Ch 12.1, 12.4: Unsupervised Learning & Clustering

Lecture 32 - CMSE 381

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Wednesday, Nov 19, 2025

Announcements

Last time:

- Convolutional Neural Nets

This lecture:

- Clustering (Just hierarchical clustering)

Announcements:

- Fri 11/21: Review - submit your questions here!
- Monday 11/24: Exam 3
  - Content since 2nd Exam (Ch 7 and on)
  - One page (8.5x11) handwritten cheat sheet
  - no-internet Calculator
- after: Project office hours, zoom only (link on website).

21	F	10/24	Polynomial & Step Functions	7.1-7.2	HW #5 Due Sun 10/26
22	M	10/27	Step Functions; Basis functions; Start Splines	7.2-7.4	
23	W	10/29	Regression Splines	7.4	
24	F	10/31	Decision Trees	8.1	HW #6 Due Sun 11/2
25	M	11/3	Random Forests	8.2.1, 8.2.2	
26	W	11/5	Maximal Margin Classifier	9.1	
27	F	11/7	SVC	9.2	HW #7 Due Sun 11/9
28	M	11/10	SVM	9.3, 9.4	
29	W	11/12	Single Layer NN	10.1	
30	F	11/13	Multi Layer NN	10.2	HW #8 Due Sun 11/16
31	M	11/17	CNN	10.3	
32	W	11/19	Unsupervised learning / clustering	12.1, 12.4	
33	F	11/21	***Review***		HW #9 Due Sun 11/23
	M	11/24	**Midterm #3**		
	W	11/26	Virtual: Project Office Hours		
	F	11/28	Thanksgiving		
	M	12/1	Virtual: Project Office Hours		
	W	12/3	Virtual: Project Office Hours		
	F	12/5			**Project Due**
	M	12/8			
	W	12/10			
	F	12/12	**No final exam**		**Honors Project Due**

What will you learn today?

- What is the difference between supervised vs unsupervised learning?
- What do clustering methods aim to accomplish?
- How to interpret a dendrogram of hierarchical clustering?
- How are different linkage methods defined?
- How to perform hierarchical clustering in Python?

Section 1

Unsupervised learning

Supervised vs Unsupervised Learning

Supervised

Unsupervised

Some examples of unsupervised problems

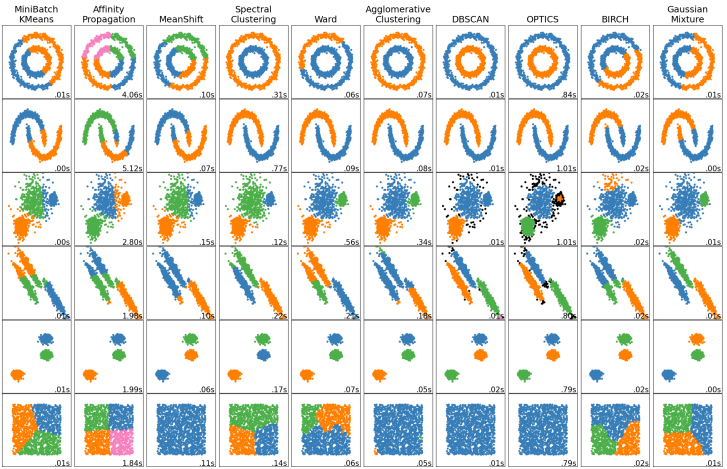
- Assay gene expression levels in 100 patients with breast cancer, looking for subgroups with similar qualities
- Online shopping: find groups of shoppers with similar browsing and purchase histories and show relevant related products.
- Search engine picking results to show

