Machine Learning – Clustering

Professor Widom's Instructional Odyssey

www.professorwidom.org

Stanford University

Google

Instabase

Google Cloud Platform

Association for Computing Machinery

Very Large Data Bases Endowment Inc.

amazon web services

Data Tools and Techniques

- Basic Data Manipulation and Analysis
  Performing well-defined computations or asking well-defined questions (“queries”)
- Data Mining
  Looking for patterns in data
- Machine Learning
  Using data to build models and make predictions
- Data Visualization
  Graphical depiction of data
- Data Collection and Preparation

Machine Learning

Using data to build models and make predictions

Supervised machine learning

- Set of labeled examples to learn from: training data
- Develop model from training data
- Use model to make predictions about new data

Unsupervised machine learning

- Unlabeled data, look for patterns or structure (similar to data mining)

Clustering

Like classification, data items consist of values for a set of features (numeric or categorical)

- Medical patients

  Feature values: age, gender, symptom1-severity, symptom2-severity, test-result1, test-result2

- Web pages

  Feature values: URL domain, length, #images, heading_1, heading_2, …, heading_n

- Products

  Feature values: category, name, size, weight, price

Clustering

Like classification, data items consist of values for a set of features (numeric or categorical)

- Medical patients

  Feature values: age, g

  symptom2-severity, test-result1, test-result2

- Web pages

  Feature values: URL domain, length, #images, heading_1, heading_2, ..., heading_n

- Products

  Feature values: category, name, size, weight, price

Unlike classification, there is no label

Clustering

Like K-nearest neighbors, for any pair of data items i_1 and i_2, from their feature values can compute distance function: $distance(i_1,i_2)$

Example:

Features - gender, profession, age, income, postal-code

person$_1$ = (male, teacher, 47, $25K, 94305)
person$_2$ = (female, teacher, 43, $28K, 94309)

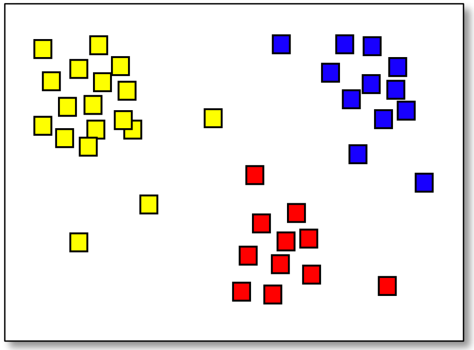
distance(person$_1$, person$_2$)

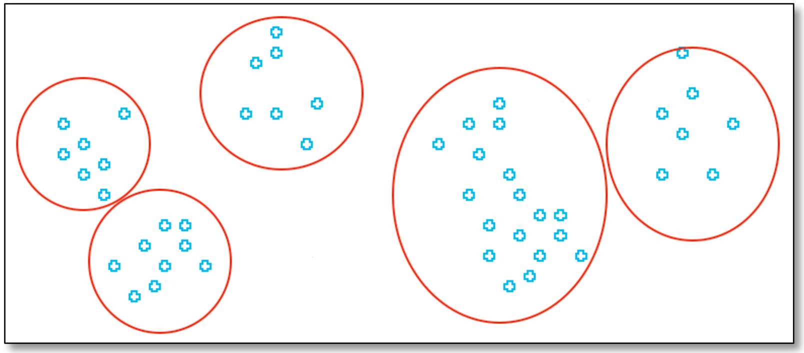
distance() can be defined as inverse of *similarity*()

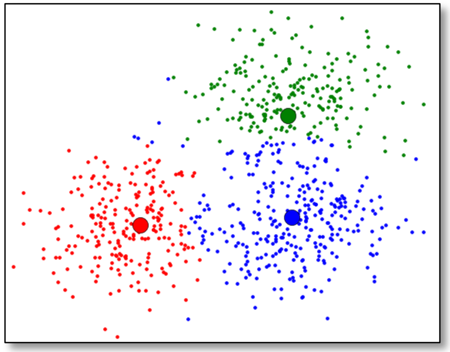
Clustering

GOAL: Given a set of data items, partition them into groups (= clusters) so that items within groups are close to each other based on distance function

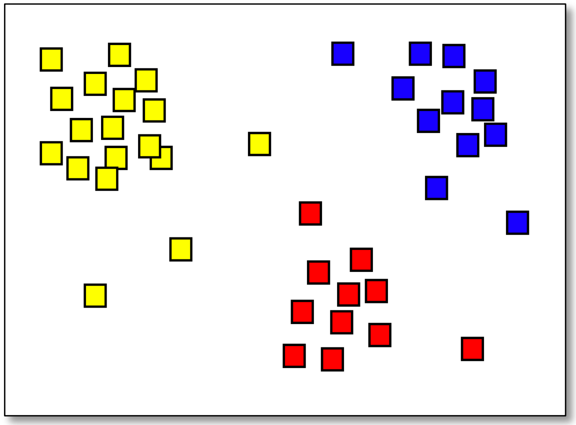
- Sometimes number of clusters is pre-specified
- Typically clusters need not be same size







Some Uses for Clustering

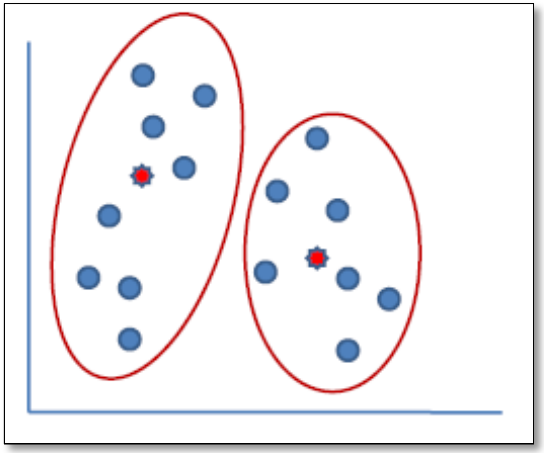


- Classification!
  - Add labels to clusters
  - Now have labeled training data for future classification
- Identify similar items
  - For substitutes or recommendations
  - For de-duplication
- Anomaly (outlier) detection
  - Items that are far from any cluster

