CS 540 Introduction to Artificial Intelligence

Machine Learning Overview

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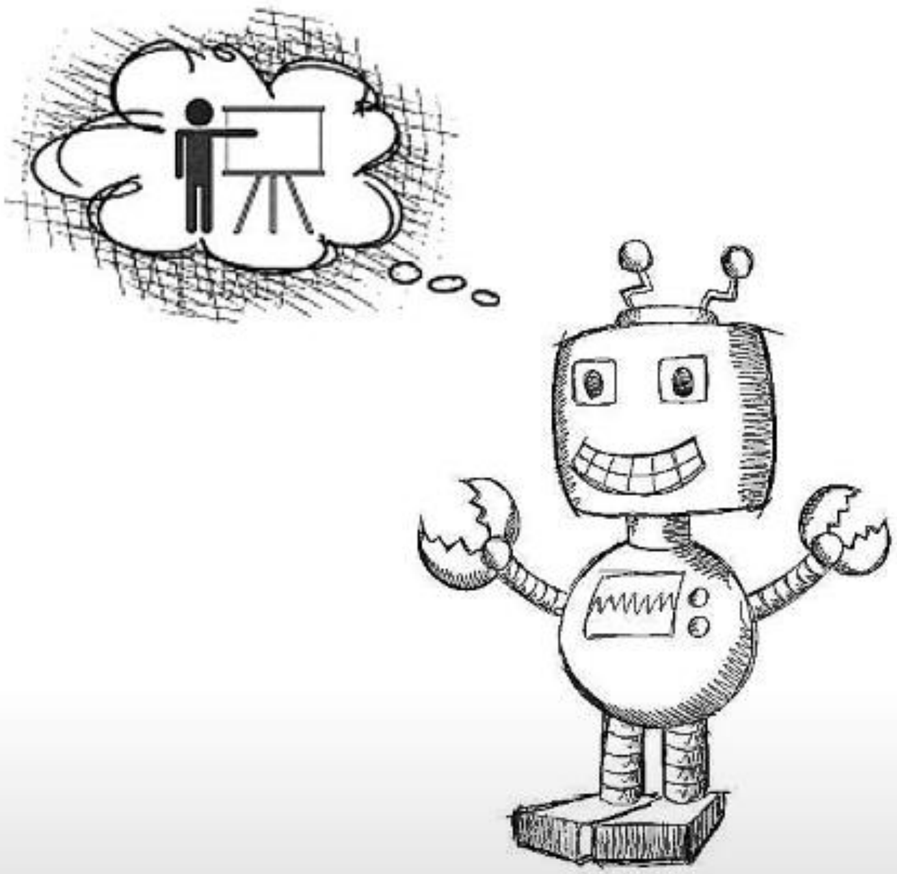
Slides created by Sharon Li [modified by Yingyu Liang]

Today’s outline

- What is machine learning?
- Supervised Learning
  - Classification
  - Regression
- Unsupervised Learning
  - Clustering
- Reinforcement Learning

Part I: What is machine learning?

HUMANS LEARN FROM
PAST EXPERIENCES

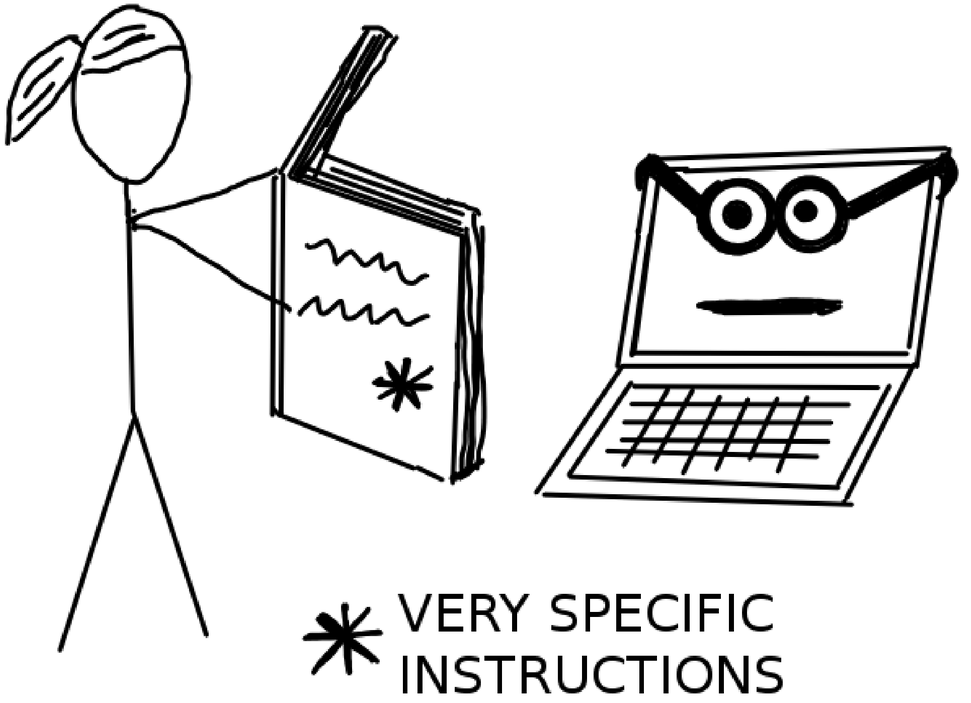


MACHINES FOLLOW INSTRUCTIONS
GIVEN BY HUMANS

What is machine learning?

- Arthur Samuel (1959): Machine learning is the field of study that gives the computer the ability to learn **without being explicitly programmed**.

Without Machine Learning



With Machine Learning

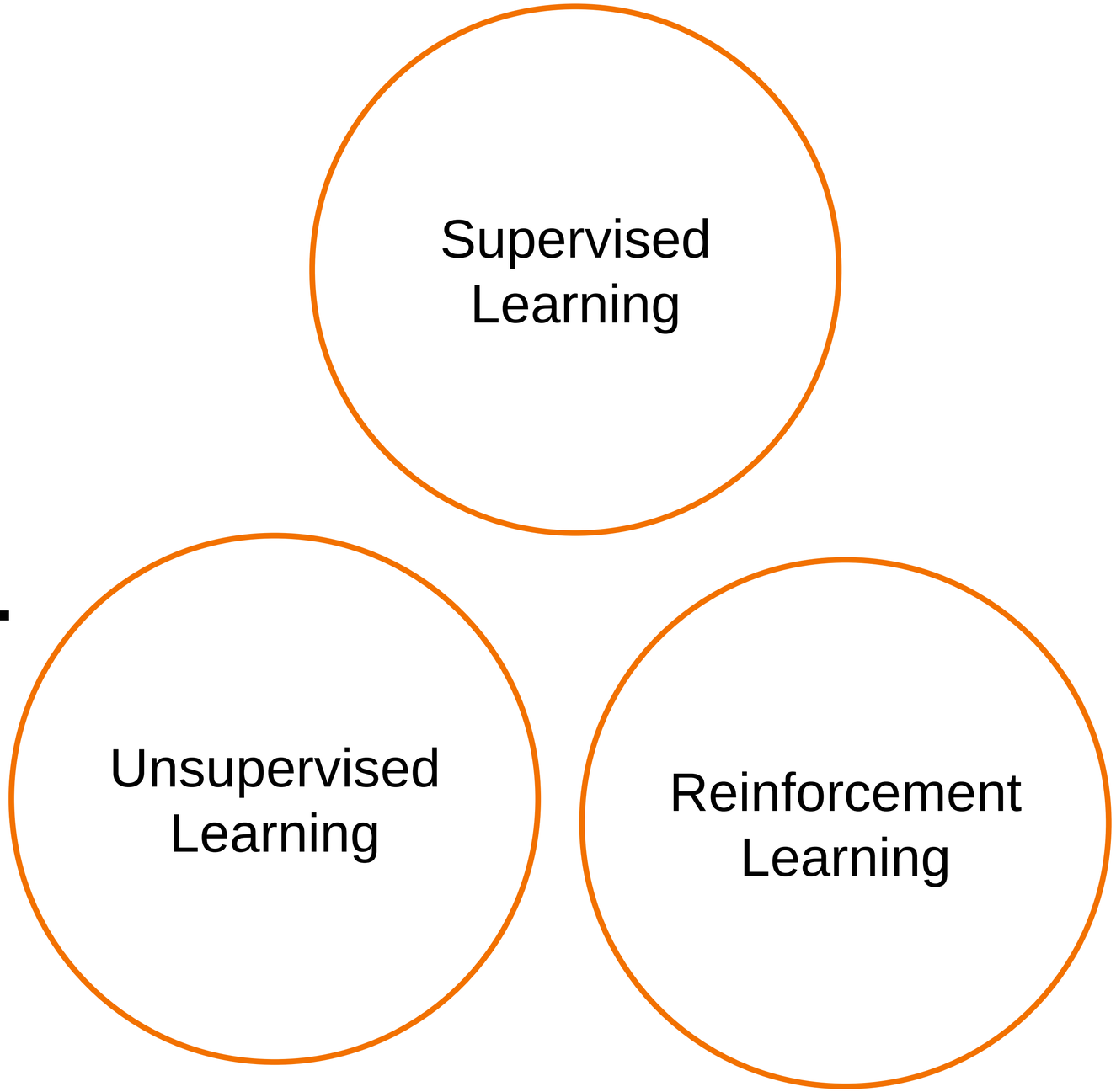
https://tung-dn.github.io/programming.html

What is machine learning?

- Arthur Samuel (1959): Machine learning is the field of study that gives the computer the ability to learn **without being explicitly programmed**.

- Tom Mitchell (1997): A computer program is said to learn from **experience E** with respect to some class of **tasks T** and **performance measure P**, if its performance at tasks in T as measured by P, improves with experience E.

