Lecture 9: Unsupervised Learning and Clustering

INFO 1998: Introduction to Machine Learning

CDS Education

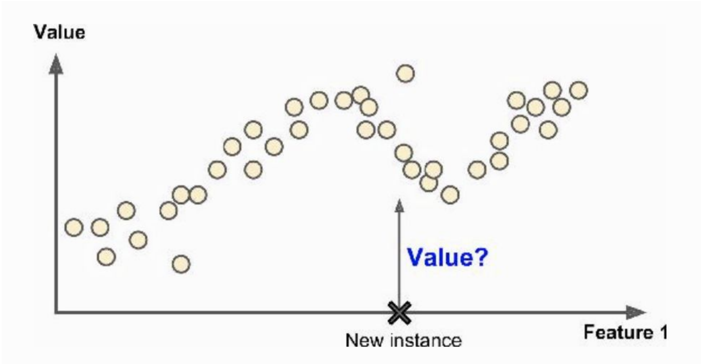
We explore, learn, and educate big minds.

Announcements

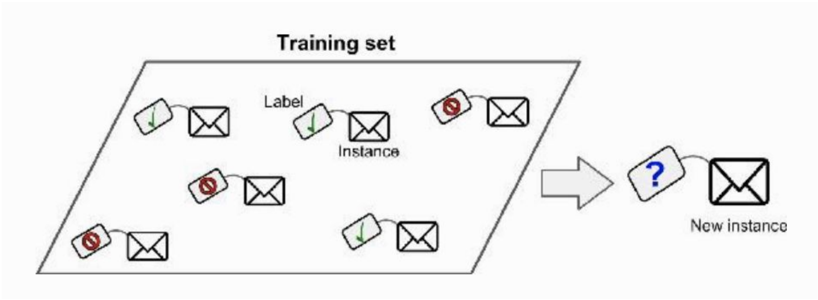
- Final project due May 1st!

Recap: Supervised Learning

- The training data you feed into your algorithm includes **desired solutions**
- Two types you've seen so far: **regressors and classifiers**
- In both cases, there are definitive “answers” to learn from



Example 1: Regressor
Predicts value

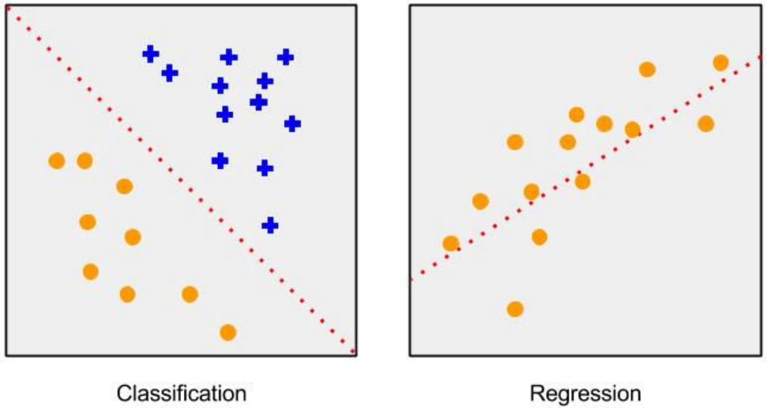


Example 2: Classifier
Predicts label

Recap: Supervised Learning

Supervised learning algorithms we have covered so far:

- k-Nearest Neighbors
- Linear Regression
- Logistic Regression
- Perceptron / SVM
- Decision Trees / Random Forest