K-Means Clustering

Reminder: for any pair of data items i_1 and i_2 have *distance*(i_1,i_2)

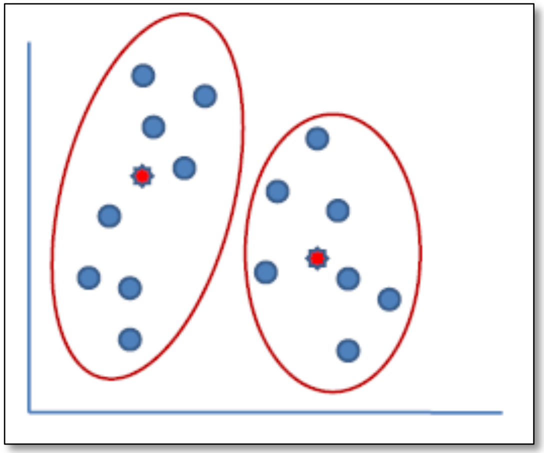
For a group of items, the mean value (centroid) of the group is the item *i* (in the group or not) that minimizes the sum of *distance*(i,i') for all i' in the group



K-Means Clustering

For a group of items, the mean value (centroid) of the group is the item i (in the group or not) that minimizes the sum of $distance(i,i')$ for all i' in the group

- Error for each item: distance d from the mean for its group; squared error is d^2
- Error for the entire clustering: sum of squared errors (SSE)

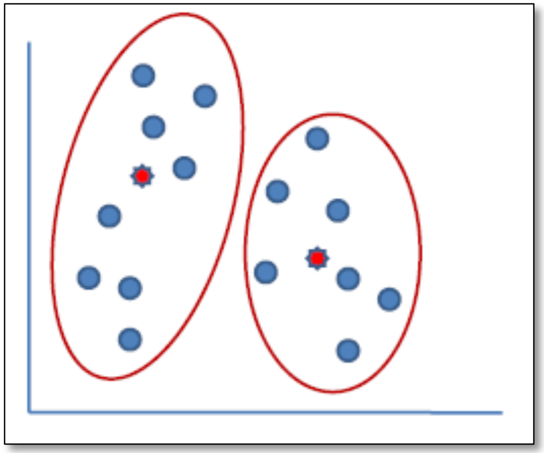


Remind you of anything?

K-Means Clustering

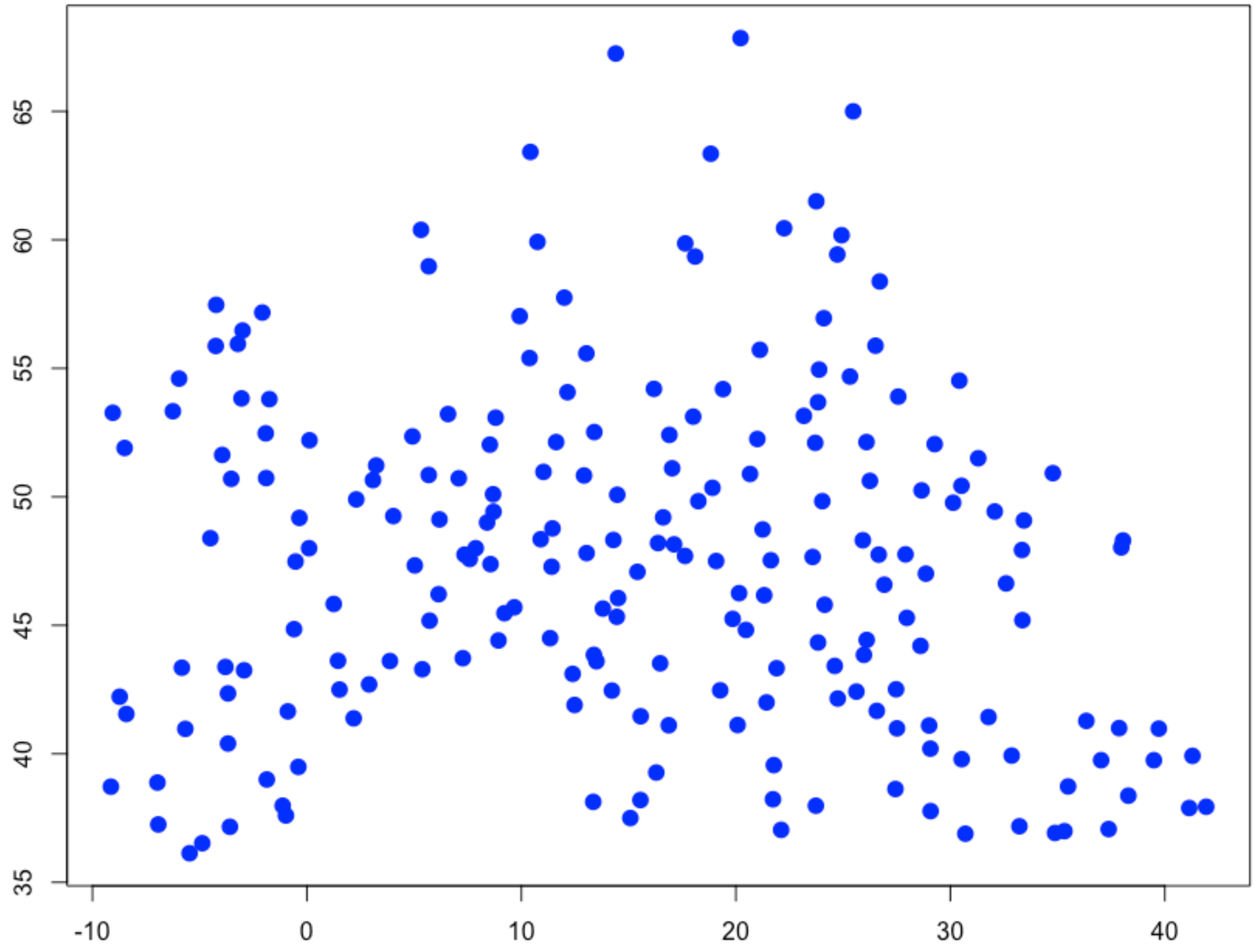
Given set of data items and desired number of clusters *k*, K-means groups the items into *k* clusters minimizing the SSE