Taxonomy of ML



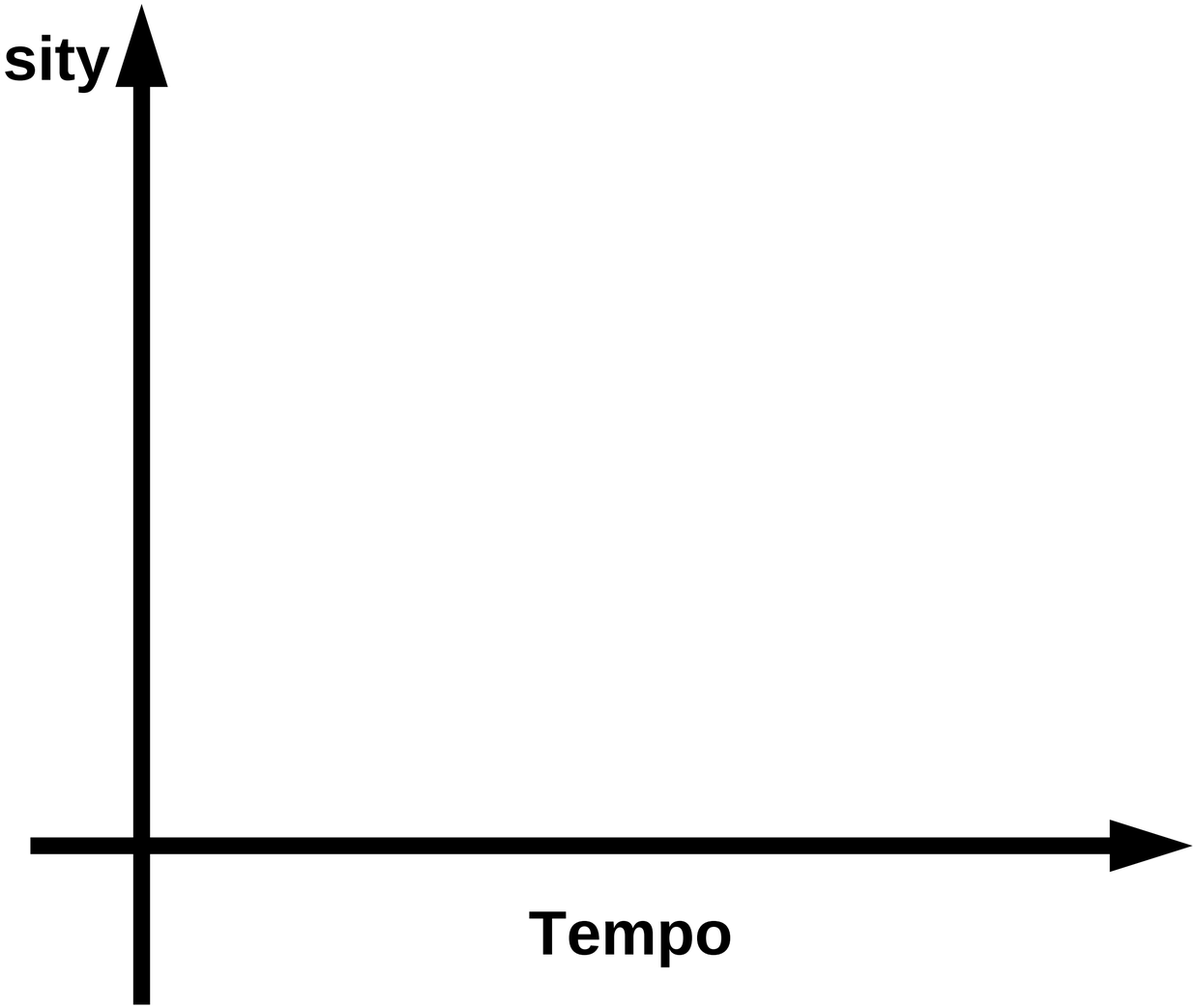
Part II: Supervised Learning

Example 1: Predict whether a user likes a song or not

model

Example 1: Predict whether a user likes a song or not

User Sharon

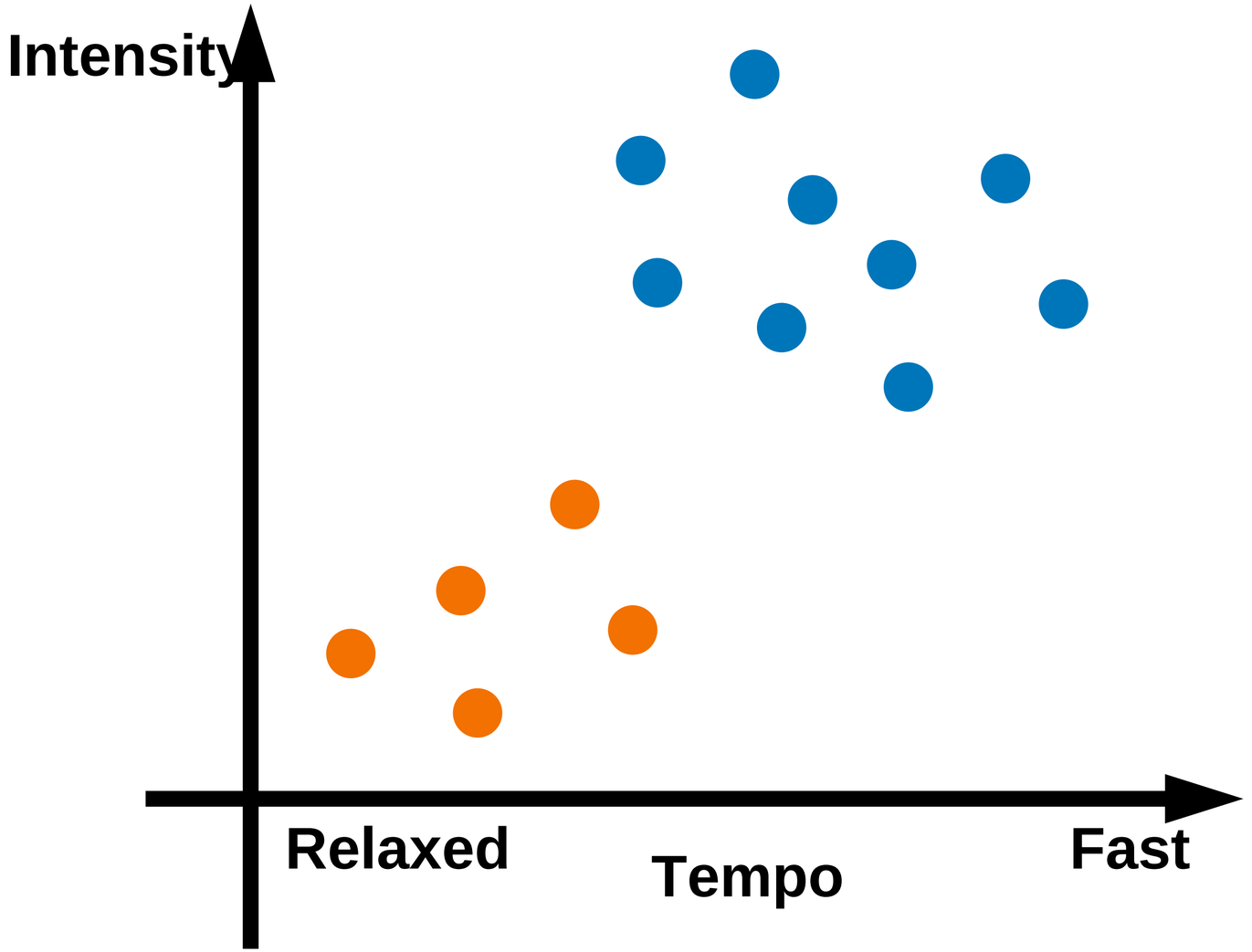


Example 1: Predict whether a user likes a song or not

User Sharon

DisLike

Like



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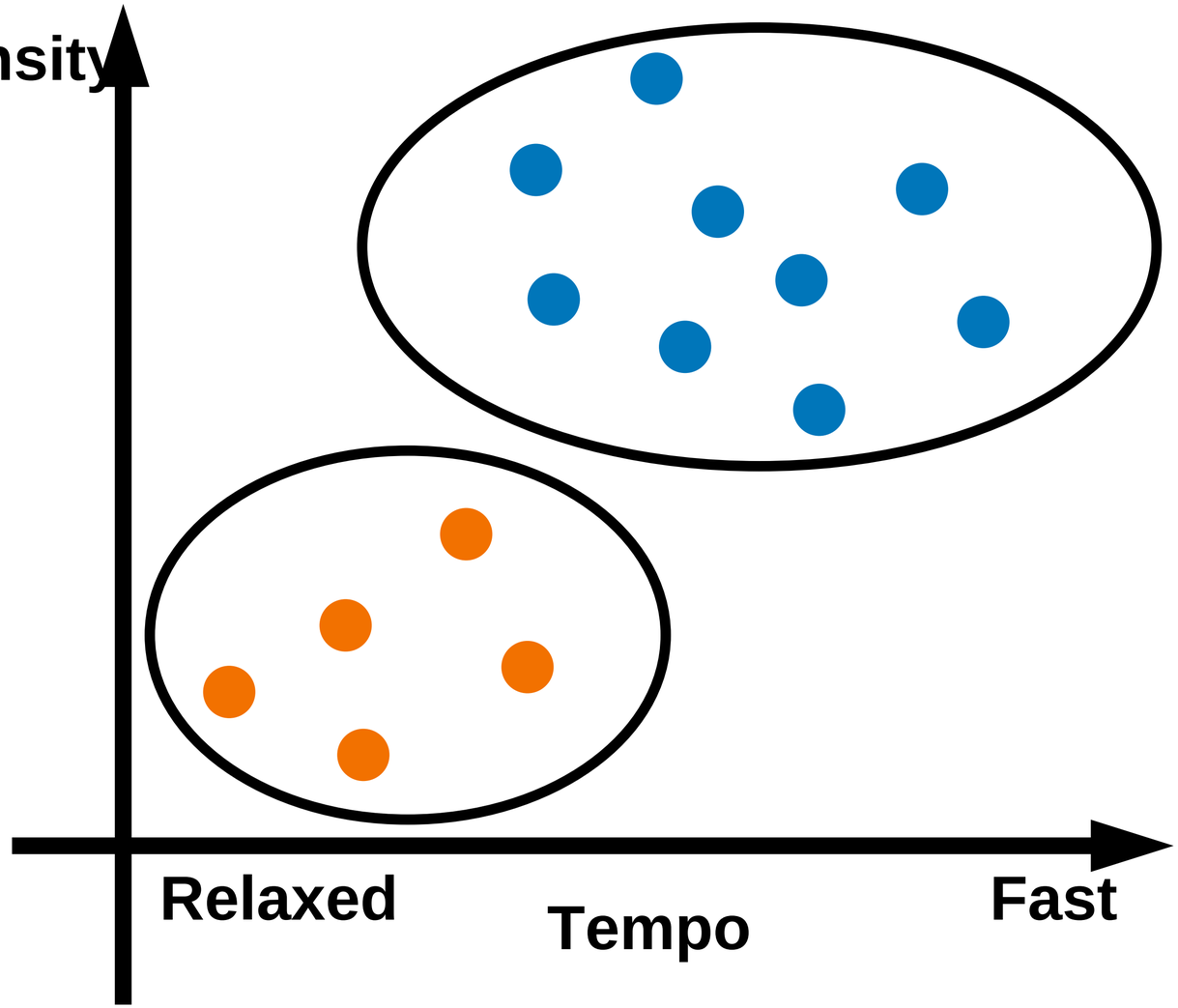

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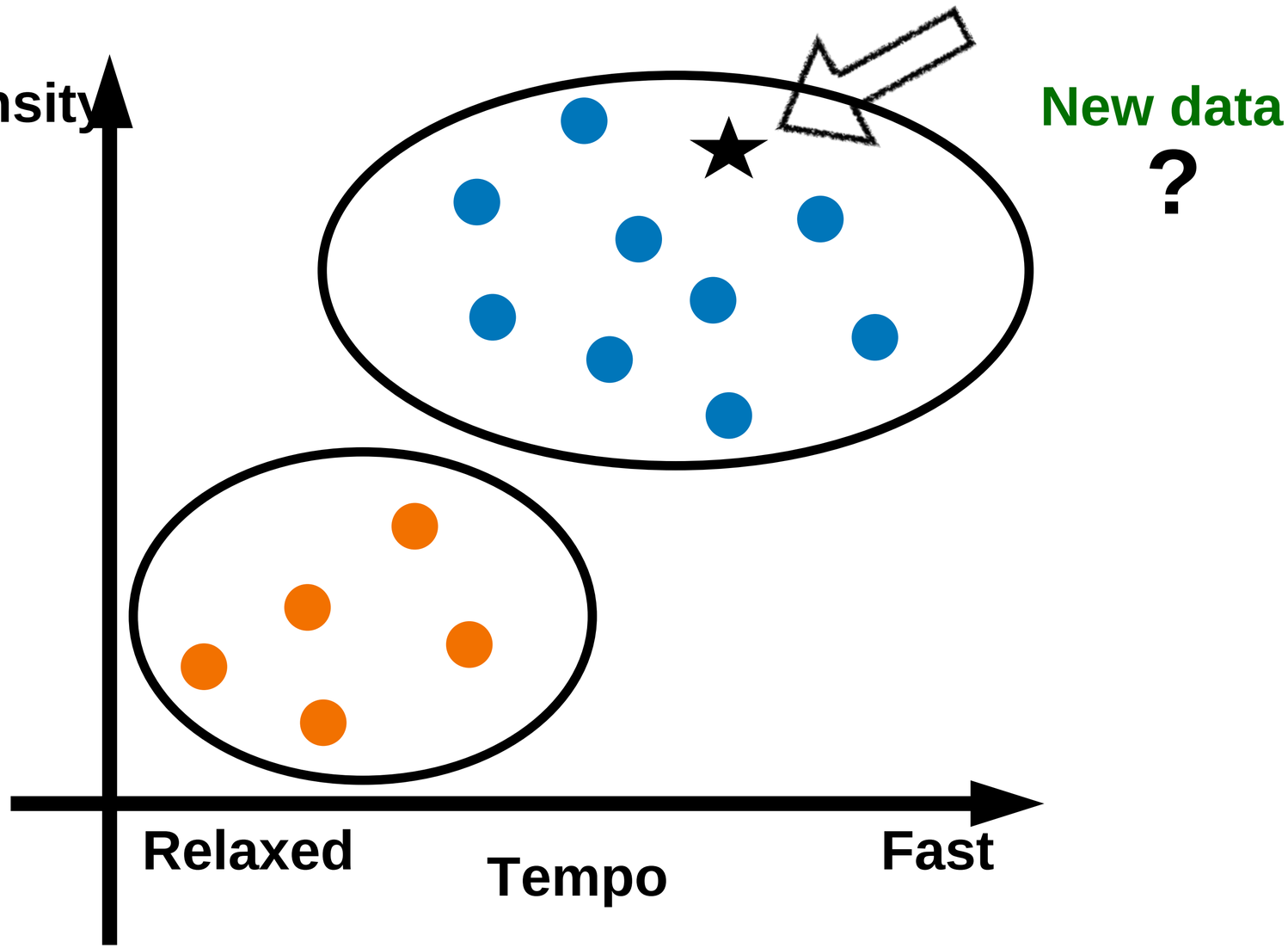

