

Machine Learning

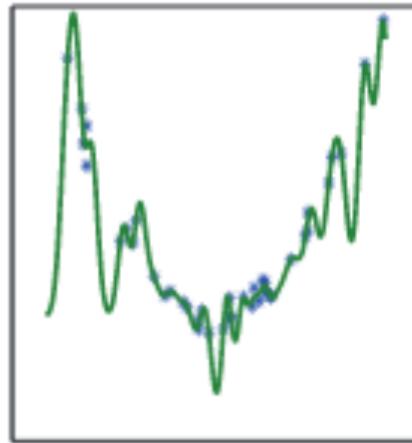
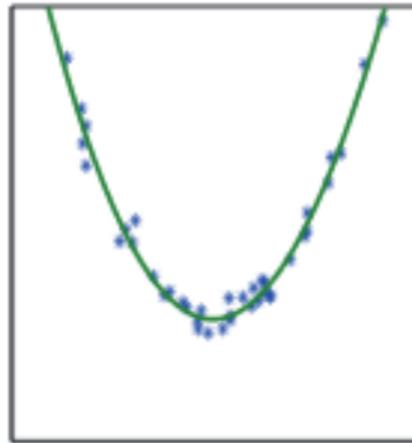
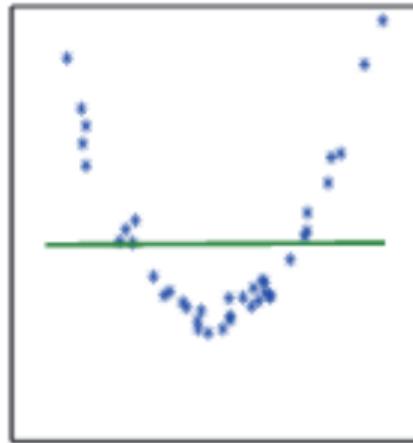
Faces, Clustering, Anomalies

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Review

Underfitting, overfitting



Linear Regression

Logistic Regression

SVM

CART

Random Forests

PCA

PCA

Motivation

?

Motivation

Remember the Curse of Dimensionality?

Principle

- Linear transformations have axes
- Find them (eigenvectors of the covariance matrix)
- Pick the biggest ones

Principle

- Linear transformations have axes
- Find them (eigenvectors of the covariance matrix)
- Pick the biggest ones

Fitting an n -dimensional ellipsoid to the data

Uses

- Exploratory data analysis
- Compression
- Visualisation

Face Recognition

Eigenfaces

- Sirovich and Kirby (1987)
- Turk and Pentland (1991)

Turk, Matthew A and Pentland, Alex P. Face recognition using eigenfaces. Computer Vision and Pattern Recognition, 1991. Proceedings CVPR'91., IEEE Computer Society Conference on 1991.

Eigenfaces

Want: a low-dimensional representation of a face

Plan: cluster simplified faces

Eigenfaces

Viewed as compression:

- Use PCA on face images to form a set of basis features
- Use eigenpictures to reconstruct original faces

Eigenfaces



Eigenfaces algorithm

Let $X = \{x_1, x_2, \dots, x_n\}$ be a random vector with observations $x_i \in \mathbb{R}^d$.

Compute

$$\mu = \frac{1}{n} \sum_{i=1}^n x_i$$

OpenCV

Eigenfaces algorithm

Compute the covariance matrix S :

$$\begin{aligned} S_{i,j} &= \mathbf{Cov}(x_i, x_j) \\ &= \mathbf{E}[(x_i - \mu_i)(x_j - \mu_j)^T] \end{aligned}$$

$$S = (S_{i,j})$$

Eigenfaces algorithm

Compute the eigenvectors of S :

$$Sv_i = \lambda_i v_i \quad i = 1, 2, \dots, n$$

Sort the eigenvectors in decreasing order.

We want the k principal components, so take the first k .

Eigenfaces algorithm

Compute the eigenvectors of S :

$$Sv_i = \lambda_i v_i \quad i = 1, 2, \dots, n$$

Sort the eigenvectors in decreasing order.

