Business Analytics

Session 5a. Clustering

Renyu (Philip) Zhang

New York University Shanghai

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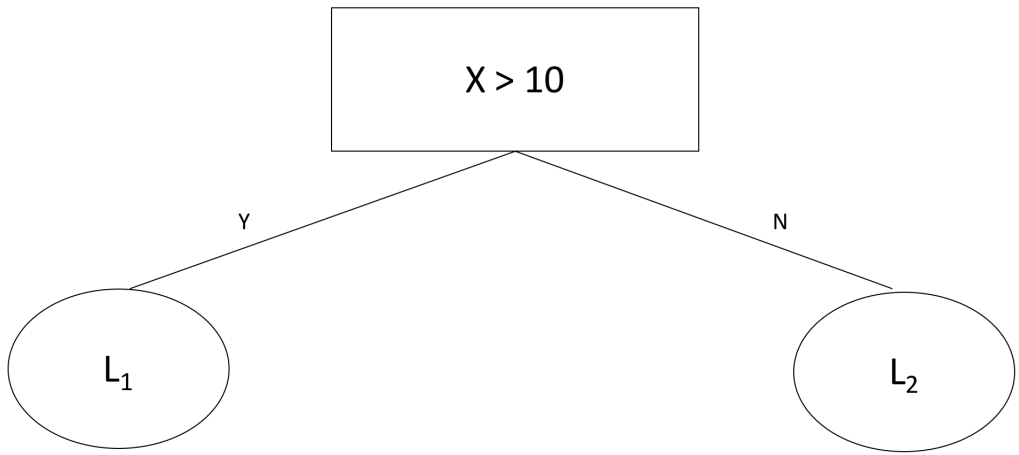
Exercises

- (T/F) By constructing a tree, we can increase the Gini index of a data set.
- What is the Gini index of the following tree:



	$y = 0$	$y = 1$
L_1	10	30
L_2	30	10

How about the Gini index of the set?

Recommender System of Netflix

Clustering as Unsupervised Learning

- Unsupervised learning finds patterns/relationships/structures in data, without being optimized to solve a particular predictive task (i.e., there's no outcome).
  - Examples: Image segmentation, customer segmentation, portfolio selection, industry analysis, and many more.

- Clustering: Segment the data into a set of homogeneous clusters of observations to generate insights.
  - Observations in the *same* group should be *similar* to each other.
  - Observations in *different* groups should be as *dissimilar* to other groups as possible.

Netflix

- Online DVD rental and streaming video services.
- More than 40 million subscribers and $3.6 billion in revenue.
- Key to Netflix: Offer customers accurate movie recommendations based on a customer's own preferences and viewing history.
  - From 2006-2009, Netflix ran a contest to predict user ratings for movies.
  - A grand prize of $1 million to who could beat their algorithm, Cinematch, by 10%, measured in RMSE.

Predicting the User Ratings

- Predicting the rating is crucial to their business.

- What data can be used in the prediction?
  - Every movie has the rating from all users who rated the movie.
  - Facts about the movie itself: Actors, director, genre classification, year released, etc.

Collaborative Filtering: Using Other Users' Ratings

	Men in Black	Apollo 13	Top Gun	Terminator
Amy	5	4	5	4
Bob	3		2	5
Carl		5	4	4
Dan	4	2		

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Carl		5	4	4
Dan	4	2		

- Question: Will Carl like the movie "Men in Black"?
  - Likely to happen.
  - Amy and Carl have similar preferences over other movies, and Amy rated "Men in Black" high.

- This technique is called Collaborative Filtering.

Content Filtering: Using Movie Information

- Amy liked "Men In Black"
  - Directed by Sonnenfeld
  - Classified in the genres of action, adventure, sci-fi and comedy
  - It stars Will Smith

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- Consider recommending to Amy:
  - Barry Sonnenfeld's movie "Get Shorty"
  - "Jurassic Park", also in the genres of action, adventure, and sci-fi
  - Will Smith's movie "Hitch"
- This is called Content Filtering.
- Netflix uses both collaborative filtering and content filtering.