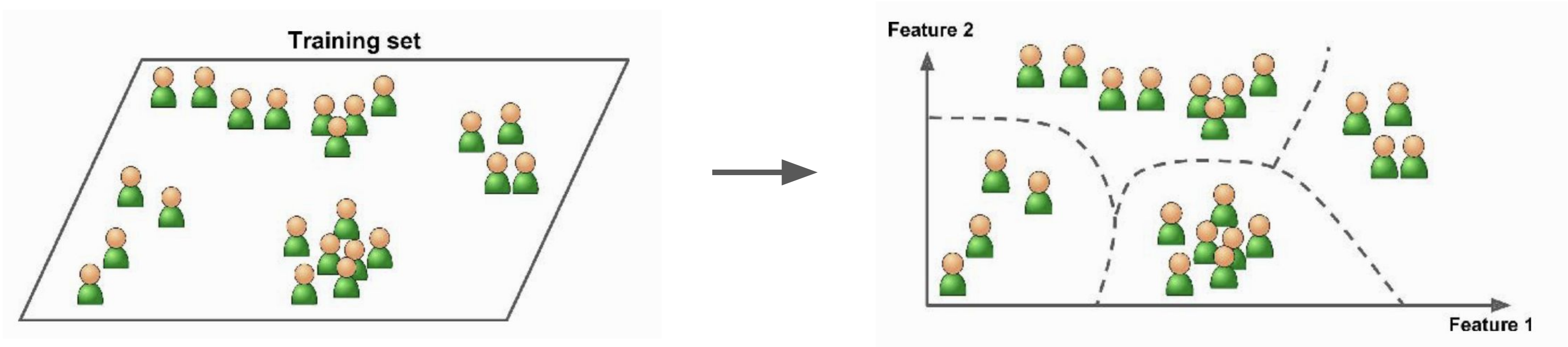


Which of these are classifiers? Which are regressors?

What are some **limitations** of supervised learning?

Today: Unsupervised Learning

- In unsupervised learning, the training data is **unlabeled**
- Algorithm tries to learn by itself



An Example: Clustering

Unsupervised Learning

Some types of unsupervised learning problems:

1. **Clustering**
   k-Means, Hierarchical Cluster Analysis (HCA), Gaussian Mixture Models (GMMs), etc.
2. **Dimensionality Reduction**
   Principal Component Analysis (PCA), Locally Linear Embedding (LLE)
3. **Association Rule Learning**
   Apriori, Eclat, Market Basket Analysis

… *More*

Unsupervised Learning

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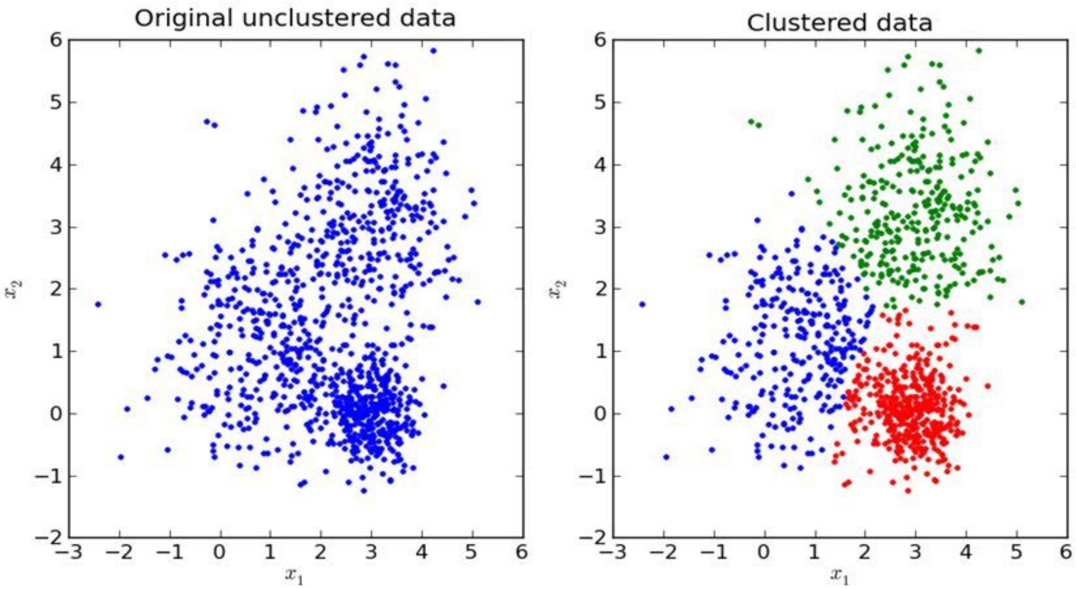
Cluster Analysis

- **Loose definition:** Clusters have objects which are “similar in some way” (and “dissimilar to objects in other clusters)
- Clusters are **latent variables (variables that are unknown)**
- Understanding clusters can:
    - Yield underlying trends in data
    - Supply useful parameters for predictive analysis
    - Helpful exercise, take any arbitrary supervised task, pretend it’s unsupervised and work backwards. We can then see based on clustering what features/latent variables cause the trends or classifications