Section 2

Clustering

Big idea

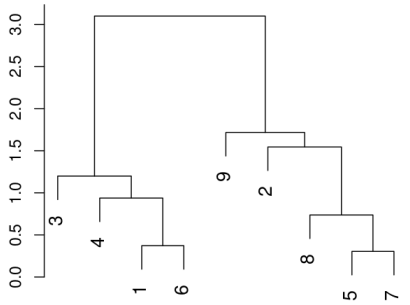
Clustering: relation between samples



Section 3

Hierarchical Clustering

Dendrogram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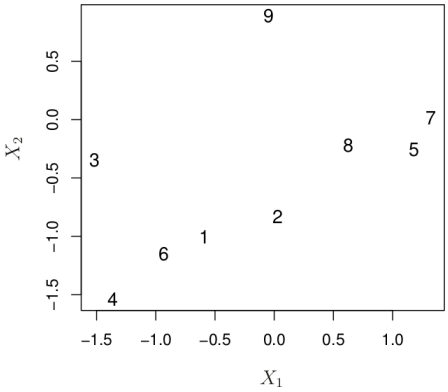
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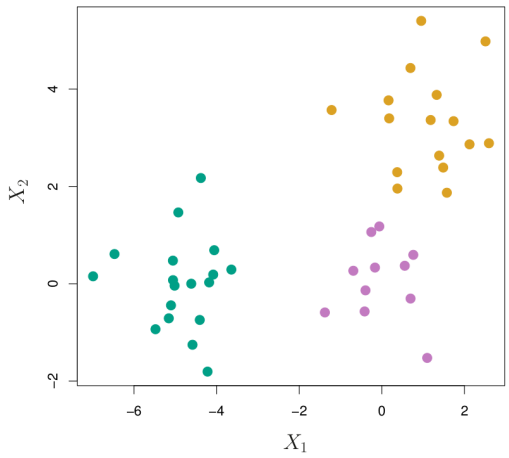
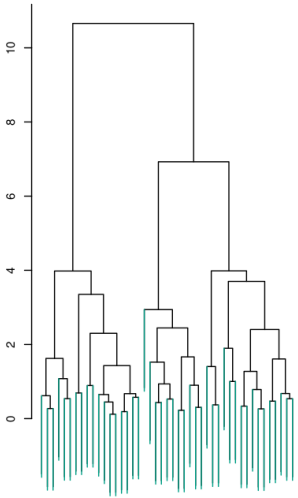
1.0
X_2
X_1

A bigger example

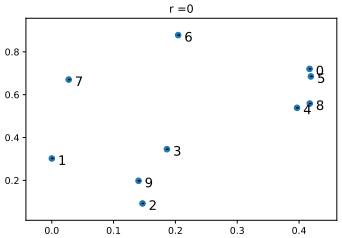


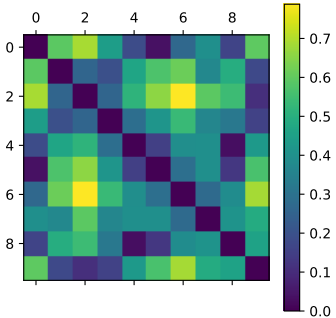


Single linkage

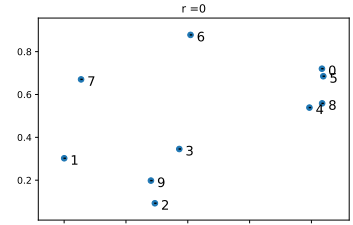
Distance between cluster A and cluster B:
Smallest distance between the points

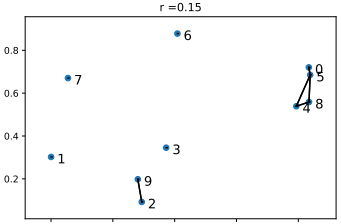
$$L(A, B) = \min_{a \in A, b \in B} \|a - b\|$$