Data

- We use the data from MovieLens to do content filtering using the clustering technique.
- Movies are categorized into different genres.
  - Action, adventure, animation, etc.
  - Each movie belongs to many genres.
- Goal: Systematically find groups of movies with similar sets of genres.
- Methods we will cover
  - Hierarchical
  - $k-$means

Distance between Clusters

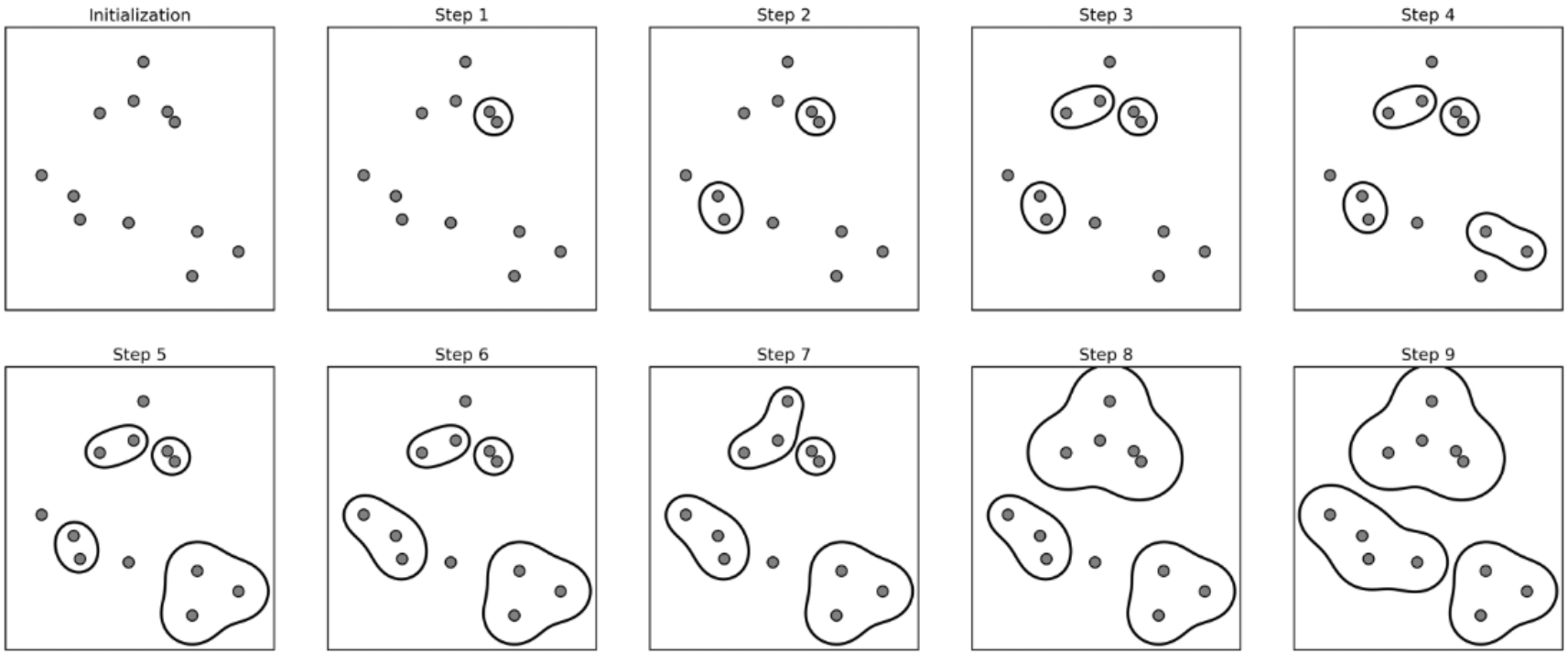
- Single linkage: Distance between points that are closest.
  $\min ||\vec{X}_i - \vec{X}_j||$ where $i \in C_1$ and $j \in C_2$
- Complete linkage: Distance between points that are farthest.
  $\max ||\vec{X}_i - \vec{X}_j||$ where $i \in C_1$ and $j \in C_2$
- Average linkage: Average distance computed over all pairs of observations between the two clusters.
  Average of $||\vec{X}_i - \vec{X}_j||$ where $i \in C_1$ and $j \in C_2$
- Average group linkage: The distance between the centers of each cluster.
  $||\vec{\mu}_1 - \vec{\mu}_2||$ where $\vec{\mu}_i$ is the center of C_i $(i = 1, 2)$
- Ward's method: How much the sum of squares will increase if we merge them.
  $\sqrt{\frac{n_1 n_2}{n_1 + n_2}} ||\vec{\mu}_1 - \vec{\mu}_2||$ where n_i is the number of data points in C_i

Hierarchical Clustering

Hierarchical Clustering Algorithm

1. Start with each data point in a cluster of its own.
2. Until there is only one cluster, do the following:
   (i) Find the closest pair of clusters
   (ii) Merge them
3. Output the tree of cluster mergers.

