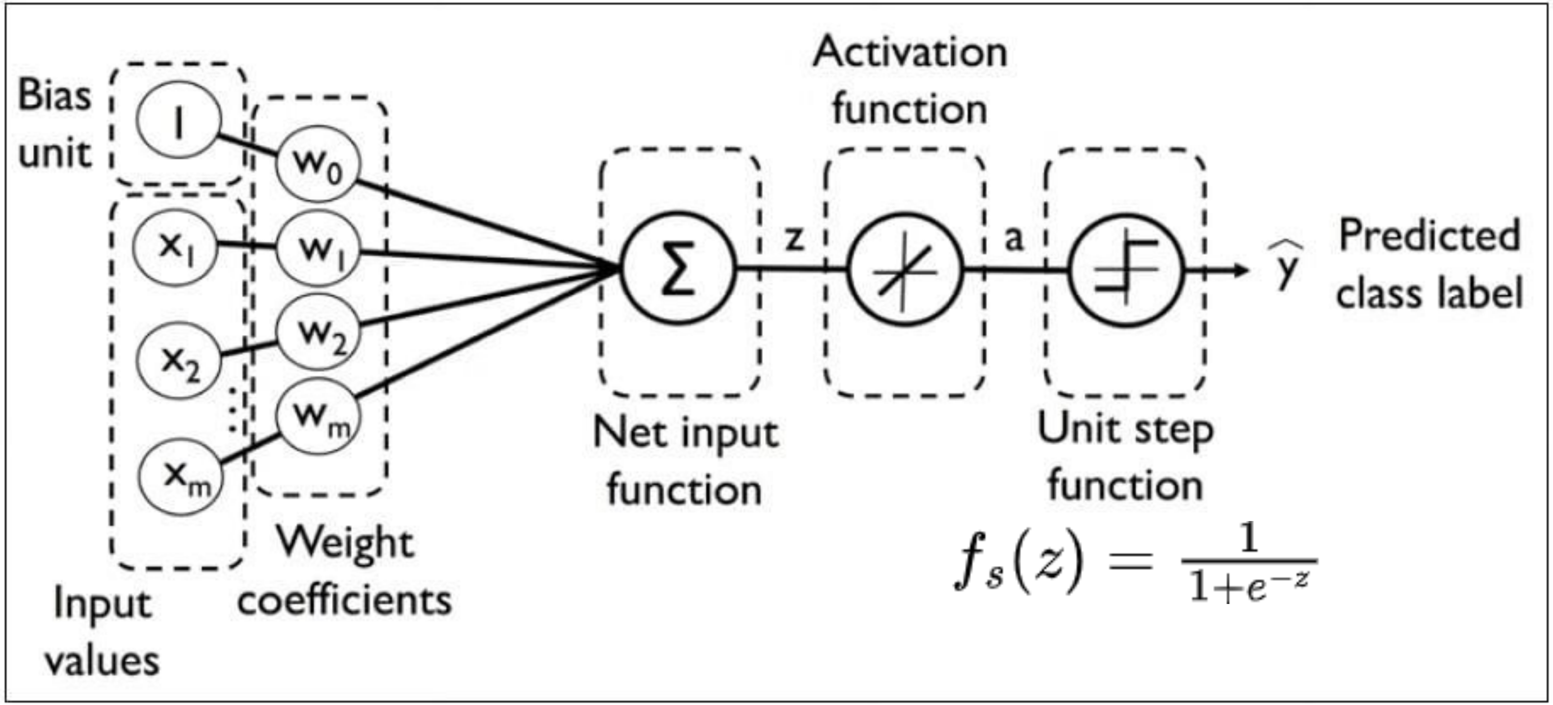
□ *test data (30%)*



Decision Trees & Random Forest



Multilayer Perceptron



$$f_s(z) = \frac{1}{1+e^{-z}}$$

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