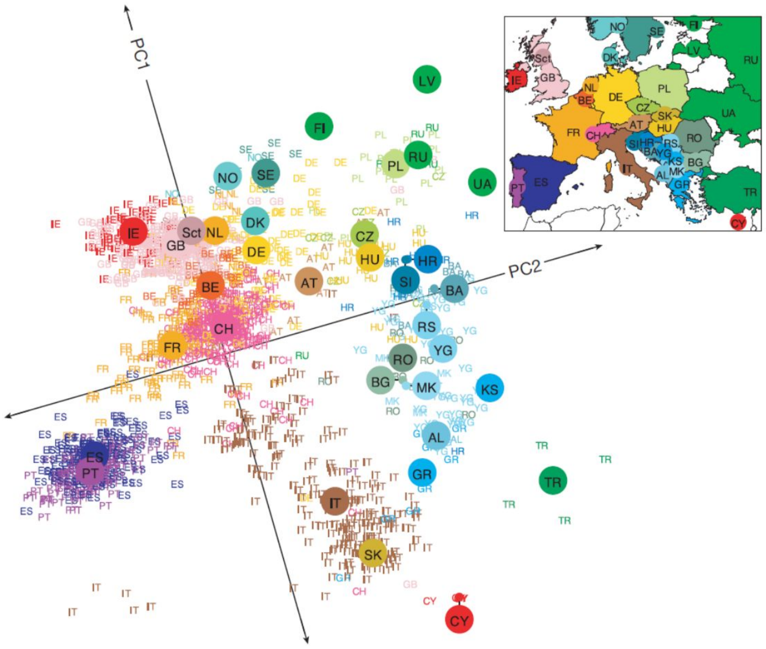
Cluster Analysis



Clustering Application

Finding Population Structure in Genetic Data

From 1,387 European samples



Clustering Application

Recommender Systems

Intuition: People who are “similar”, will like the same things

A Bunch of Cool Logos

Running Example: Recommender Systems

Use 1: Collaborative Filtering

- "People similar to you also liked X"
- Use other's rating to suggest content

Pros	Cons
If cluster behavior is clear, can yield good insights	Computationally expensive Can lead to dominance of certain groups in predictions

Running Example: Recommend MOVIES

	Amy	Jef	Mike	Chris	Ken
The Piano	–	–	+		+
Pulp Fiction	–	+	+	–	+
Clueless	+		–	+	–
Cliffhanger	–	–	+	–	+
Fargo	–	+	+	–	+

Running Example: Recommender Systems

Use 2: Content filtering

- "Content similar to what YOU are viewing"
- Use user's watch history to suggest content

Pros	Cons
Recommendations made by learner are intuitive	Limited to existing data about content
Scalable	Difficult to suggest for new users

Another Example: Cambridge Analytica

- Uses Facebook profiles to build psychological profiles, then use traits for target advertising
- Ex. has personality test measuring openness, conscientiousness, extroversion, agreeableness and neuroticism -> different types of ads

How do we actually perform this **"cluster analysis"?**

Defining 'Similarity'

- Remember from K Nearest Neighbors Discussion
- How do we calculate proximity of different data points?
- Euclidean distance:

$$E(x, y) = \sqrt{\sum_{i=0}^{n} (x_i - y_i)^2}$$

- Other distance measures:
  - Squared euclidean distance, manhattan distance

Popular Clustering Algorithms

Hierarchical Cluster Analysis (HCA)

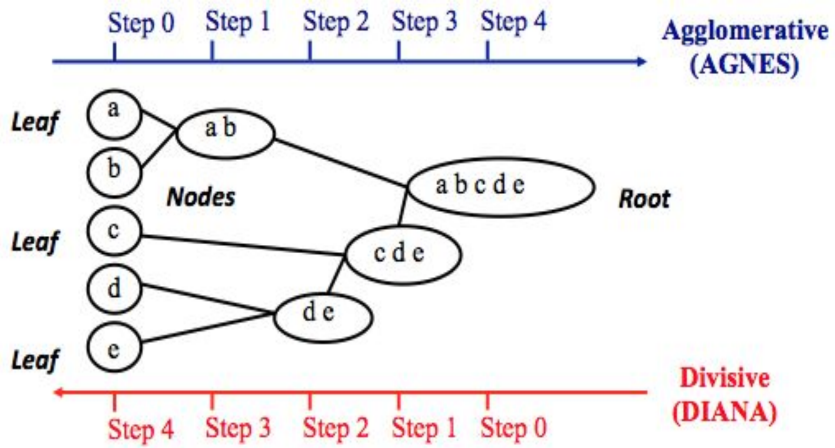
k-Means Clustering

Gaussian Mixture Models (GMMs)