Illustration of the Hierarchical Method



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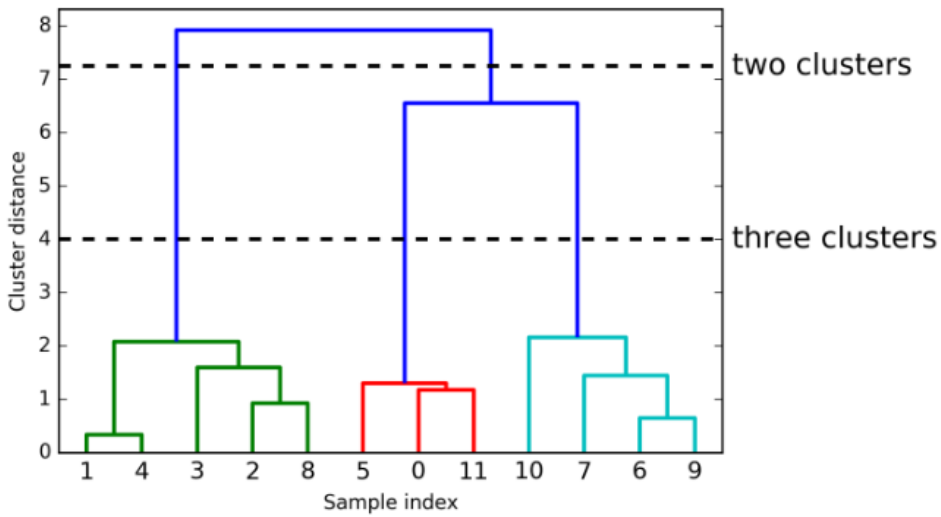

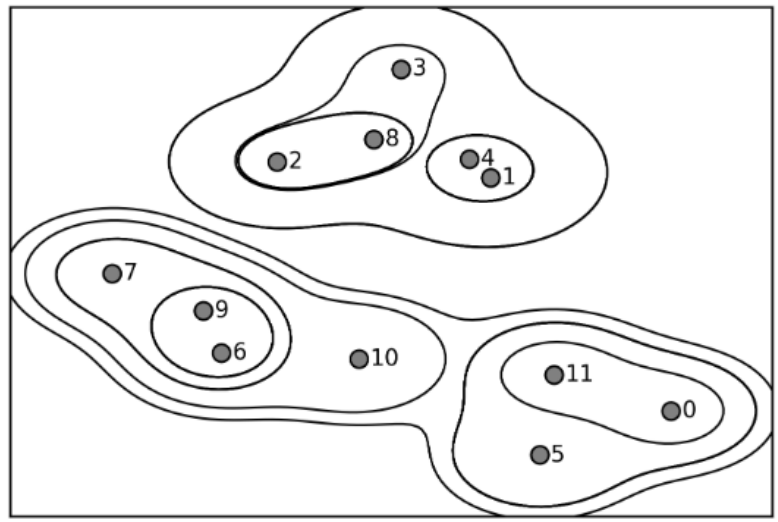

Pros and Cons of Hierarchical Method

- Hight of vertical lines represents distance between points or clusters.
- Data points listed along bottom.
- Easily select how many clusters.
- May label different clusters as outcomes.

$k-$Means Clustering

$k-$Means Algorithm

1. Specify the desired number of clusters k.
2. Randomly assign each data point to a cluster.
3. Compute cluster centers.
4. Re-assign each point to the closest cluster.
5. Re-compute cluster centers.
6. Repeat steps 4 and 5 until no improvement is made.

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The objective of $k-$means is to minimize:

$$\sum_{j=1}^{k} \sum_{i \in C_j} (\vec{X}_i - \vec{\mu}_j)^2,$$

where C_j is cluster j and $\vec{\mu}_j$ is the center of C_j.