- Extremely difficult to compute efficiently
  - In fact, impossible
- Most algorithms compute an approximate solution (might not be absolute lowest SSE)



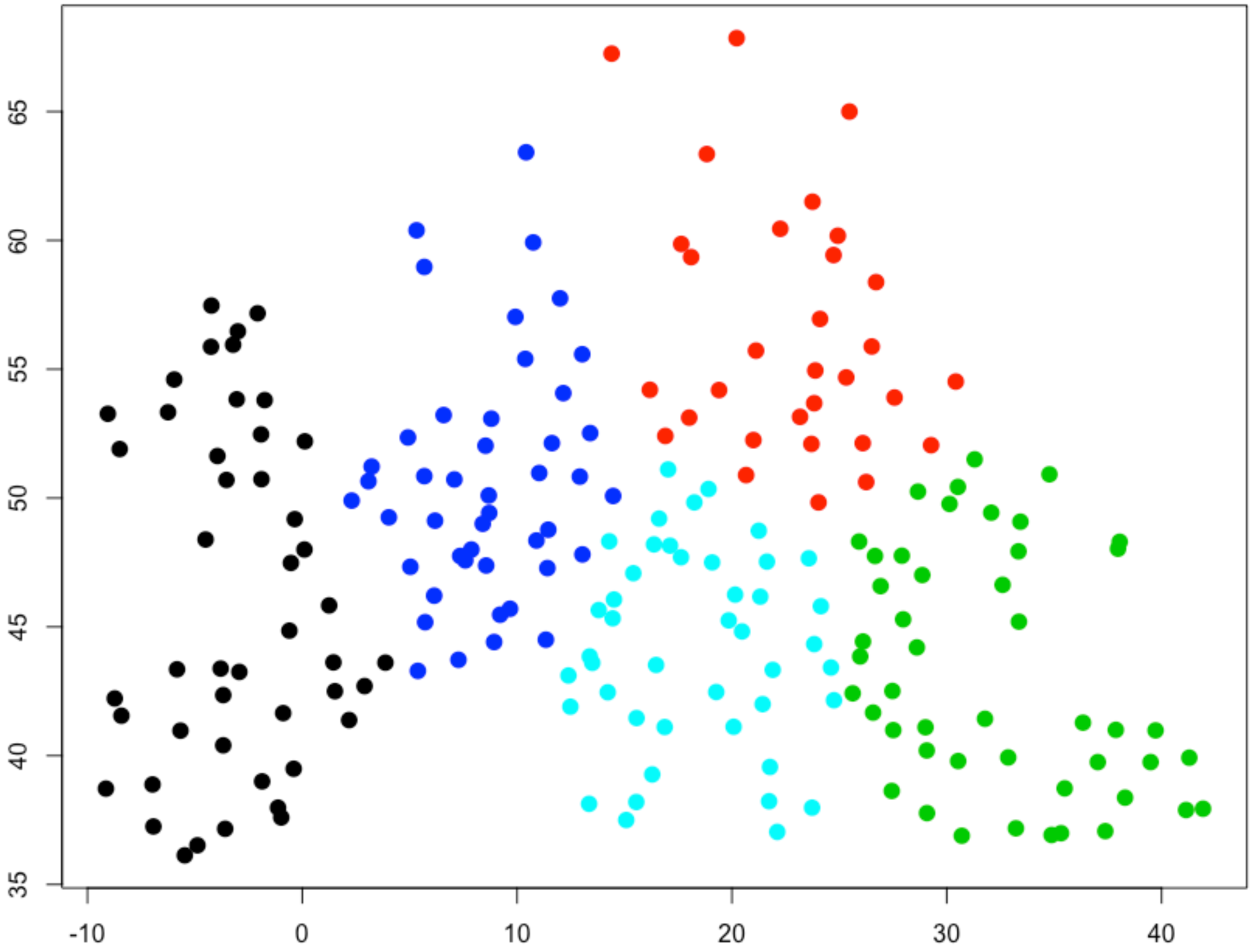
Clustering European Cities