Algorithm 1: Hierarchical Clustering

Two types:

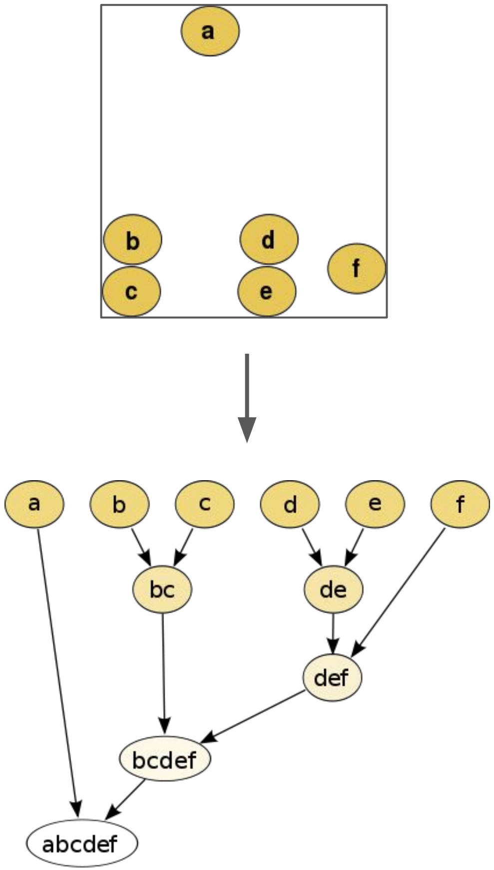
- Agglomerative Clustering
  - Creates a tree of **increasingly large** clusters *(Bottom-up)*
- Divisive Hierarchical Clustering
  - Creates a tree of **increasingly small** clusters *(Top-down)*



Agglomerative Clustering Algorithm

- Steps:
  - Start with each point in its own cluster
  - Unite adjacent clusters together
  - Repeat

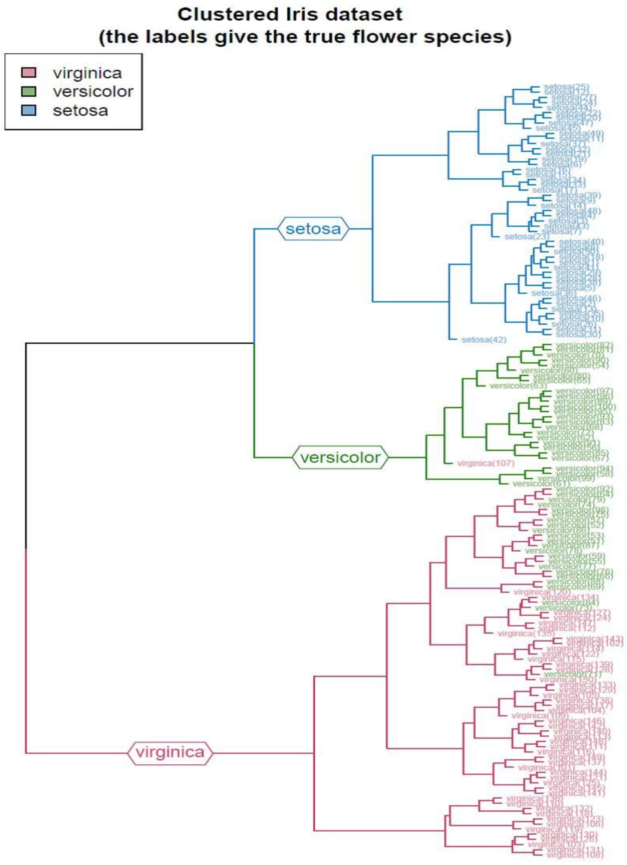
- Creates a tree of **increasingly large** clusters