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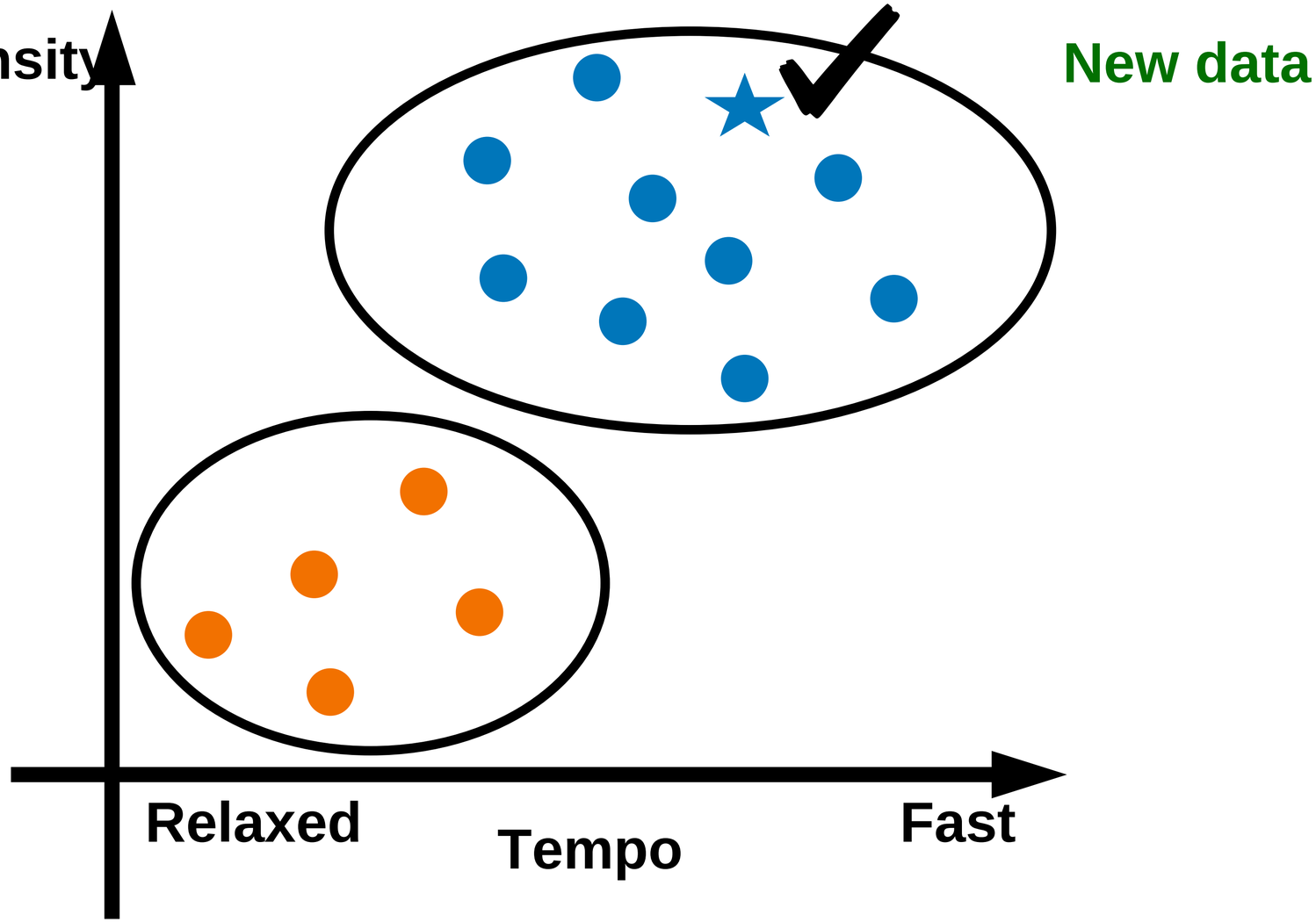
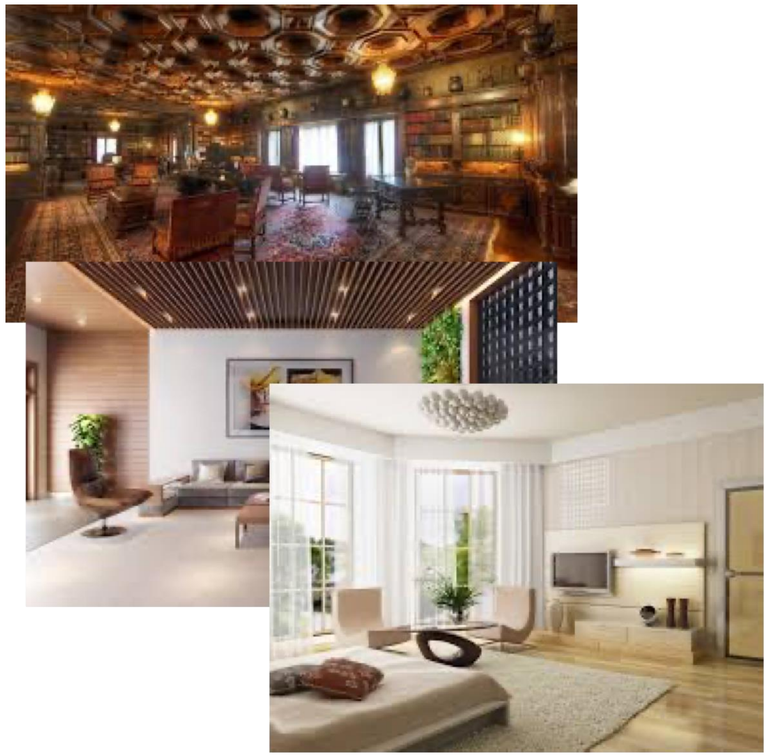


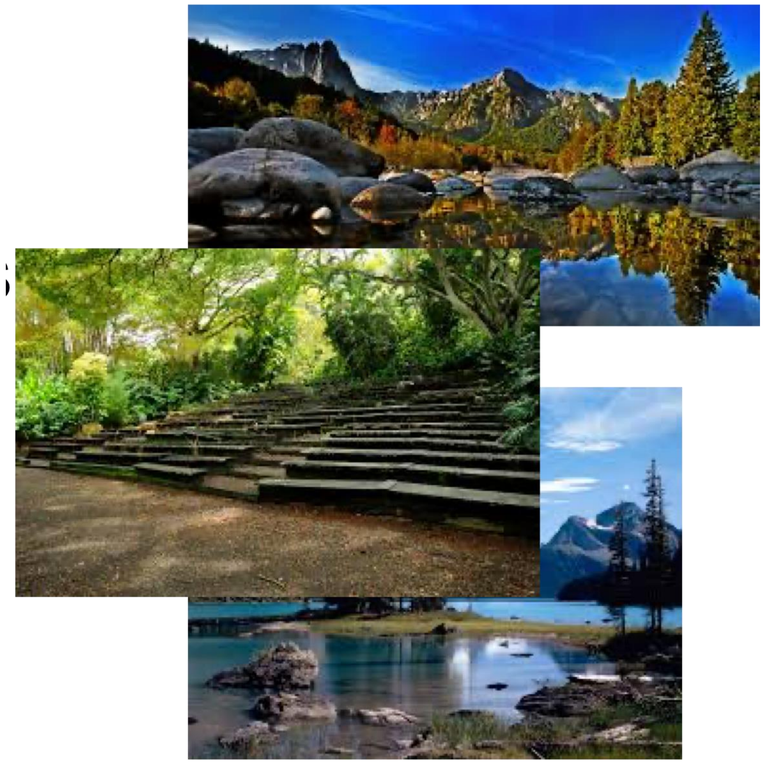
Example 2: Classify Images

http://www.image-net.org/

Example 2: Classify Images

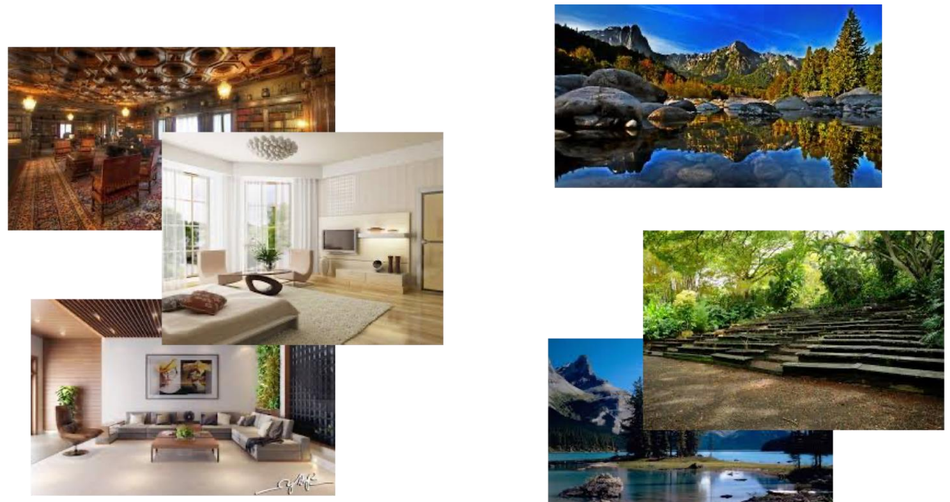


indoor

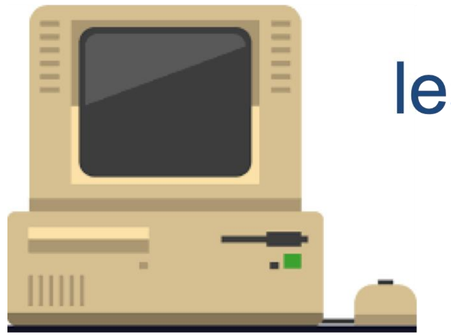


outdoor

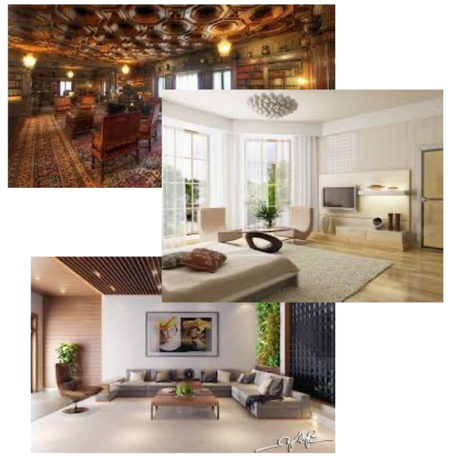
Example 2: Classify Images



Training data



learning (i.e.,training)



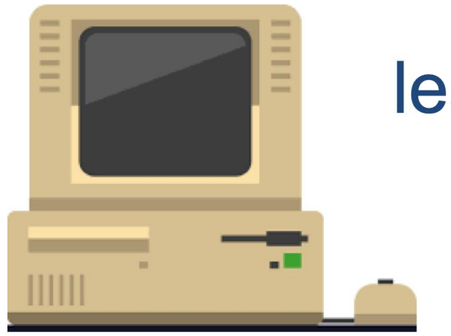
Training data

Label: outdoor

Label: indoor

Test data

learning (i.e.,training)



testing

performance

How to represent data?

input data

$x \in \mathbb{R}^d$

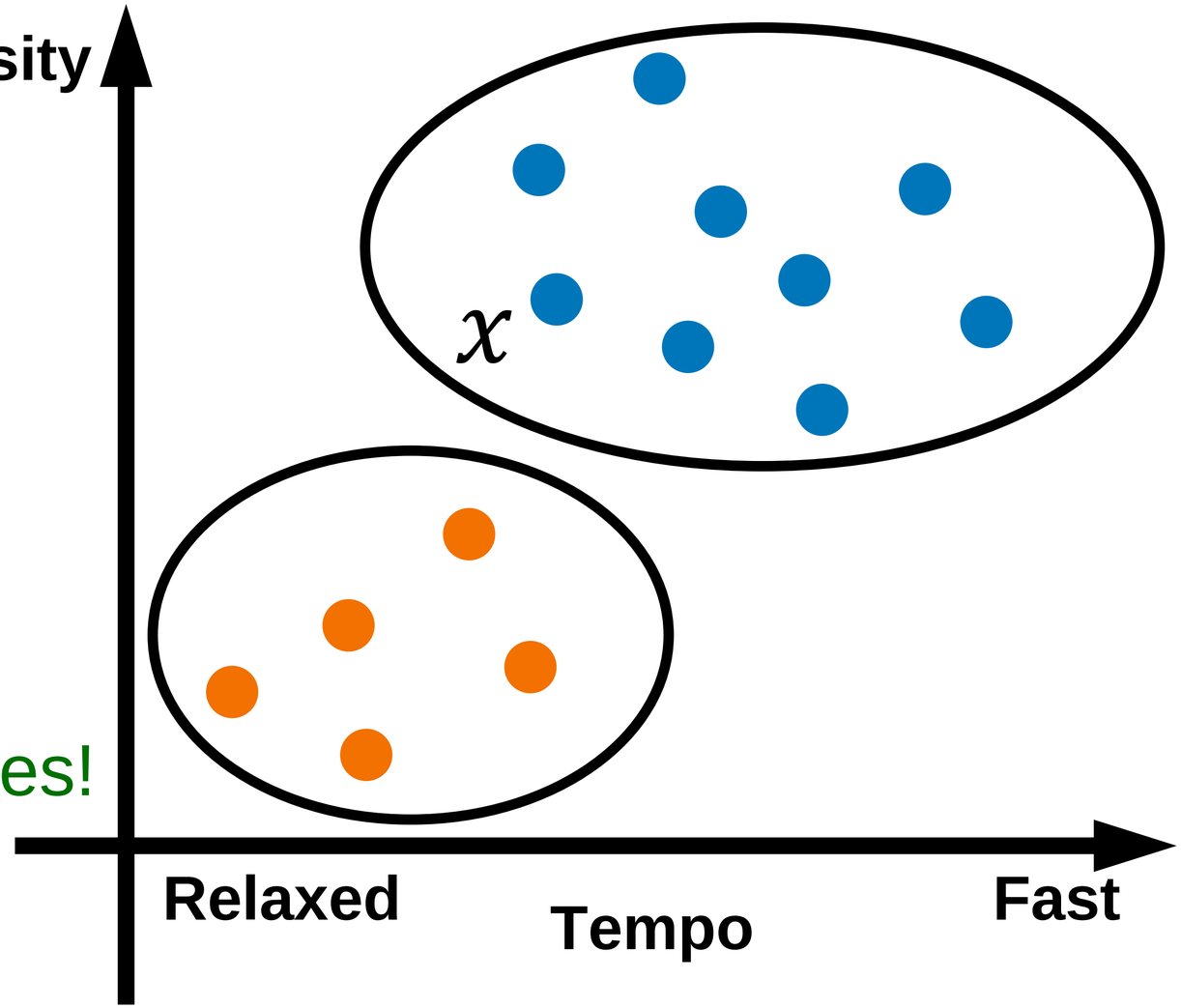
d : feature dimension

$$x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

x_1 Tempo

x_2 Intensity

There can be many features!