We want the k principal components, so take the first k .

This is PCA.

Eigenfaces algorithm

The k principal components of the observed vector x are then given by

$$y = W^T(x - \mu)$$

where

$$W = \begin{bmatrix} | & | & & | \\ v_1 & v_2 & \cdots & v_k \\ | & | & & | \end{bmatrix}$$

Eigenfaces algorithm

The reconstruction from the PCA basis is then

$$x = Wy + \mu$$

Eigenfaces algorithm

So the plan is this:

- Project all training samples in the PCA subspace
- Project the query into the PCA subspace
- Find the nearest neighbour to the projected query image among the projected training images

Eigenfaces algorithm



Eigenfaces algorithm

Some advantages:

- Easy, relatively inexpensive
- Recognition cheaper than preprocessing
- Reasonably large database possible

Eigenfaces algorithm

Some problems:

- Need controlled environment
- Needs straight-on view
- Sensitive to expression changes
- If lots of variance is external (e.g., lighting)...

Handwriting Recognition

Introduction to Handwriting Recognition

Choices

- Online
- Offline

Introduction to Handwriting Recognition

Choices

- Get path information
- Get time data
- Get pressure information
- Only get image

Introduction to Handwriting Recognition

Major techniques

- Clustering (not great performance)
- SVM (until 2006 or so)
- Convolutional neural networks



questions?