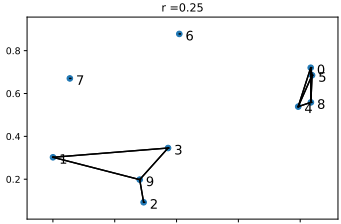


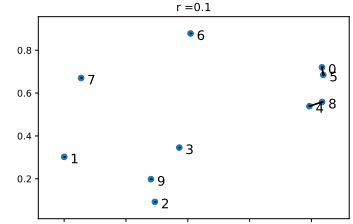


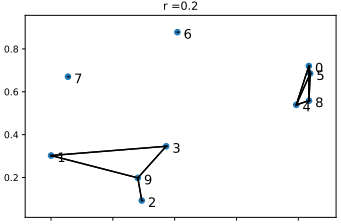
Building the dendrogram

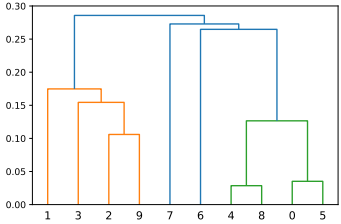




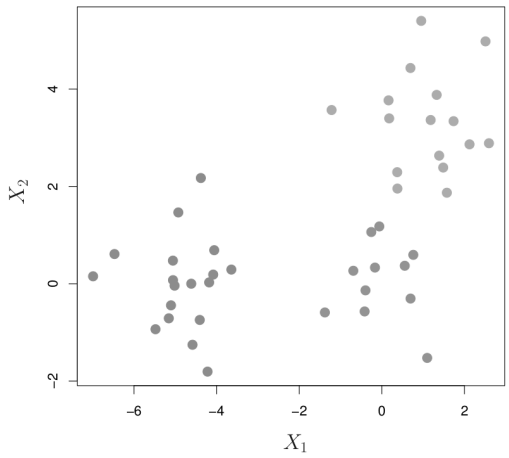


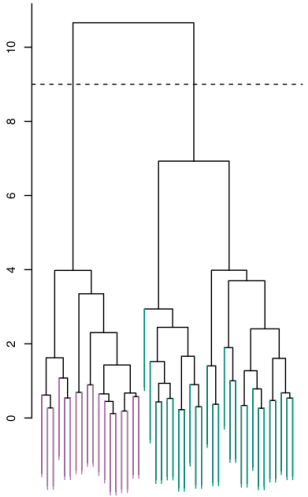




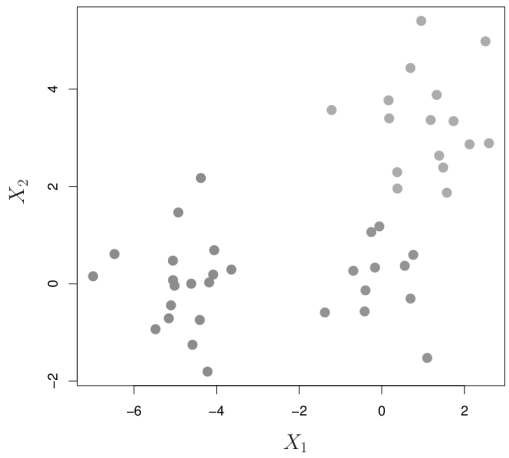


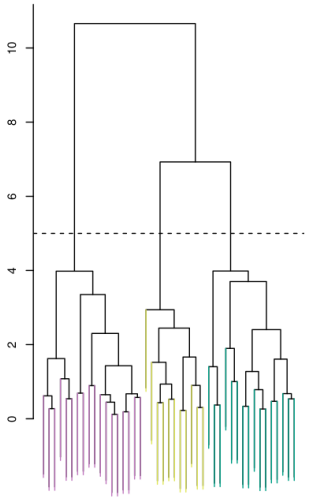
How to get clusters



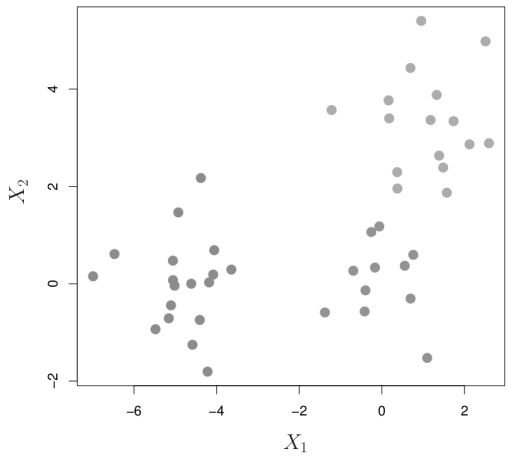


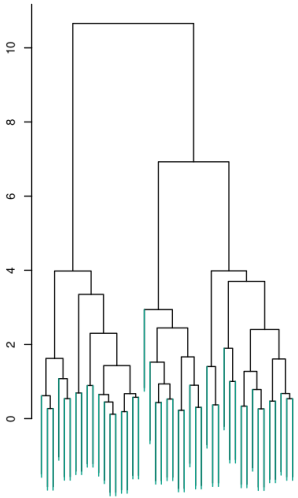
How to get different clusters





Can get any number of clusters



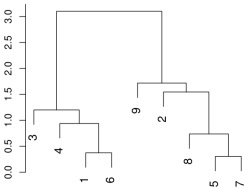


Test your understanding: PollEv

Linkage

Linkage	*Description*
Complete	Maximal intercluster dissimilarity. Compute all pairwise dissimilarities between the observations in cluster A and the observations in cluster B, and record the *largest* of these dissimilarities.