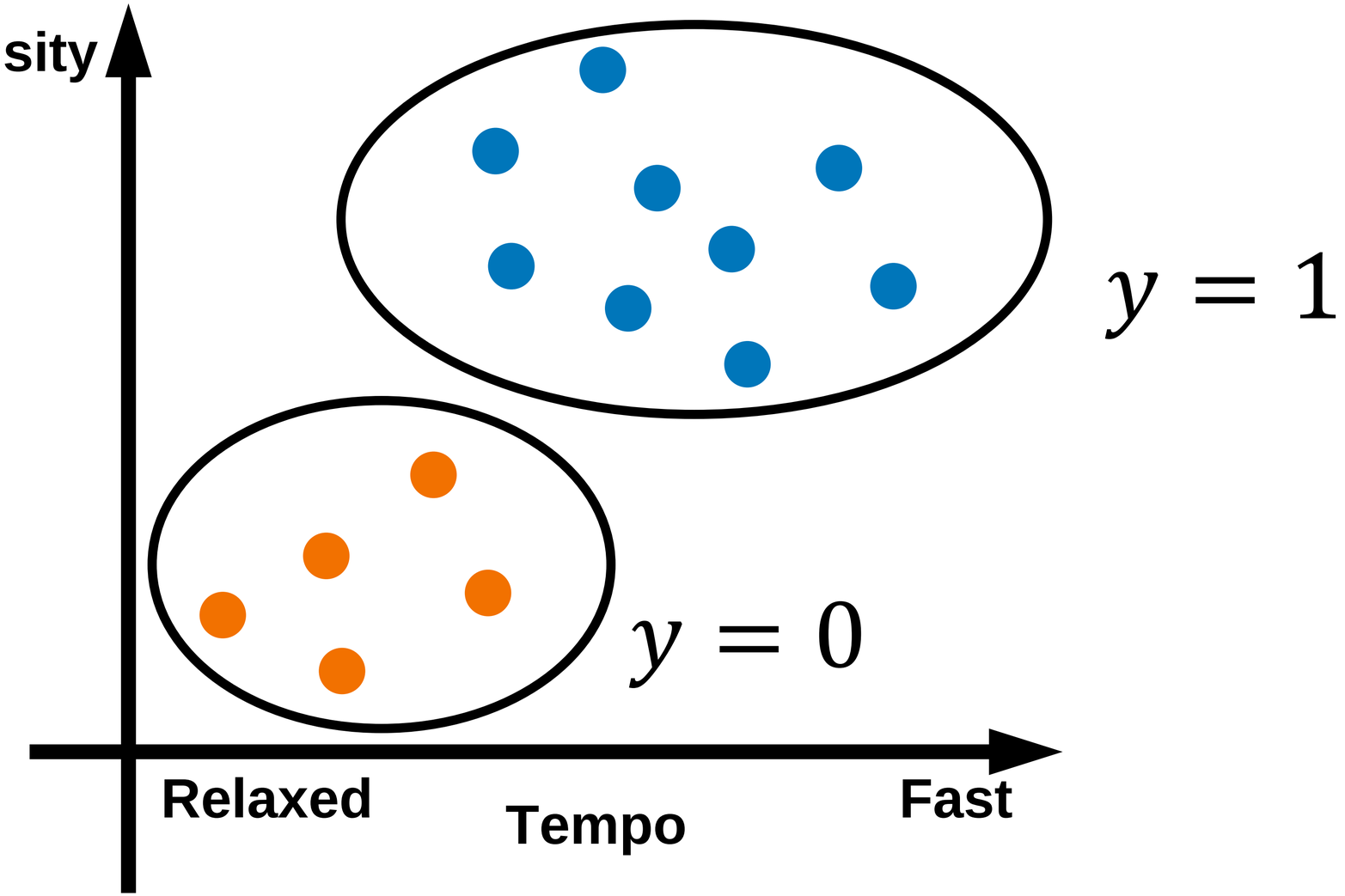


How to represent data?

Label

$y \in \{0,1\}$

Where “supervision” comes from



Represent various types of data

- Image
  - Pixel values

- Bank account
  - Credit rating, balance, # deposits in last day, week, month, year, #withdrawals

Two Types of Supervised Learning Algorithms

Classification

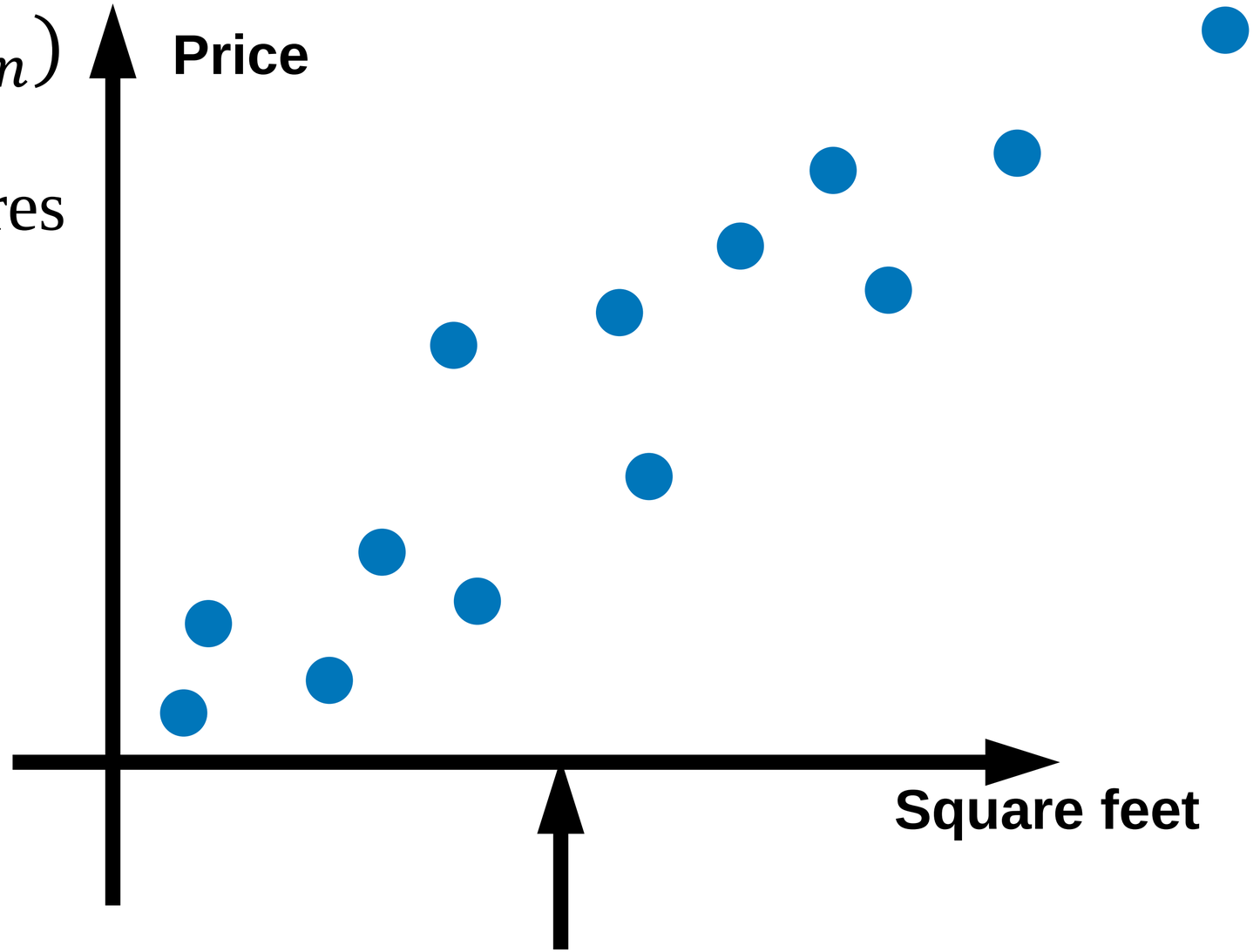
Regression

Example of regression: housing price prediction

Given: a dataset that contains n samples

$(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)$

Task: if a residence has **x** squares feet, predict the price?



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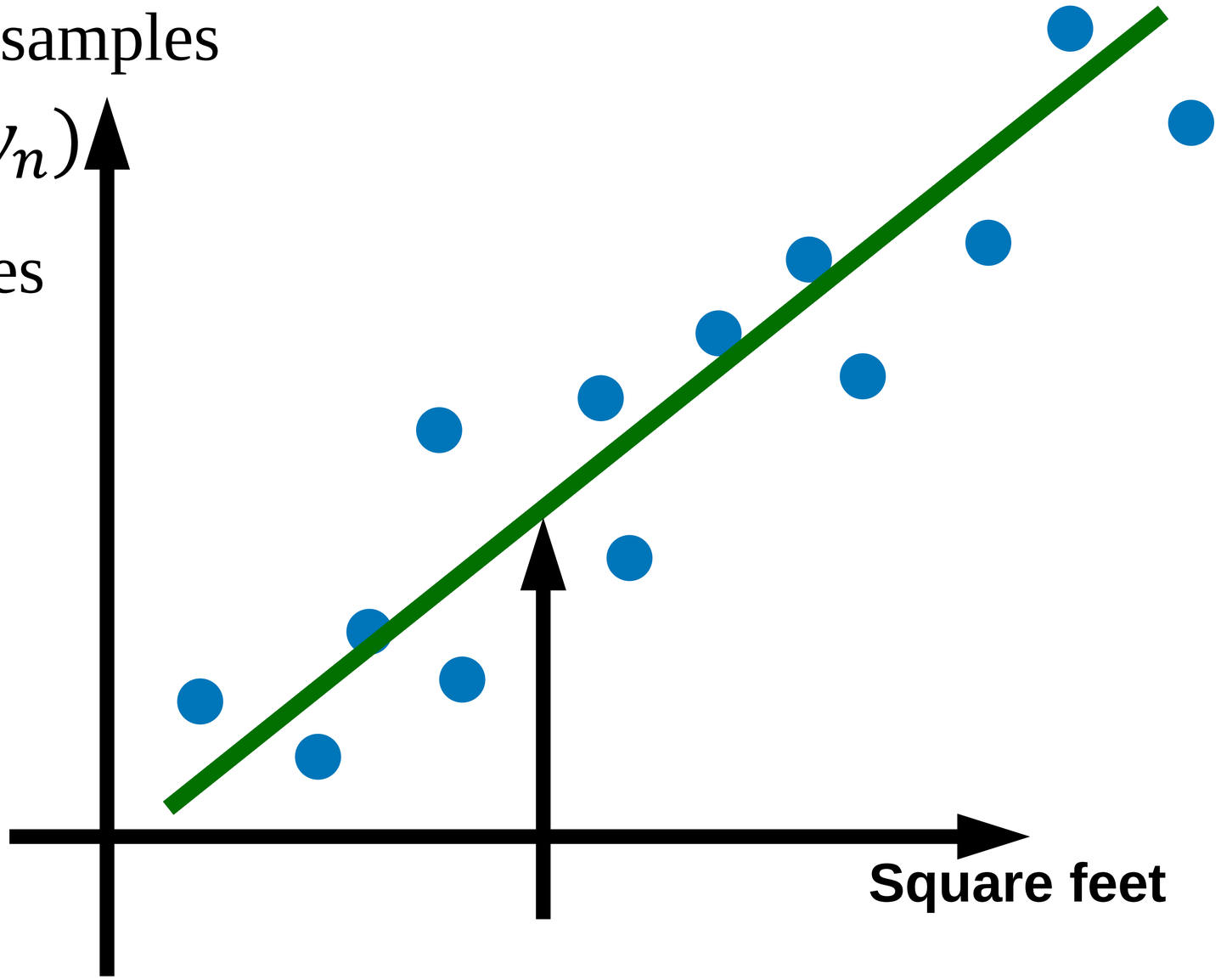
$$y \in \mathbb{R}$$



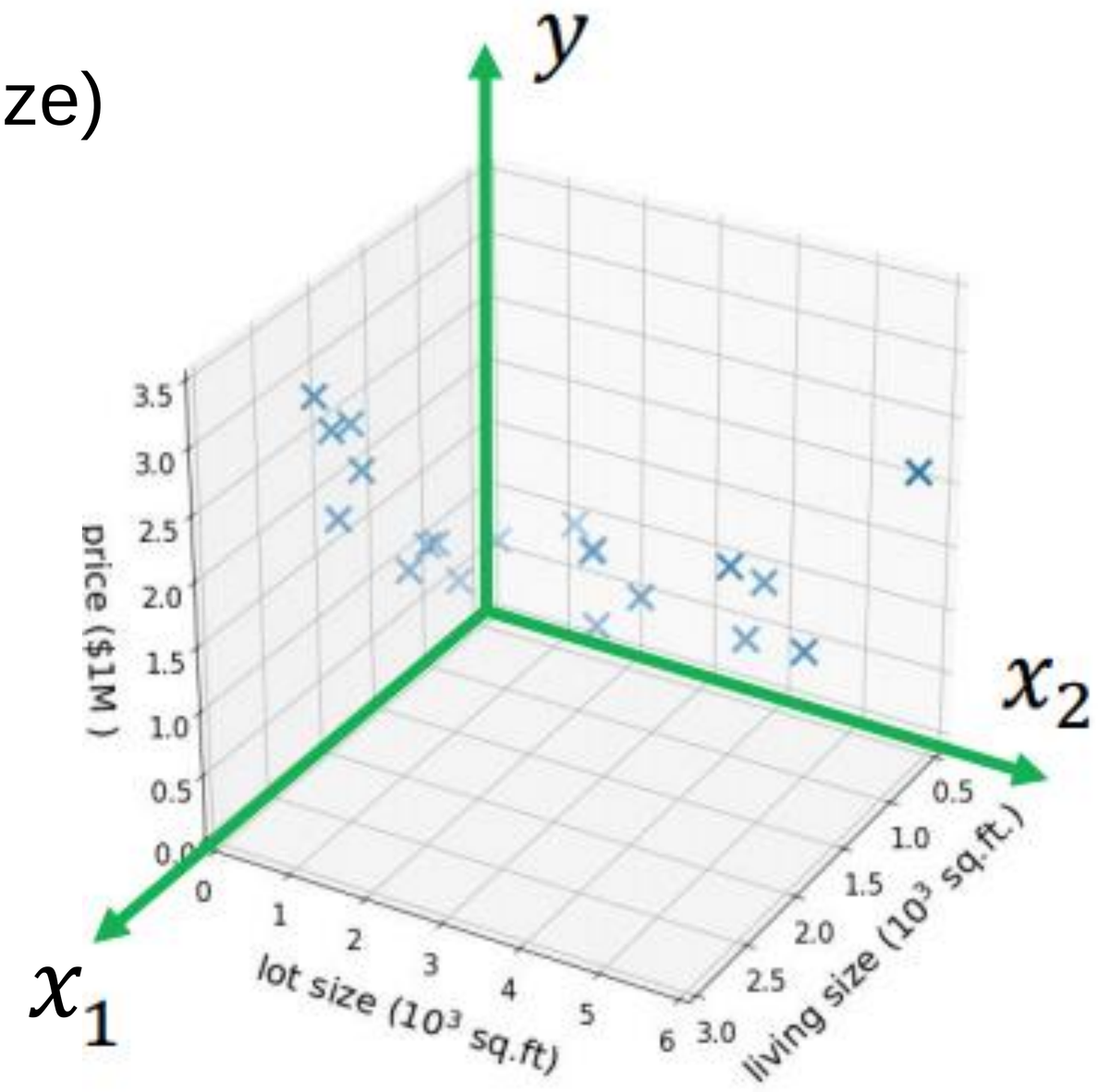
Example of regression: housing price prediction