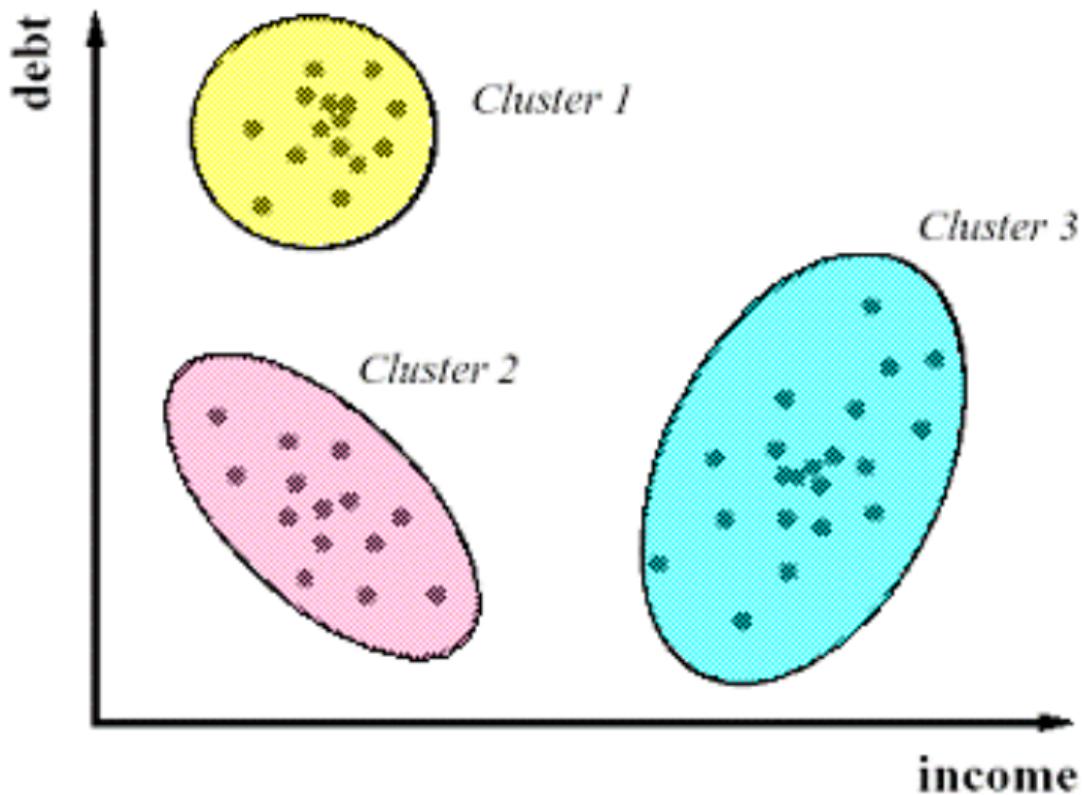
Clustering

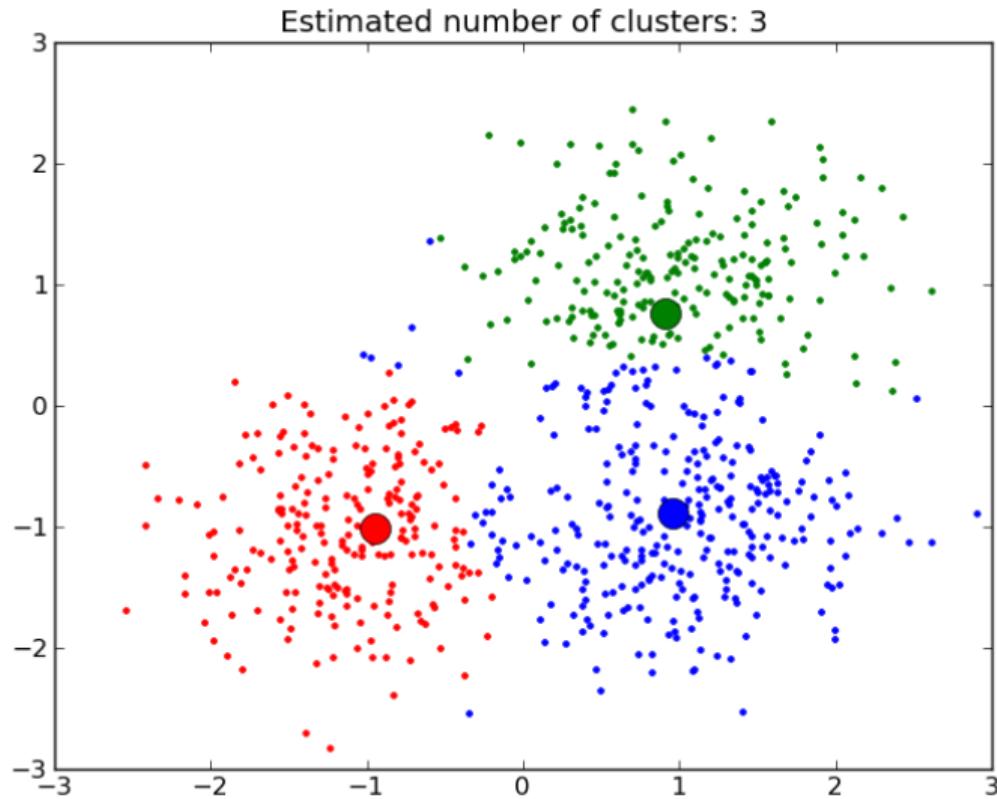
The Problem