By geographic distance, then by temperature



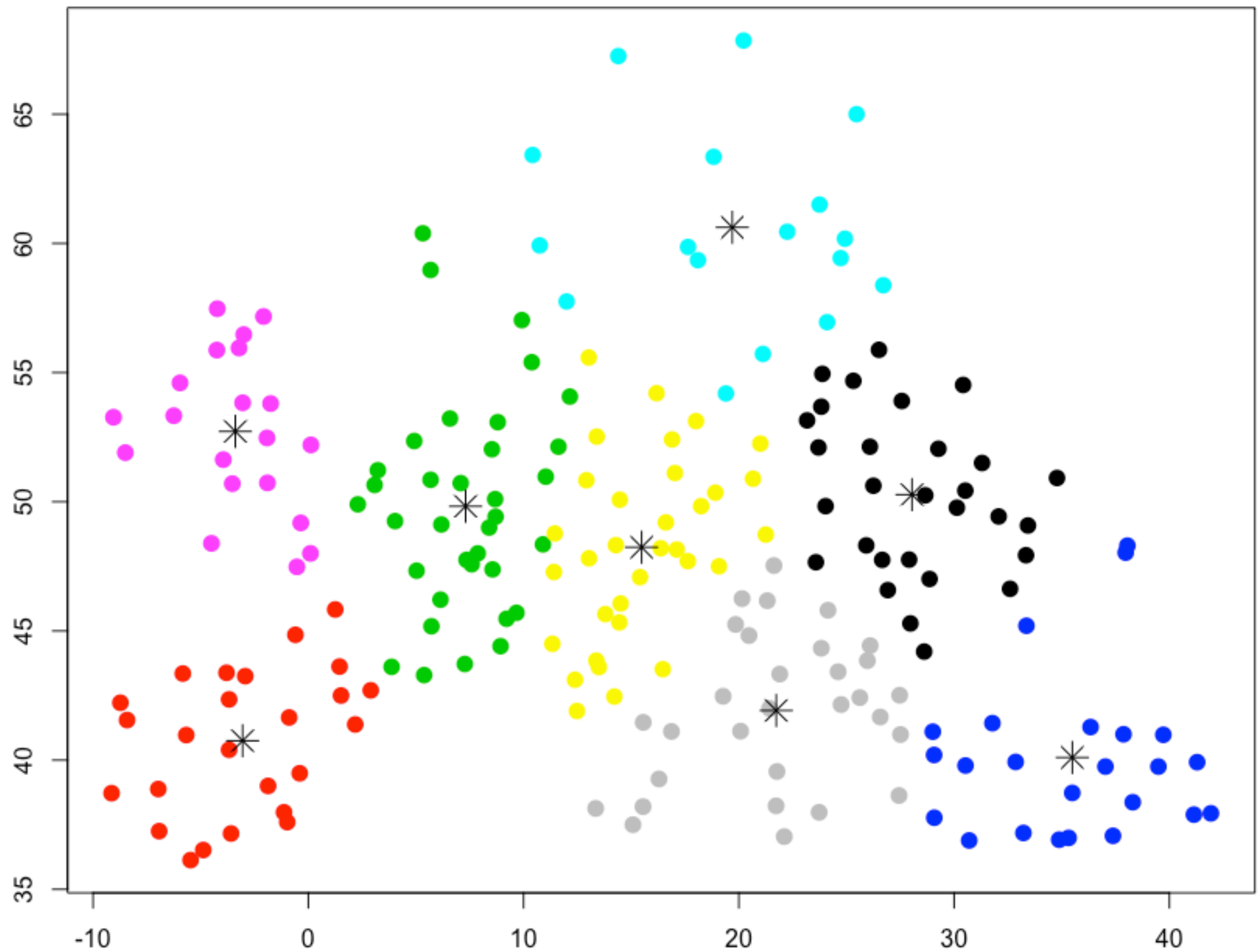
Clustering European Cities

Distance = actual distance, k = 5



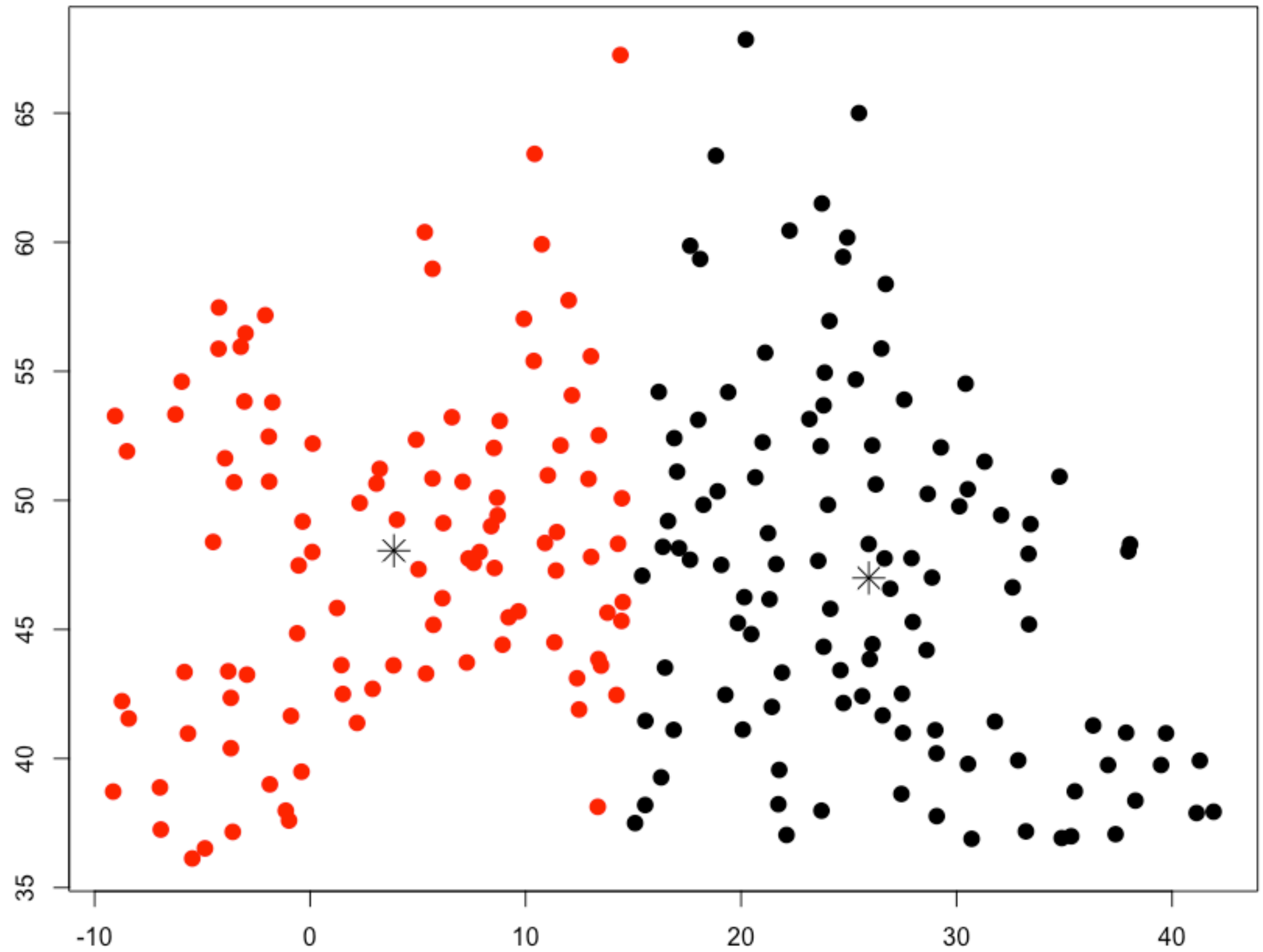
Clustering European Cities