Input with more features (e.g., lot size)

(size, lot size) → price

features/input
$x \in \mathbb{R}^2$

label/output
$y \in \mathbb{R}$

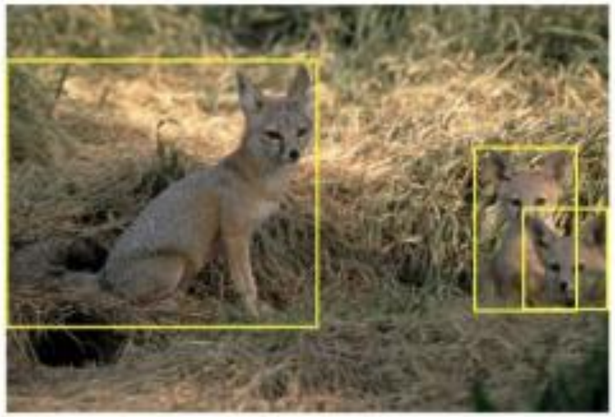


(credit: stanford CS229)

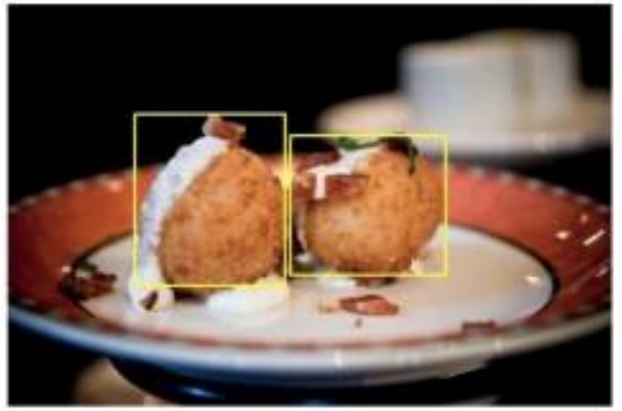
Supervised Learning: More examples

x = raw pixels of the image

y = bounding boxes



kit fox



croquette

airplane

frog

Russakovsky et al. 2015

Two Types of Supervised Learning Algorithms

Classification

- the label is a **discrete** variable

$$y \in \{1,2,3,\ldots,K\}$$

Regression

- the label is a **continuous** variable

$$y \in \mathbb{R}$$

Training Data for Supervised Learning

Training data is a collection of input instances to the learning algorithm:

$$(x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots, (x_n, y_n)$$

input label

A training data is the “**experience**” given to a learning algorithm

Goal of Supervised Learning

Given training data

$$(x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots, (x_n, y_n)$$

Learn a function mapping $f : X \to Y$, such that $f(x)$ predicts the label y on **future** data x (not in training data)

Goal of Supervised Learning

Training set error

- 0-1 loss for classification $\ell = \frac{1}{n}\sum_{i=1}^{n}(f(\mathbf{x}_i) \neq y_i)$
- Squared loss for regression: $\ell = \frac{1}{n}\sum_{i=1}^{n}(f(\mathbf{x}_i) - y_i)^2$

A learning algorithm optimizes the training objective

$$f^* = \text{argmin}\ \mathbb{E}_{(x,y)}\ell(f(x), y)$$

Details in upcoming lectures :)

Part II: Unsupervised Learning (no teacher)

Unsupervised Learning

- Given: dataset contains **no label** $x_1, x_2, \ldots, x_n$
- **Goal:** discover interesting patterns and structures in the data

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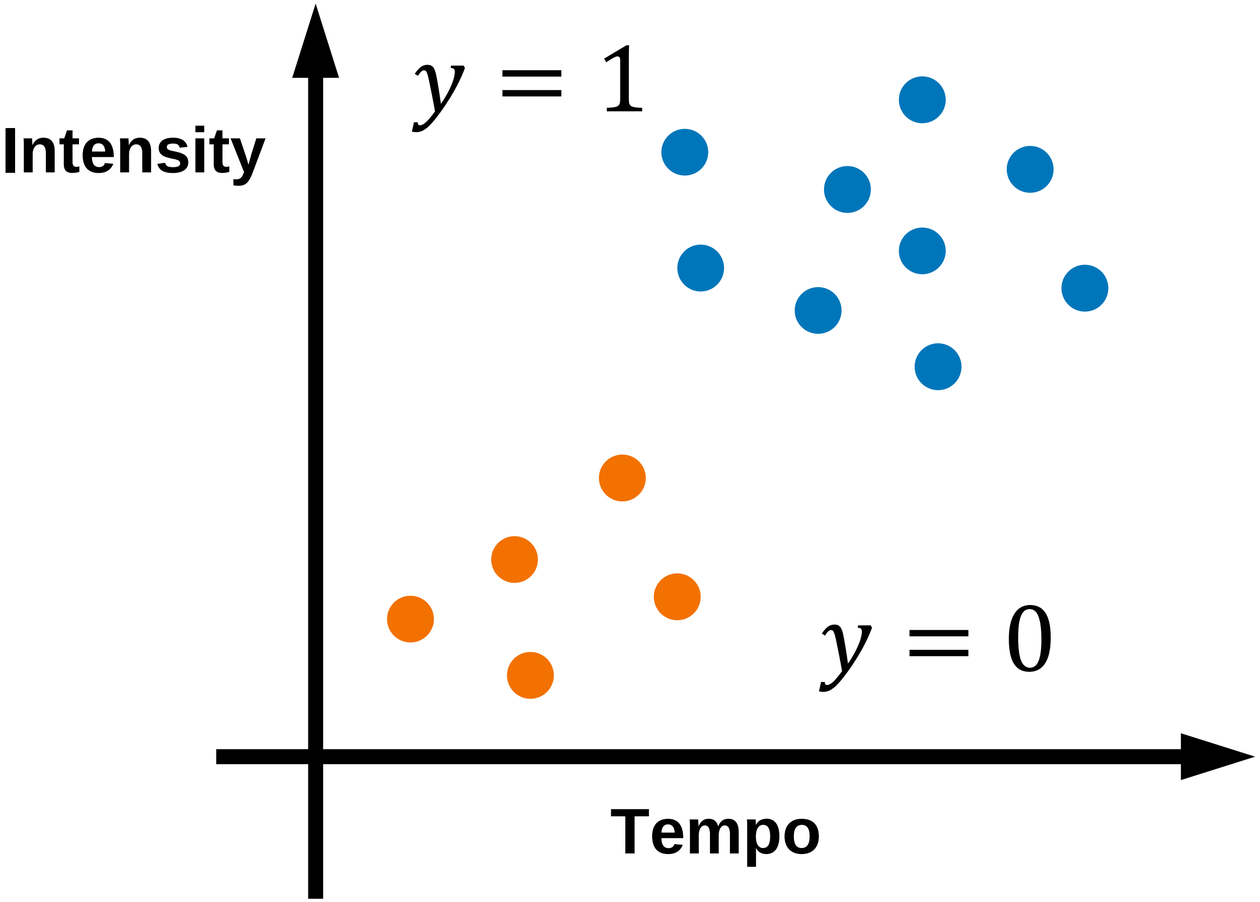