Agglomerative Clustering Algorithm

How do we visualize clustering?
Using **dendrograms**

- Each width represents distance between clusters before joining
- Useful for estimating how many clusters you have



The iris dataset that we all love

Demo 1

Popular Clustering Algorithms

Hierarchical Cluster Analysis (HCA)

k-Means Clustering

Gaussian Mixture Models (GMMs)

Algorithm 2: k-Means Clustering

Input parameter: *k*

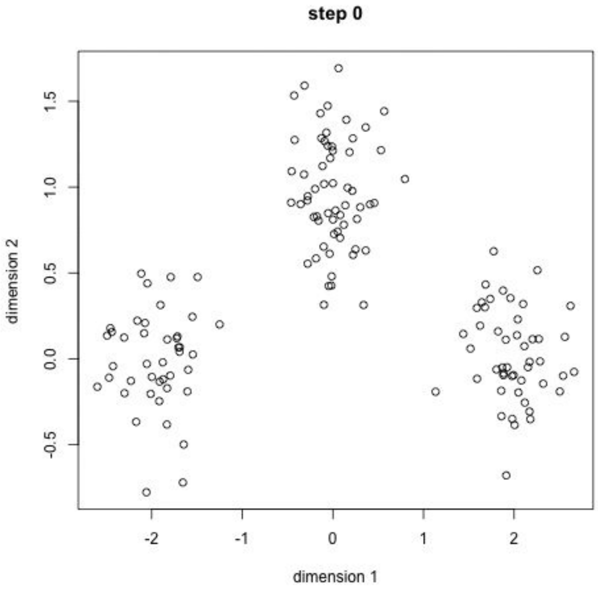
➢ Starts with *k* random centroids

➢ Cluster points by calculating distance for each point from centroids

➢ Take average of clustered points

➢ Use as new centroids

➢ Repeat until convergence



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

Algorithm 2: k-Means Clustering

- A **greedy** algorithm
- Disadvantages:
  - Initial means are randomly selected which can cause suboptimal partitions

    Possible Solution: Try a number of different starting points
  - Depends on the value of k

Demo 2

Popular Clustering Algorithms

Hierarchical Cluster Analysis (HCA)

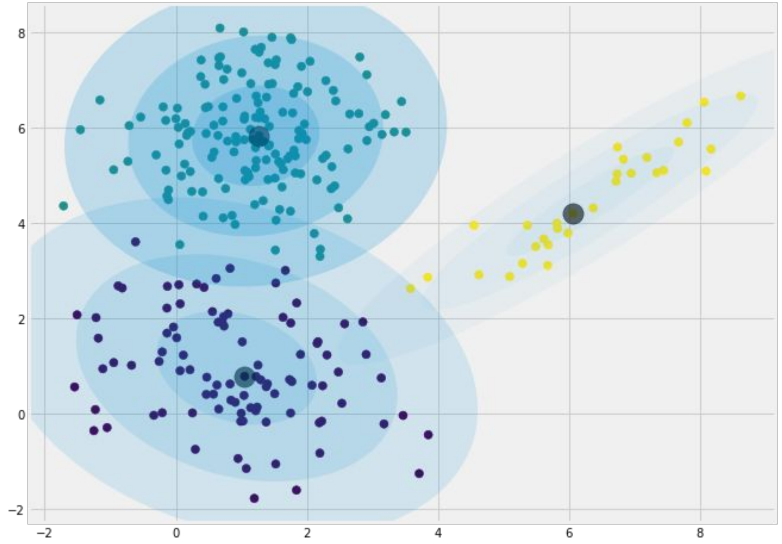
k-Means Clustering

Gaussian Mixture Models (GMMs)

Algorithm 3: Gaussian Mixture Models

Input parameter: *k*

- ➢ Starts with *k* Gaussian distributions
- ➢ Train on data to find the appropriate means and covariances for each cluster
- ➢ Compute probability of each test point lying inside each distribution and predict the one with the highest probability.



Demo 3

Coming Up

- **Assignment 9**:
  - Due next Wednesday, Nov 15th, 11:59PM
- **Last Lecture:**
  - Real-world applications of ML
- **Final Project:**
  - Due Nov 29th, 11:59PM