Distance = actual distance, k = 8, with cluster means



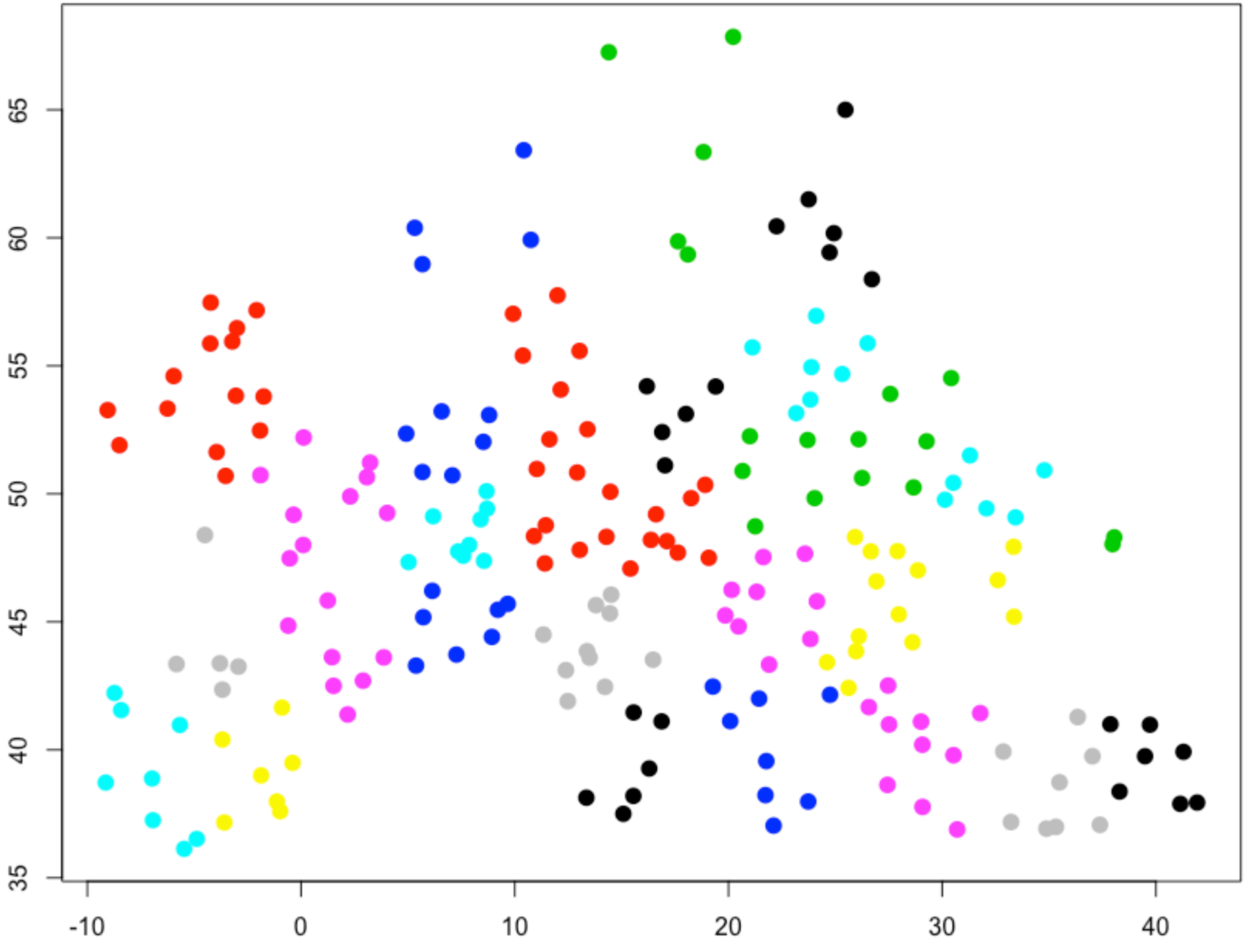
Clustering European Cities

Distance = actual distance, k = 2, with cluster means



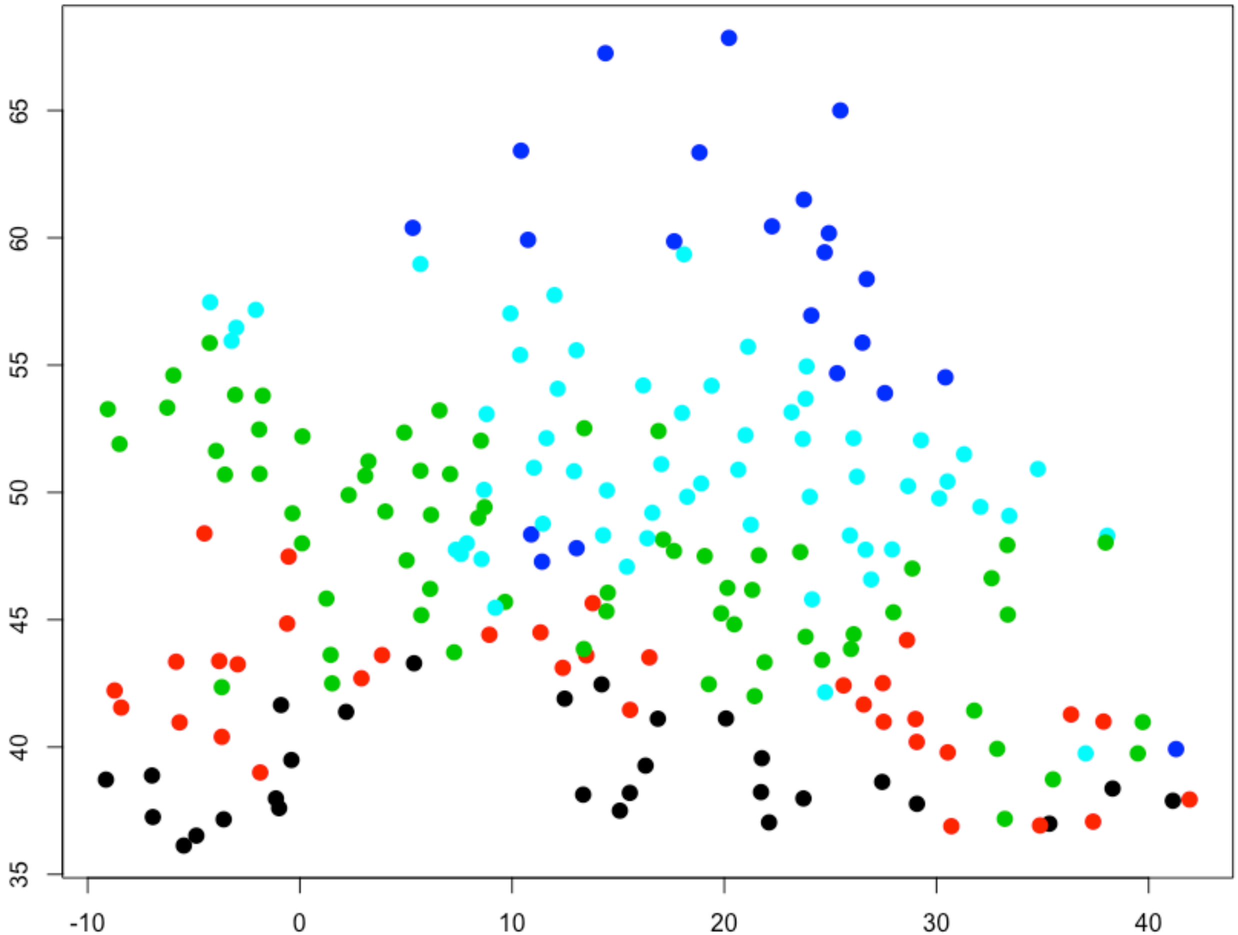