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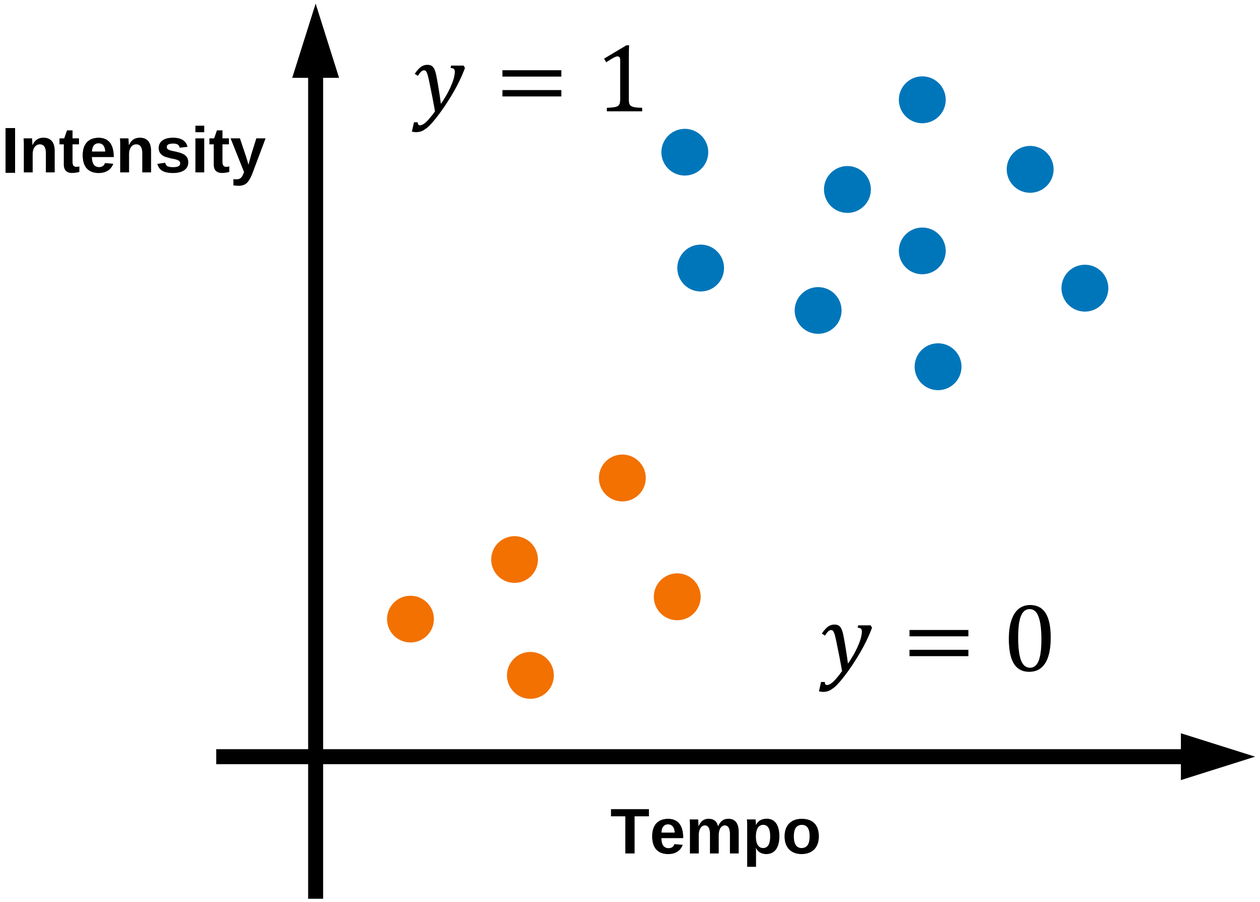
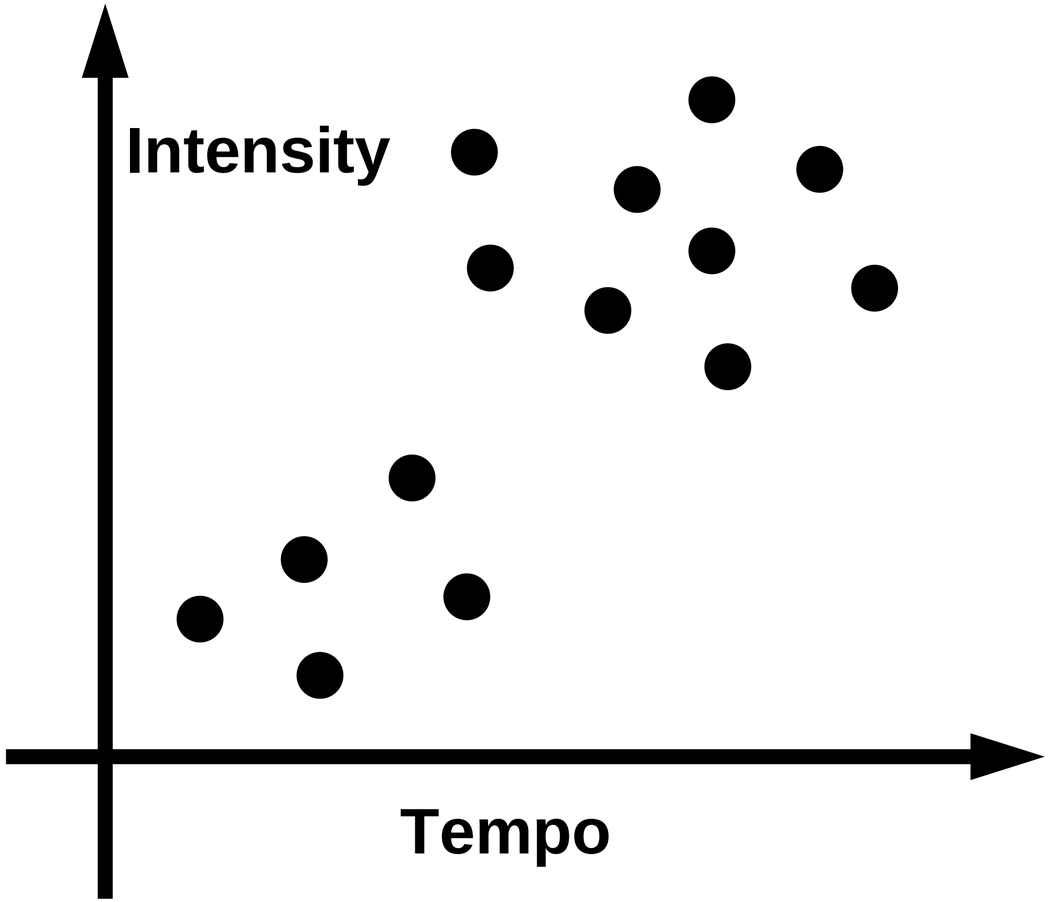
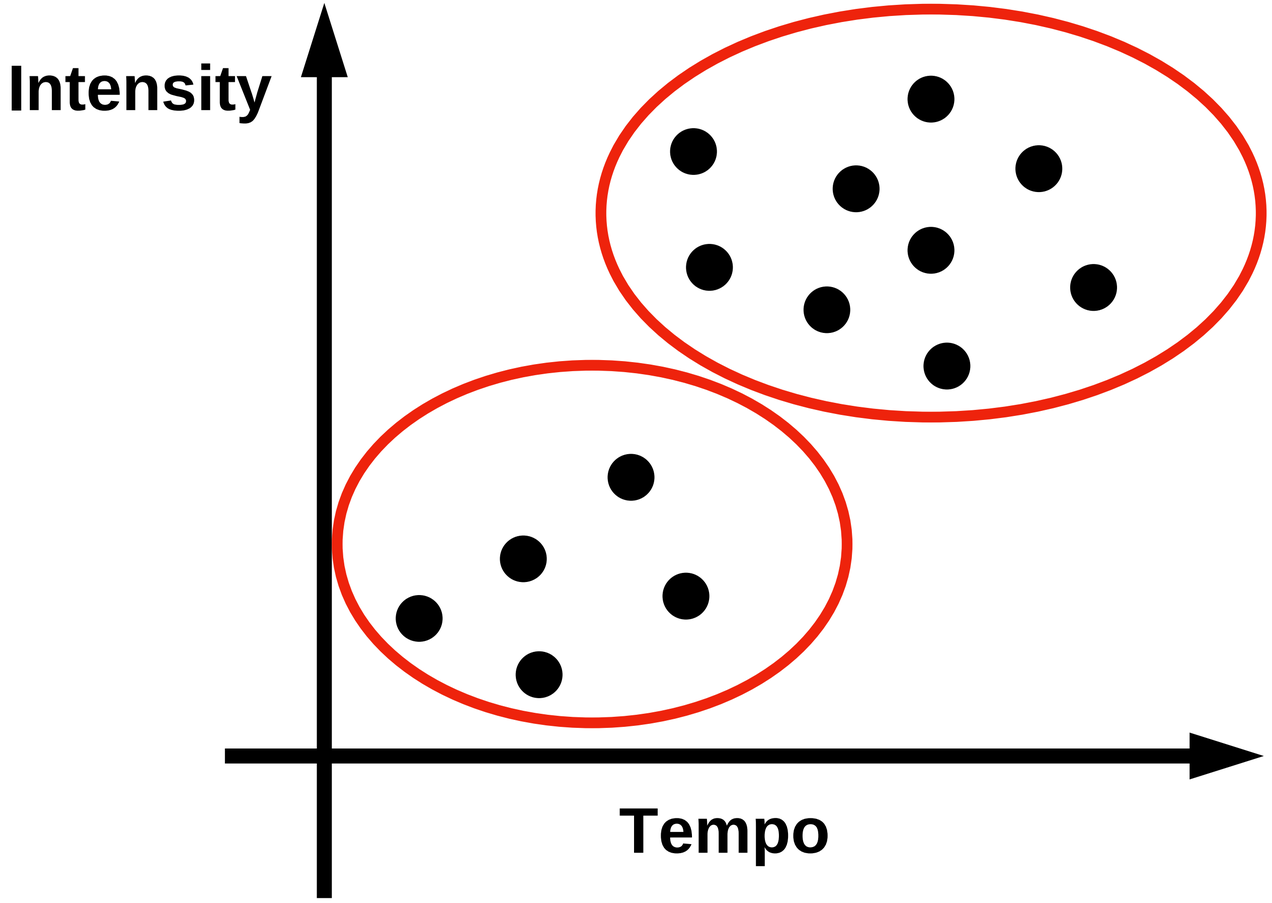


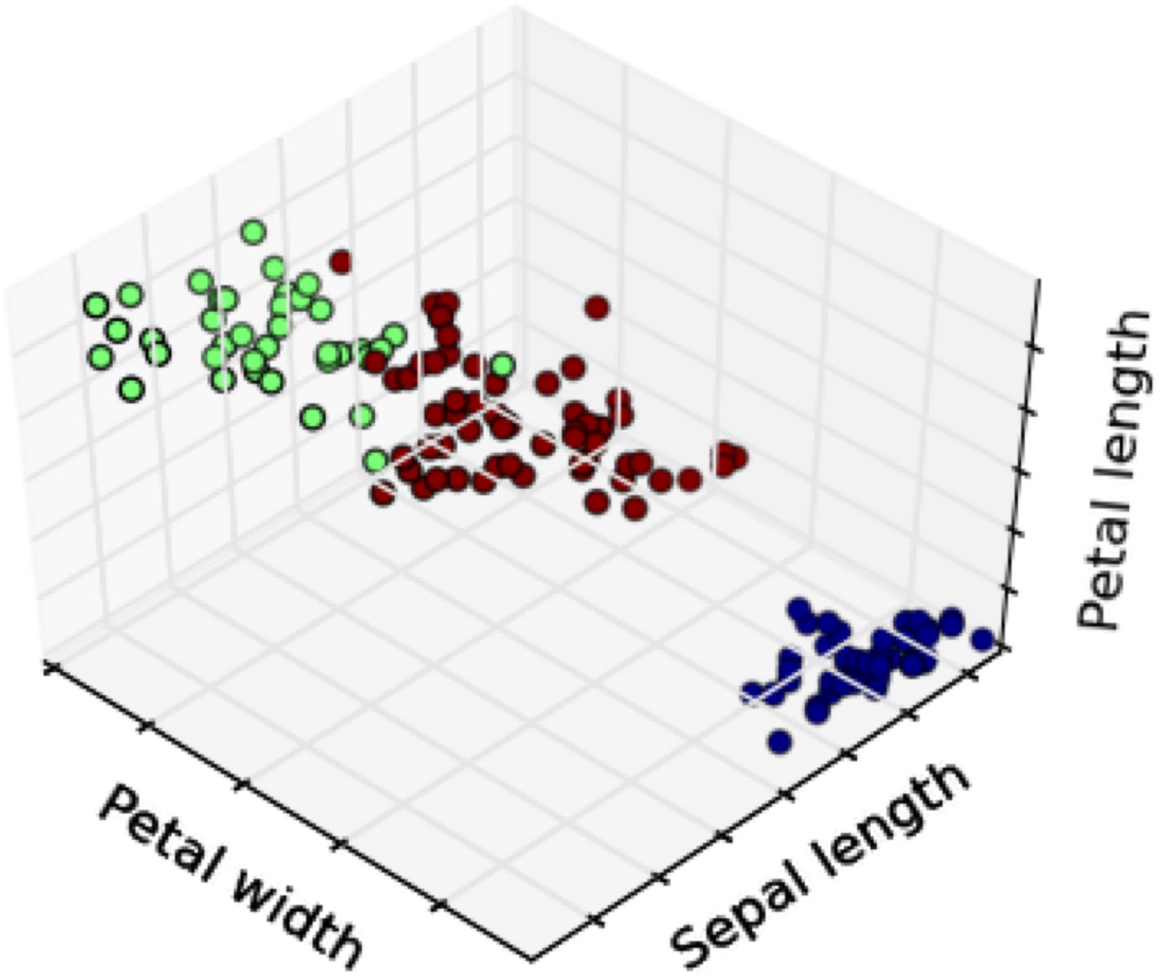


Clustering

- Given: dataset contains **no label** $x_1, x_2, \ldots, x_n$
- **Output:** divides the data into clusters such that there are intra-cluster similarity and inter-cluster dissimilarity