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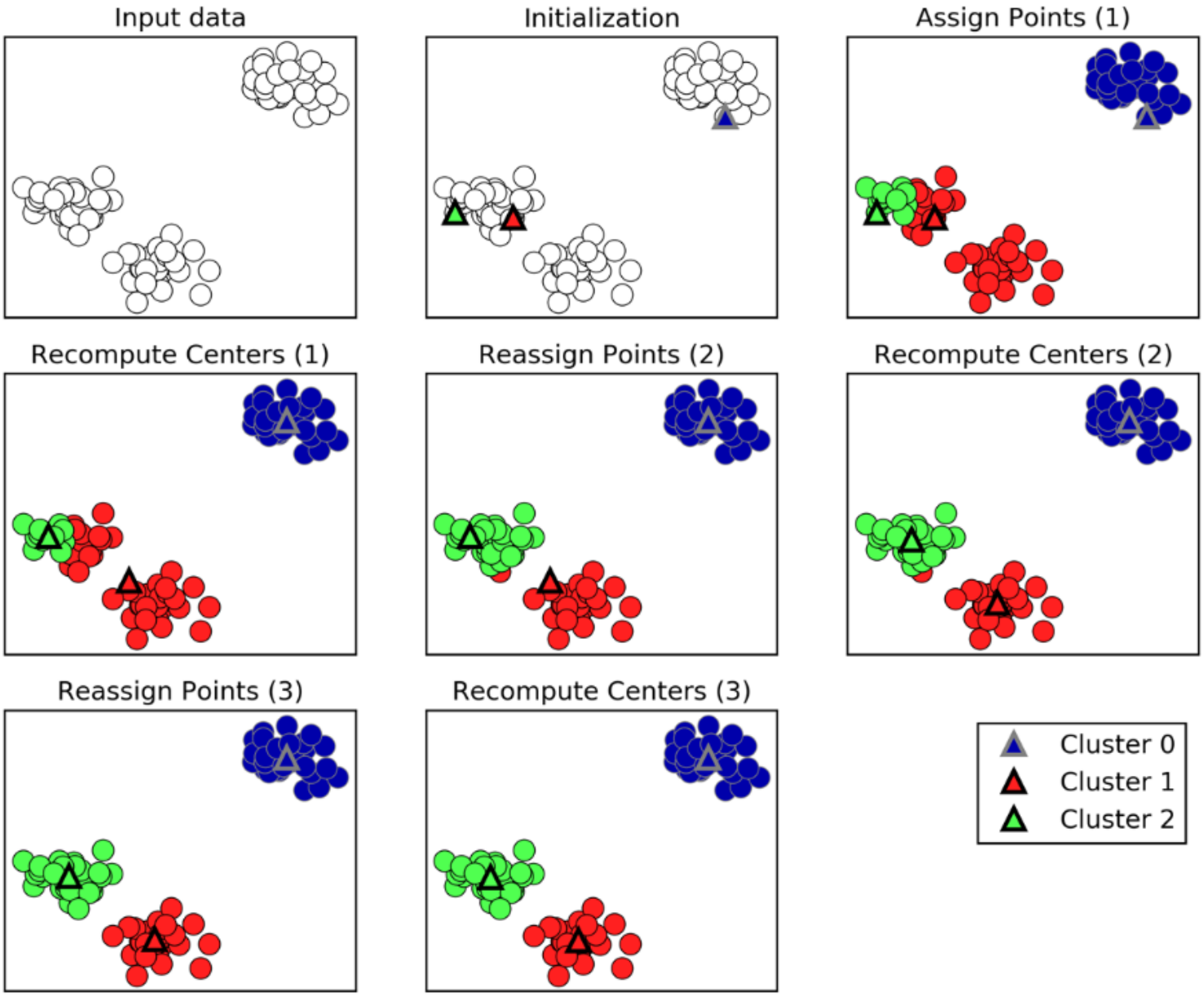
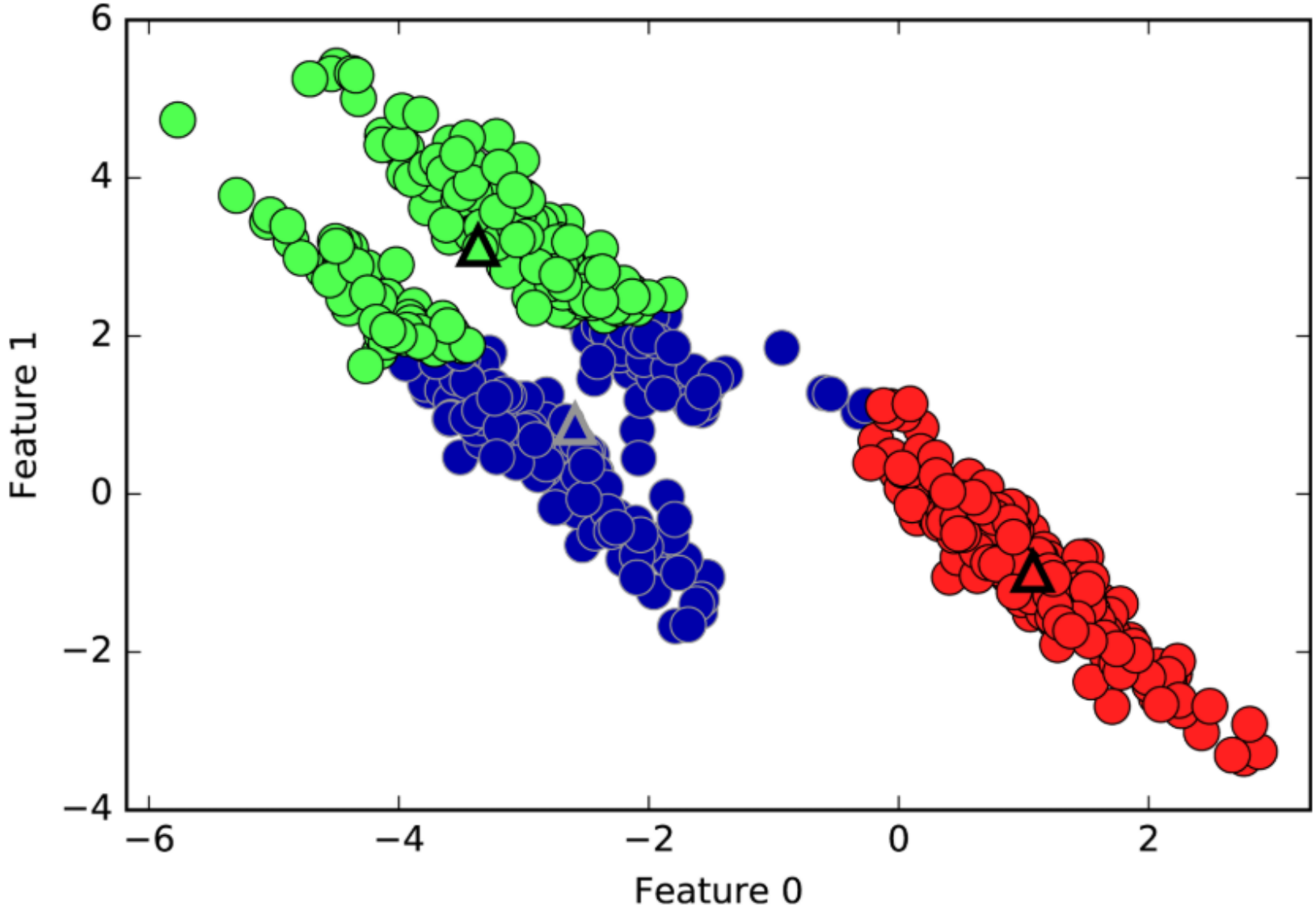