Clustering European Cities

Distance = actual distance, k = 30



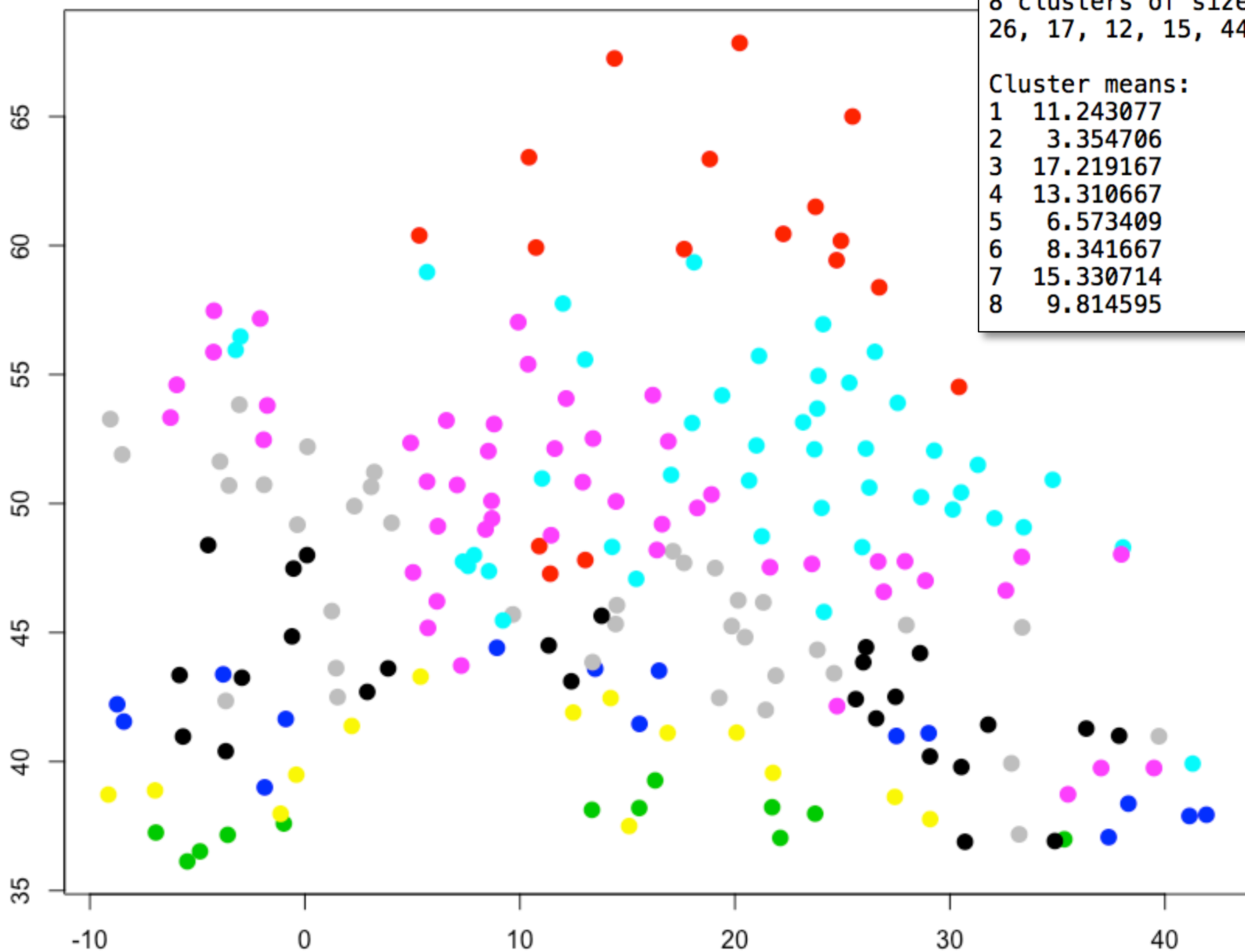
Clustering European Cities

Distance = temperature, k = 5



Clustering European Cities

Distance = temperature, k = 8, with means