Clustering

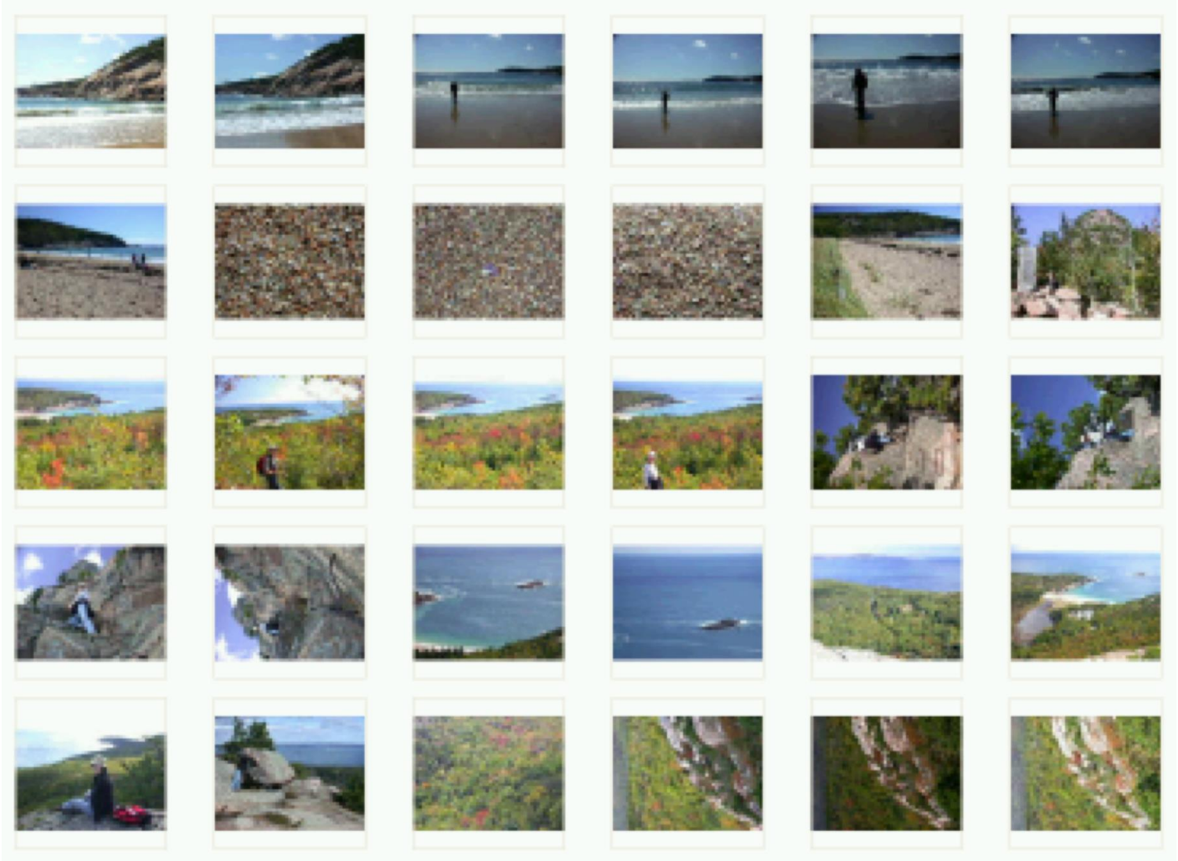


Clustering Irises using three different features

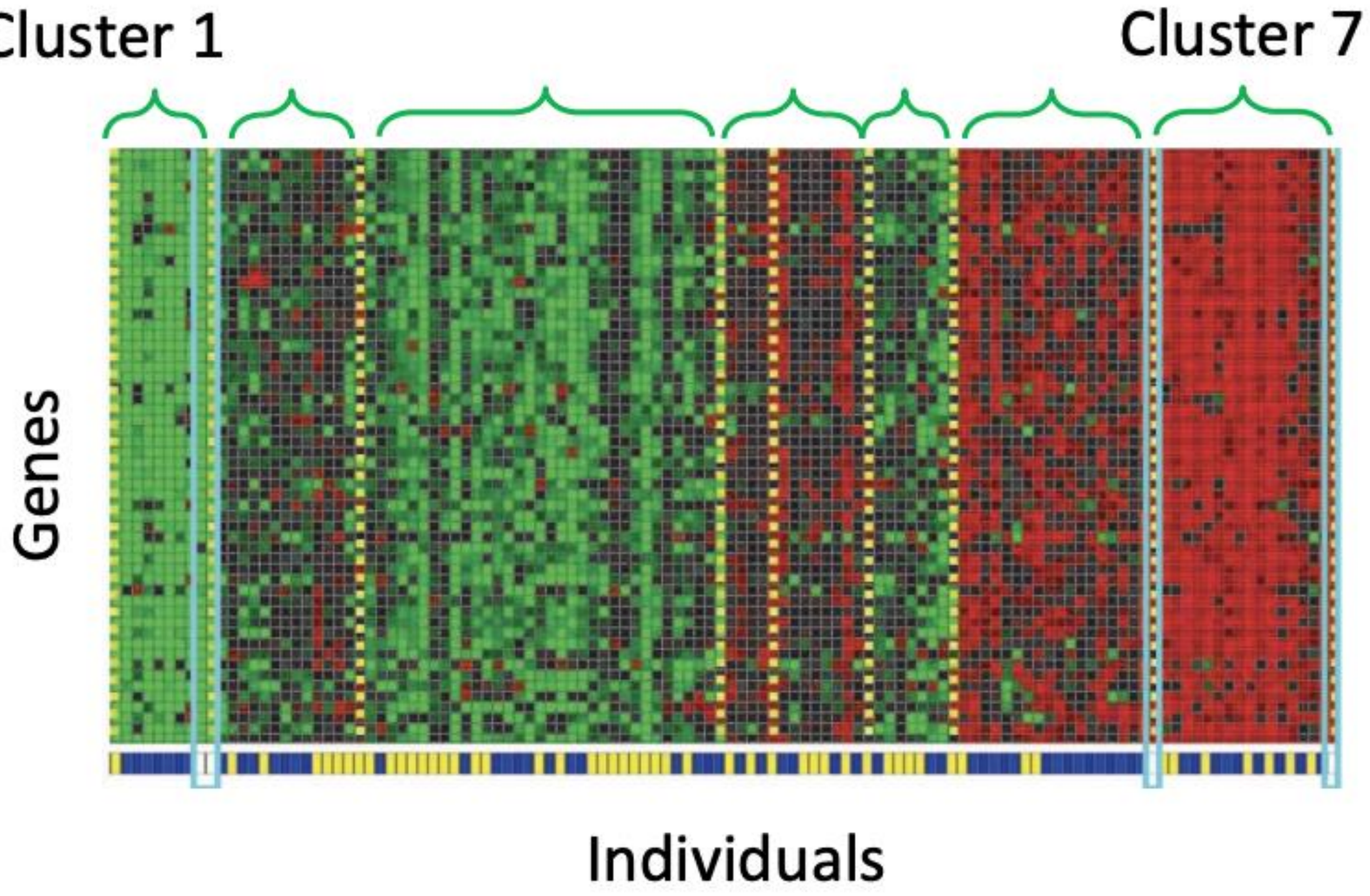
The colors represent clusters identified by the algorithm, not y’s provided as input

Clustering

- You probably have >1000 digital photos stored on your phone
- After this class you will be able to organize them better (based on visual similarity)

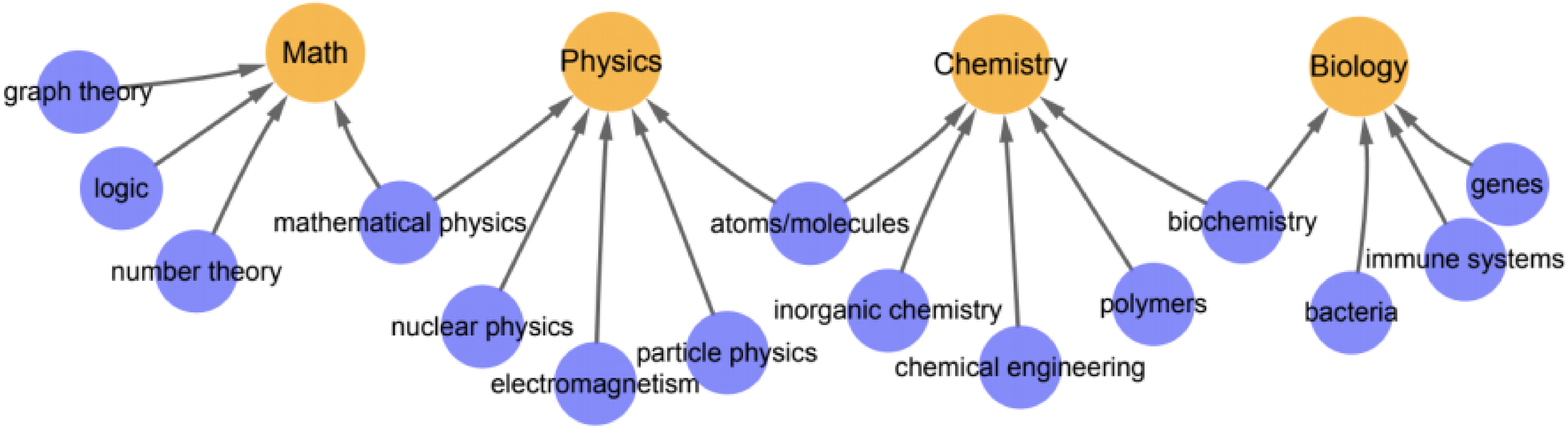


Clustering Genes



Identifying Regulatory Mechanisms using Individual Variation Reveals Key Role for Chromatin Modification. [Su-In Lee, Dana Pe'er, Aimee M. Dudley, George M. Church and Daphne Koller. '06]

Clustering Words with Similar Meanings



[Arora-Li-Liang-Ma-Risteski, TACL'17,18]

How do we perform clustering?

- Many clustering algorithms. We will look at the two most frequently used ones:
  - *K-means clustering*: we specify the desired number of clusters, and use an iterative algorithm to find them
  - *Hierarchical clustering*: we build a binary tree over the dataset

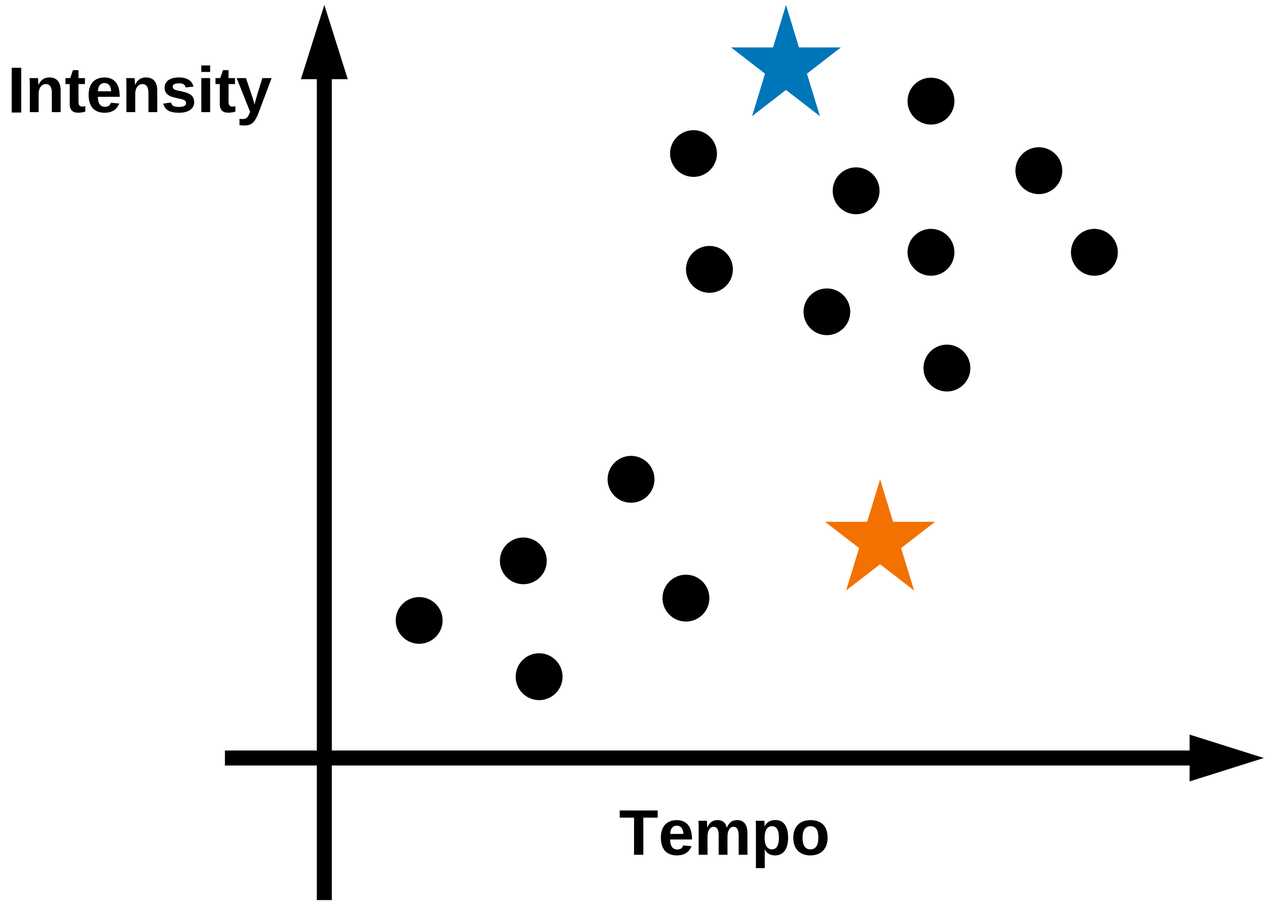
K-means clustering

- Very popular clustering method

- Input: a dataset $x_1, x_2, \ldots, x_n$, and assume the number of clusters **k** is given

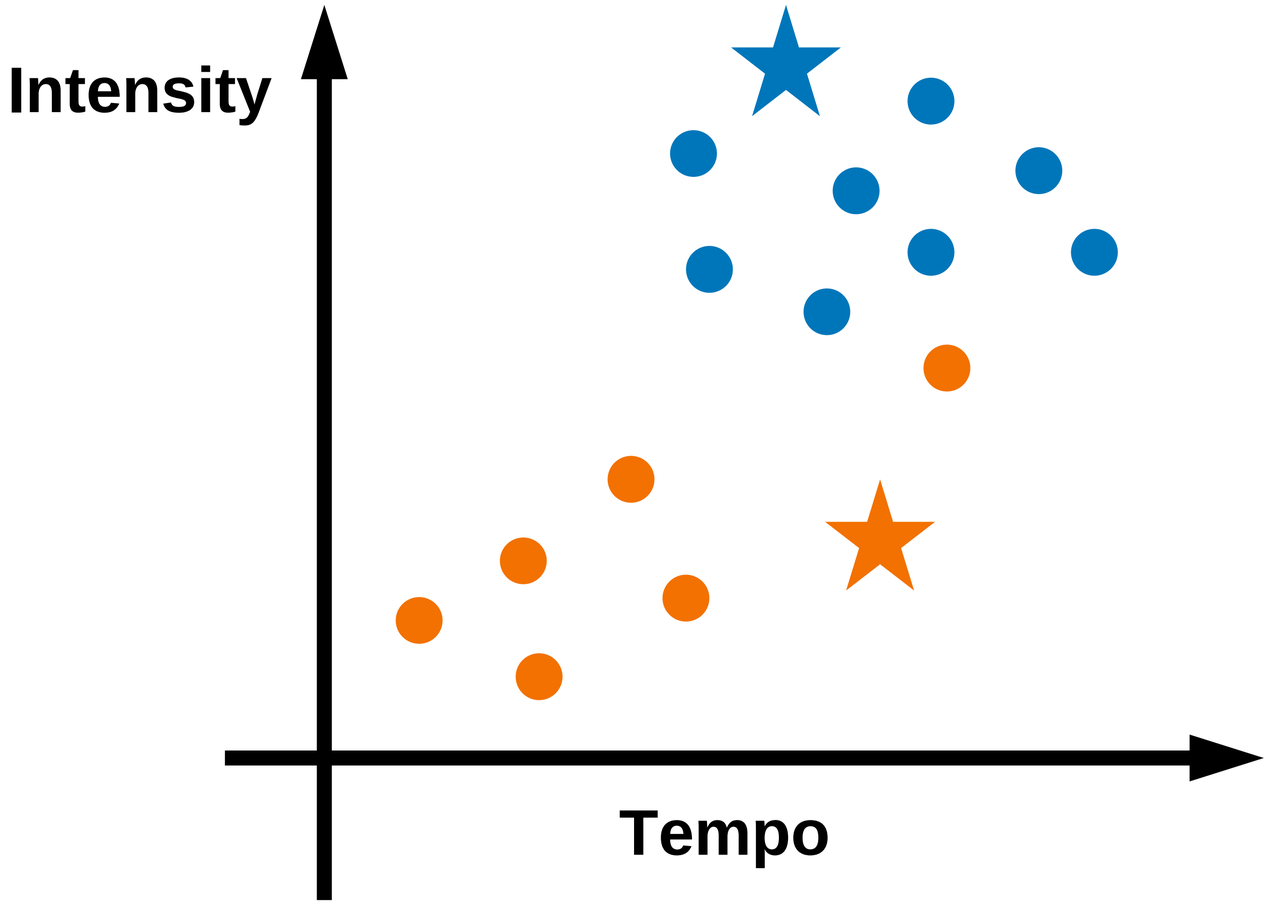
K-means clustering

Step 1: **Randomly** picking 2 positions as initial cluster centers (not necessarily a data point)