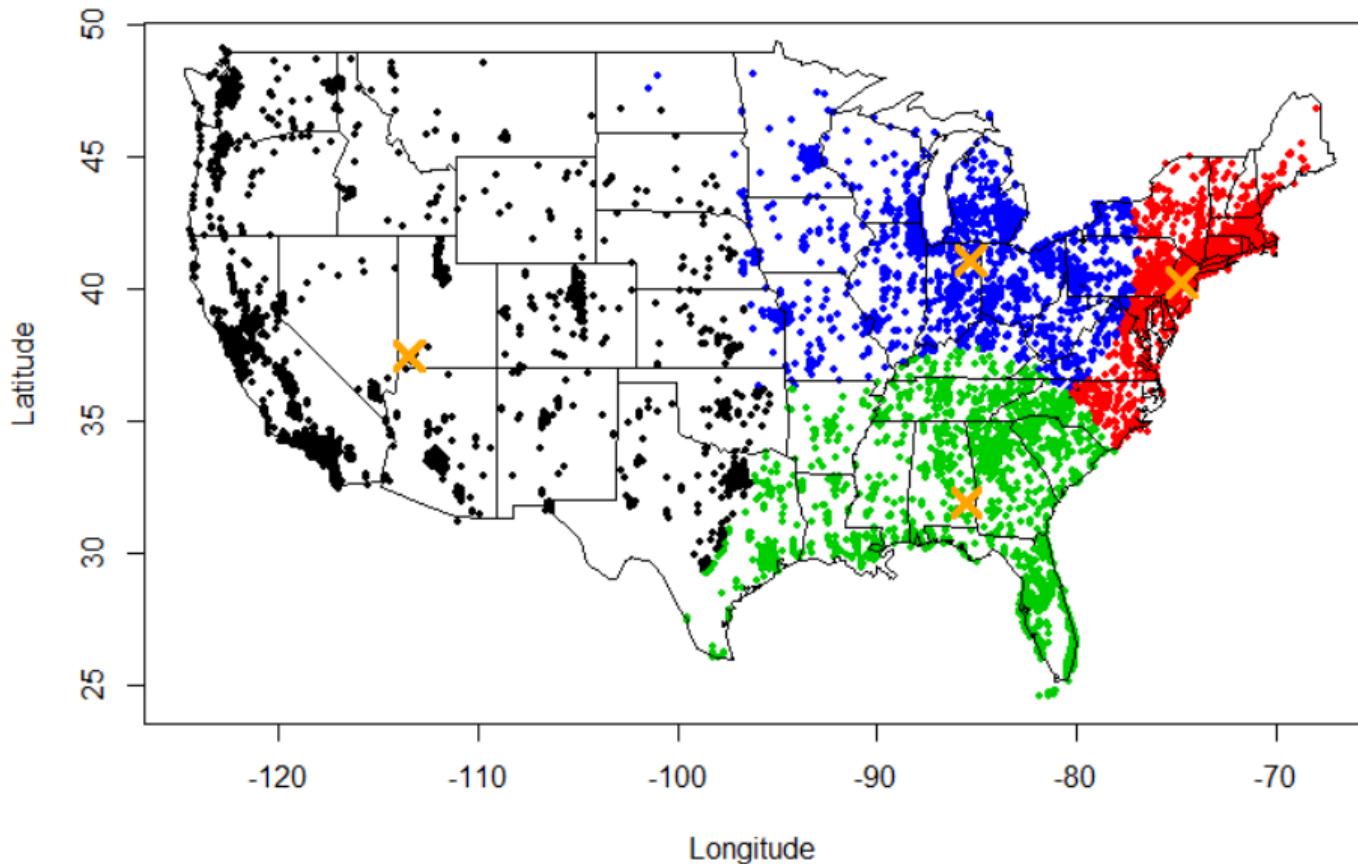
Have points $d = \{d_1, \dots, d_n\}$.

Have number of clusters k .