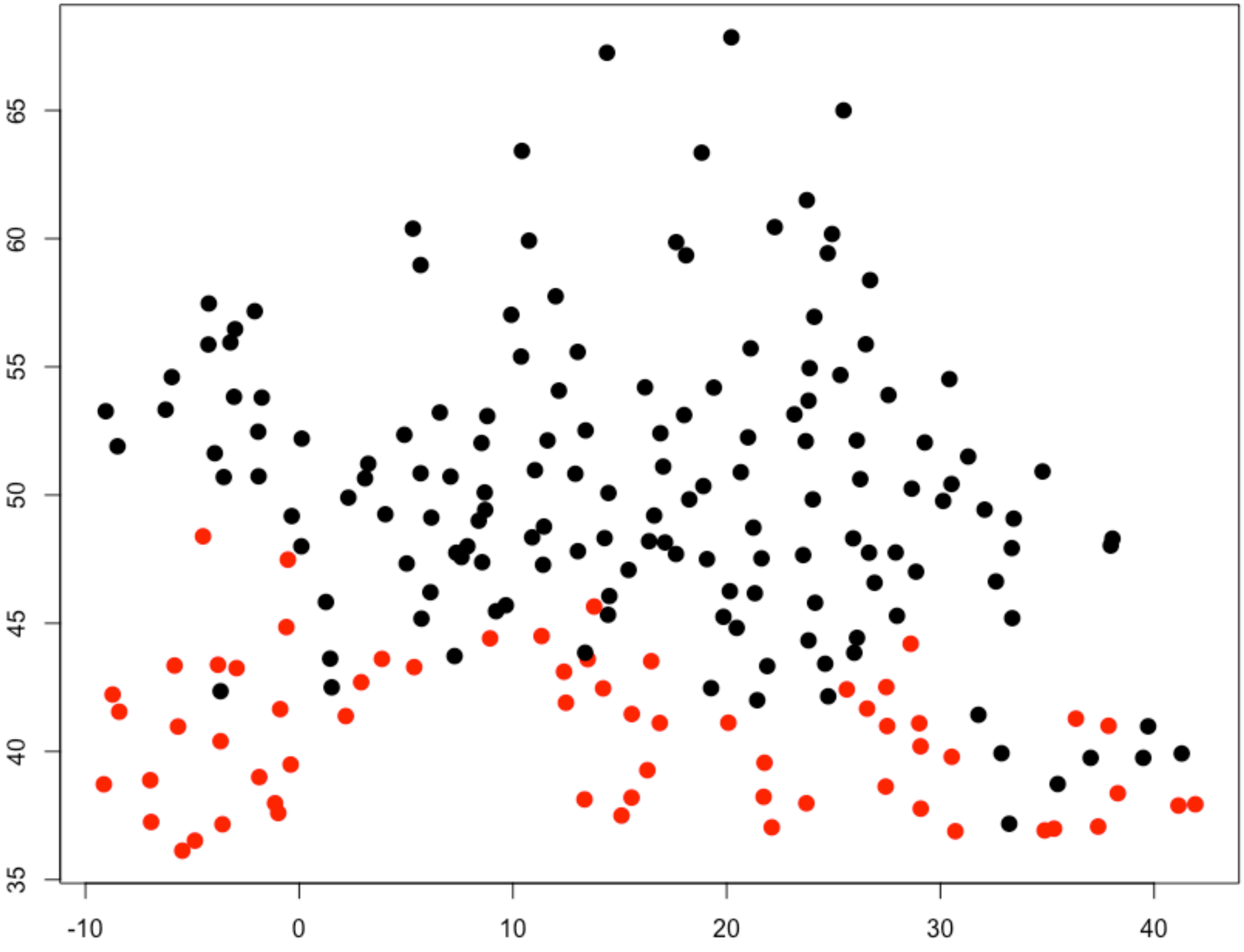



```
8 clusters of sizes:
26, 17, 12, 15, 44, 48, 14, 37

Cluster means:
1  11.243077
2   3.354706
3  17.219167
4  13.310667
5   6.573409
6   8.341667
7  15.330714
8   9.814595
```