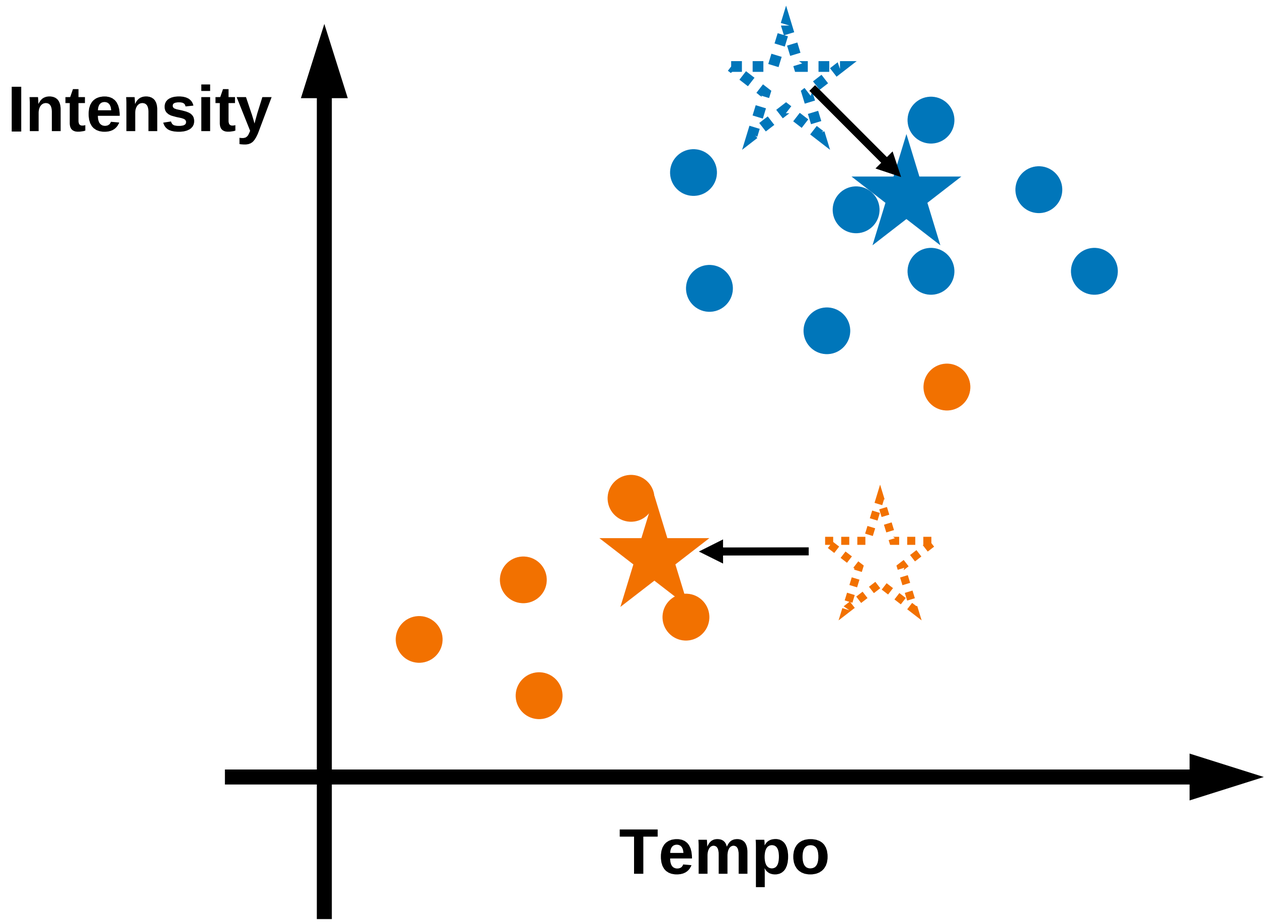
K-means clustering

Step 2: for each point x, determine its cluster: find the closest center in Euclidean space



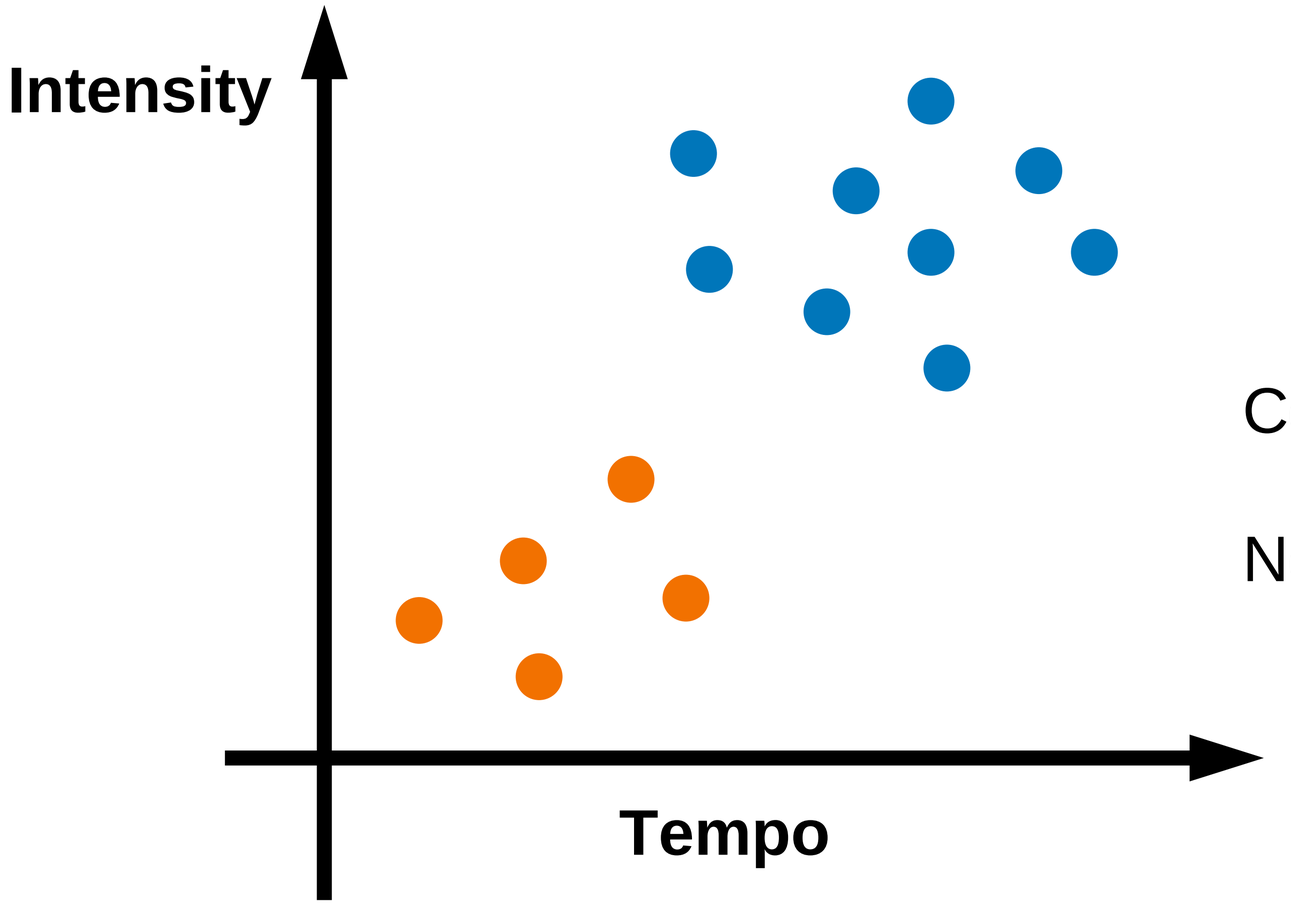
K-means clustering

Step 3: update all cluster centers as the centroids



K-means clustering

Repeat step 2 & 3 until convergence



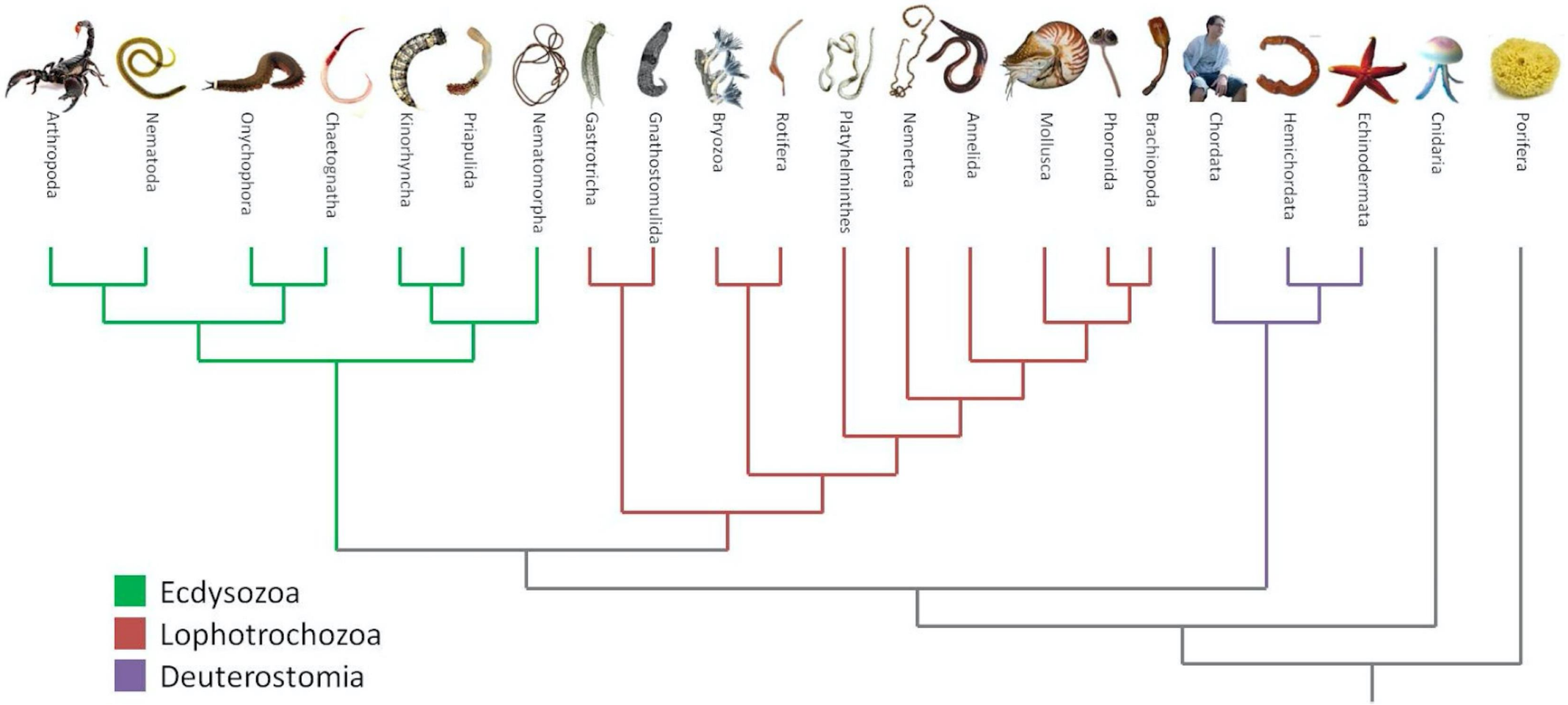
Converged solution!

No labels required!

K-means clustering: A demo

https://www.naftaliharris.com/blog/visualizing-k-means-clustering/

Hierarchical Clustering (more to follow next lecture)



Part III: Reinforcement Learning (Learn from reward)

Reinforcement Learning

- Given: an agent that can take actions and a reward function specifying how good an action is.
- **Goal:** learn to choose actions that maximize future reward total.

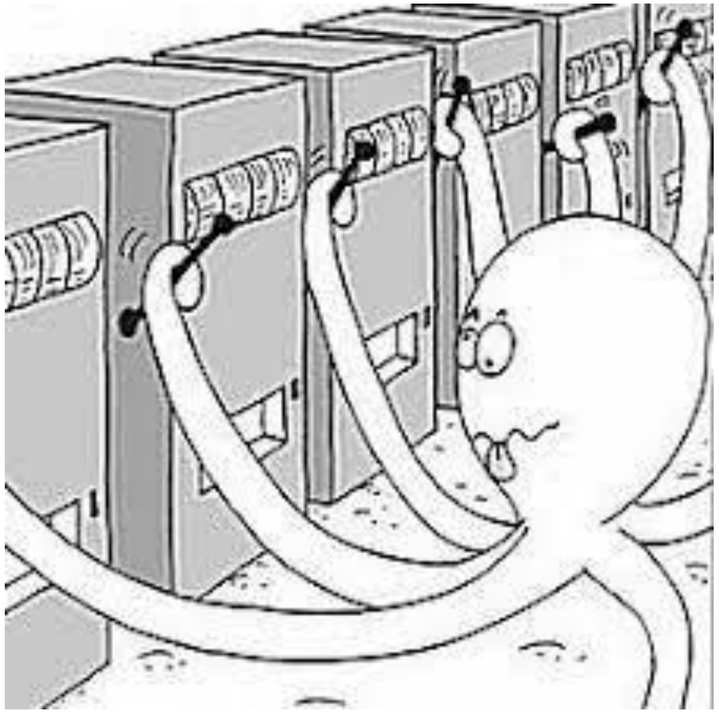
Google Deepmind

Reinforcement Learning Key Problems

1. Problem: actions may have delayed effects.
   - Requires **credit-assignment**
2. Problem: maximal reward action is unknown
   - Exploration-exploitation trade-off

"..the problem [exploration-exploitation] was proposed [by British scientist] to be dropped over Germany so that German scientists could also waste their time on it."

- Peter Whittle



Multi-armed Bandit

Today’s recap

- What is machine learning?
- Supervised Learning
  - Classification
  - Regression
- Unsupervised Learning
  - Clustering
- Reinforcement Learning

Thanks!