Comparisons of Two Methods

- Hierarchical clustering
  - Works well for small data sets
  - Convenient method if not sure about the number of clusters
  - Observes how clusters are nested
- $k-$means clustering
  - Suitable for a large data set if we know the number of clusters k.
  - Minimizes the squared error.
  - Cluster boundaries equidistant to centers: Cannot handle covariances well; Only simple cluster shapes.
- How do we choose k?
  - In general, the dissimilarity W will decrease as k increases.
  - Pick up k^* where there is a sharp decrease in successive differences of W.

Limitations of k–means



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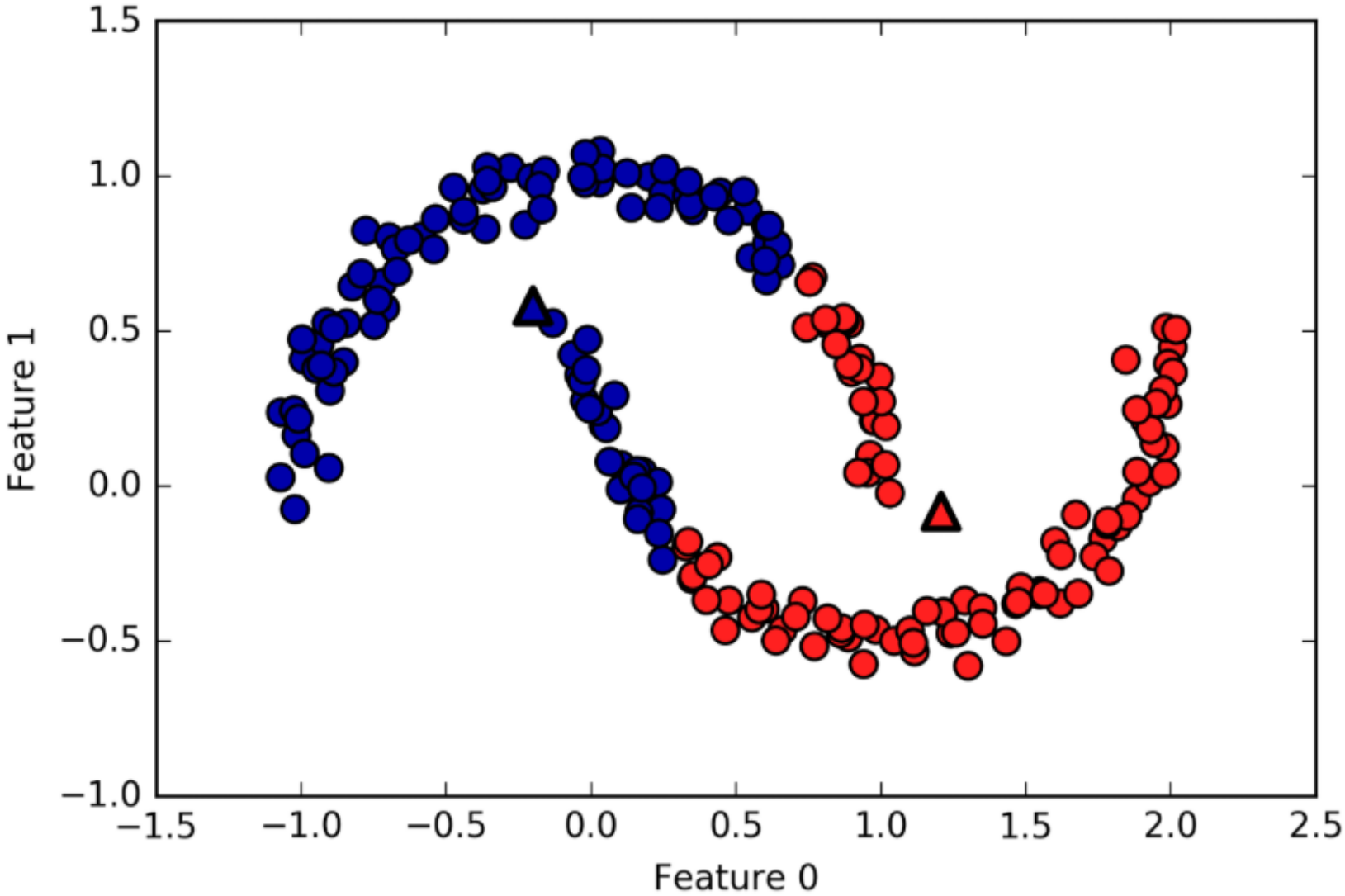

Beyond Movies: Mass Personalization

- "If I have 3 million customers on the web, I should have 3 million stores."
  - Jeff Bezos, CEO of Amazon.com

- Recommender systems build models about users' preferences to personalize the user experience.
  - A new favorite band
  - An old friend who uses the same social media network
  - A book or song they are likely to enjoy

- Clustering algorithms, tailored to find similar customers and/or similar items, form the backbone of many recommender systems.