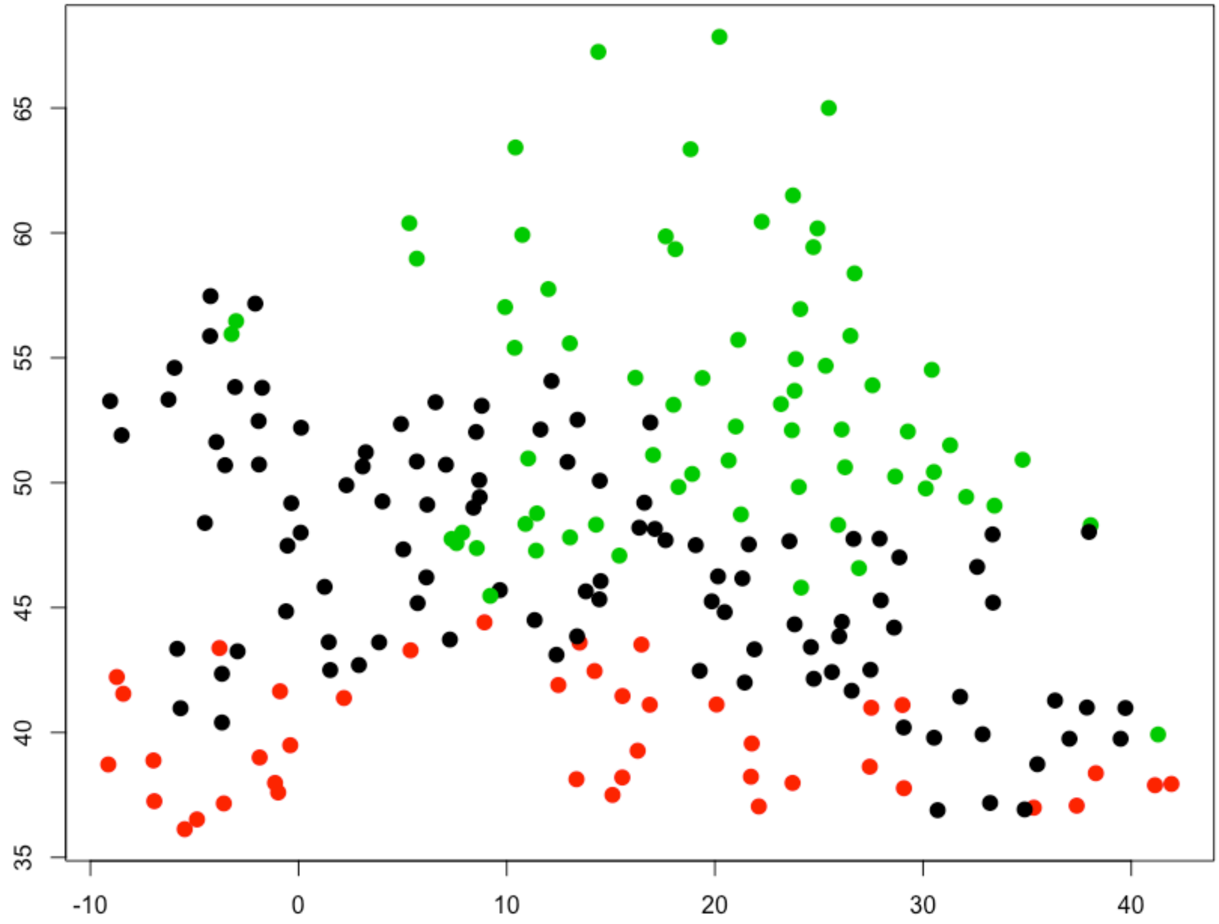
Clustering European Cities

Distance = temperature, k = 2



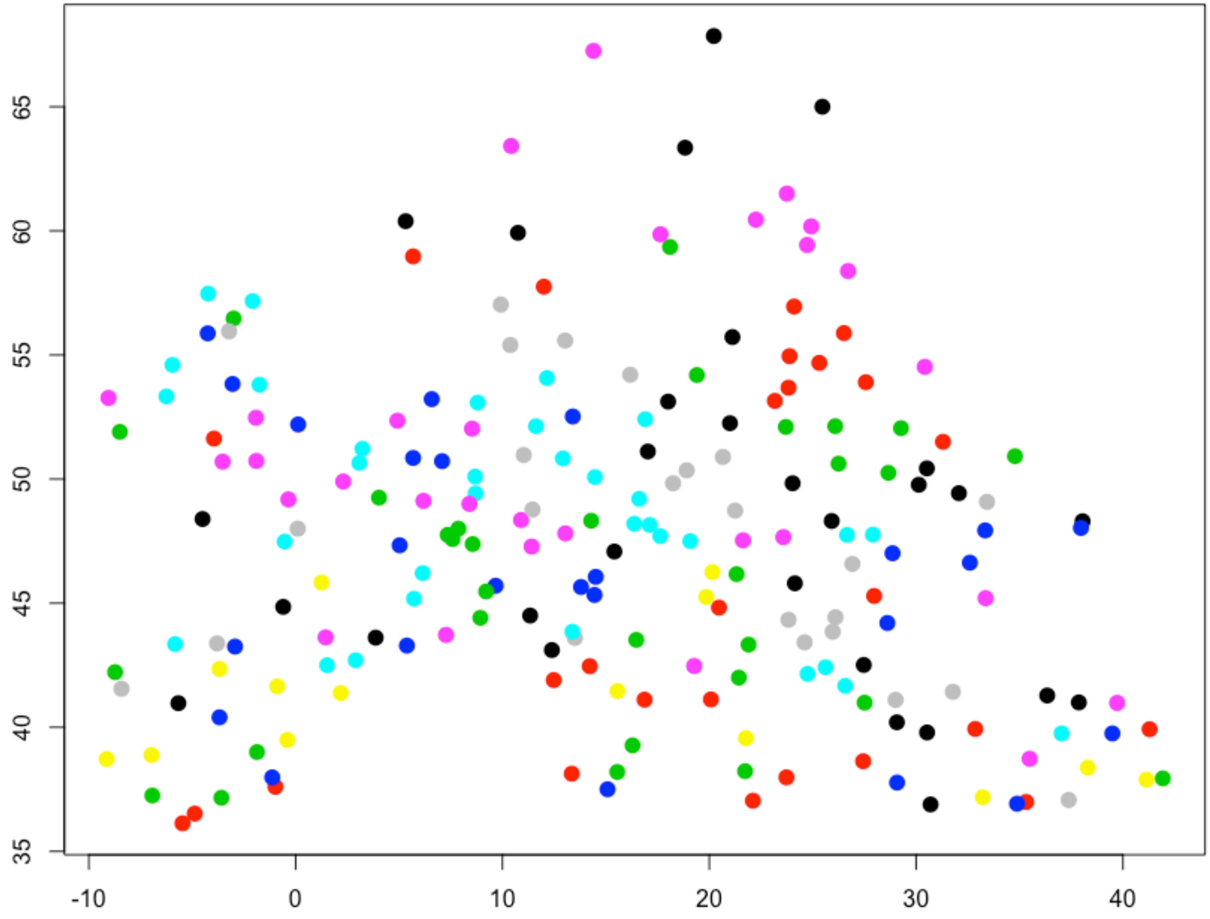
Clustering European Cities

Distance = temperature, k = 3



Clustering European Cities

Distance = temperature, k = 30



Some Uses for Clustering

- Classification
  - Assign labels to clusters
  - Now have labeled training data for future classification
- Identify similar items
  - For substitutes or recommendations
  - For de-duplication
- Anomaly (outlier) detection
  - Items that are far from any cluster