Single	Minimal intercluster dissimilarity. Compute all pairwise dissimilarities between the observations in cluster A and the observations in cluster B, and record the *smallest* of these dissimilarities. Single linkage can result in extended, trailing clusters in which single observations are fused one-at-a-time.
Average	Mean intercluster dissimilarity. Compute all pairwise dissimilarities between the observations in cluster A and the observations in cluster B, and record the *average* of these dissimilarities.
Centroid	Dissimilarity between the centroid for cluster A (a mean vector of length p) and the centroid for cluster B. Centroid linkage can result in undesirable *inversions*.

Example with complete linkage



Distance between cluster A and cluster B:
Largest distance between the points

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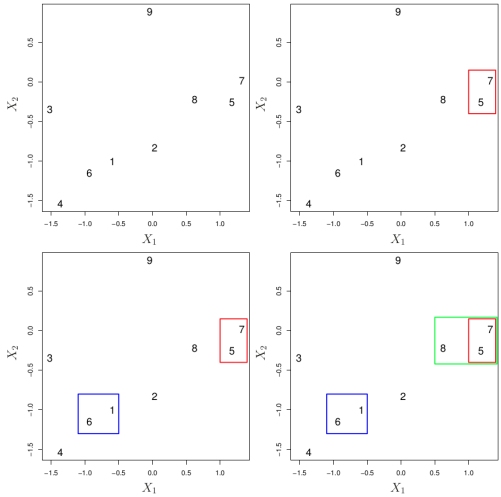
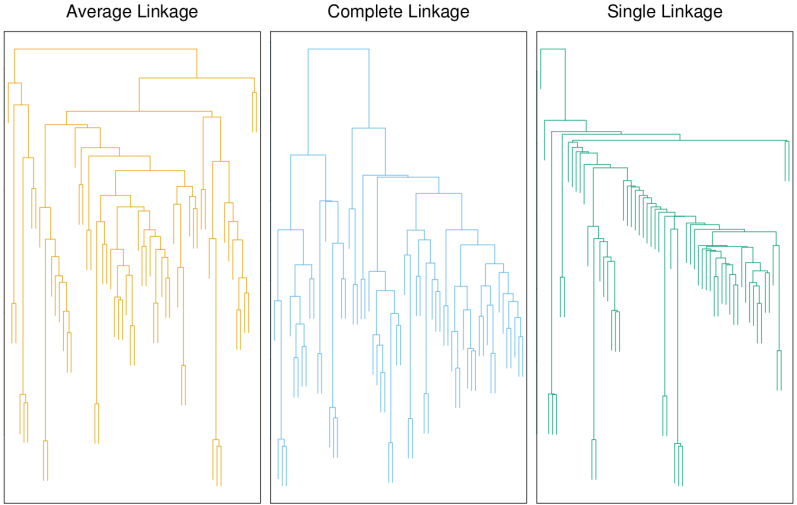


Examples of different linkage



Dependence on dissimilarity measure

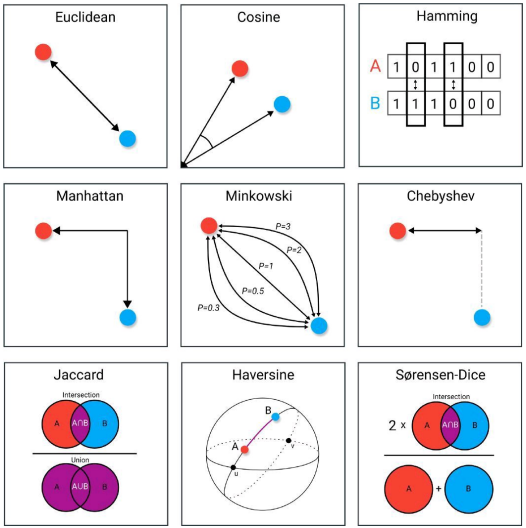


Photo Credit Link

Coding

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