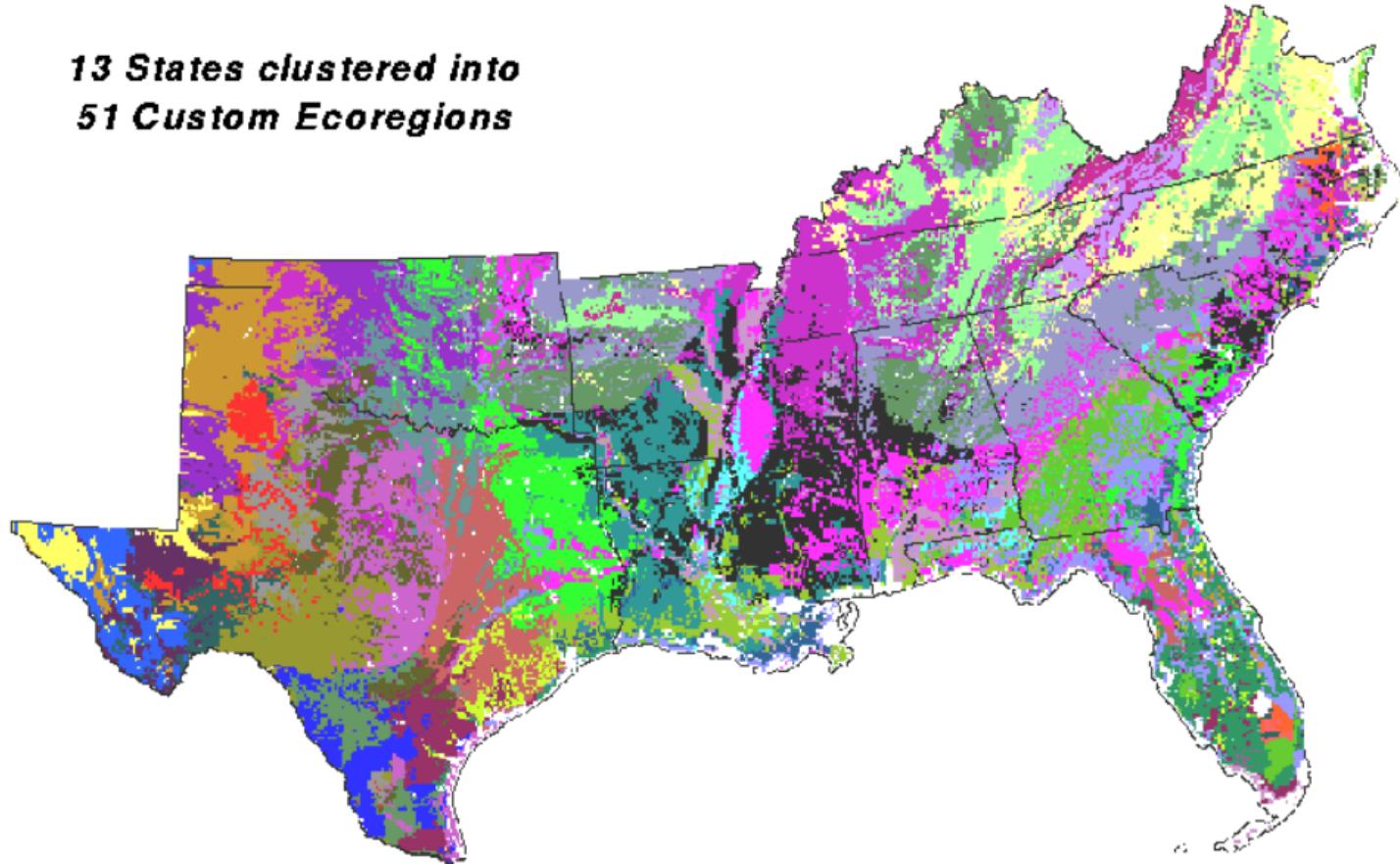
Want: an assignment of points to clusters







*13 States clustered into
51 Custom Ecoregions*



The Algorithm

- ① Assign points to clusters at random
- ② Repeat until stable:
 - ① Compute centroids of each cluster
 - ② Assign points to nearest centroid

Cost function

$$\text{cost} = \sum_i \sum_j |x_j - \mu_i|$$

Silhouette coefficient

Points $d = \{d_1, \dots, d_n\}$

Clusters $K = \{c_1, \dots, c_k\}$.

Cluster c_{d_i} is the centroid of d_i .

Silhouette coefficient

Points $d = \{d_1, \dots, d_n\}$

Clusters $K = \{c_1, \dots, c_k\}$.

Cluster c_{d_i} is the centroid of d_i .

Let a_i be the average dissimilarity of d_i to all points in its cluster.

Let b_i be the least average dissimilarity of d_i to any cluster other than k_{d_i}

Silhouette coefficient

$$s_i = \frac{b_i - a_i}{\max\{a_i, b_i\}}$$

Silhouette coefficient

$$s_i = \frac{b_i - a_i}{\max\{a_i, b_i\}}$$

$$s_i = \begin{cases} 1 - a_i/b_i & \text{if } a_i < b_i \\ 0 & \text{if } a_i = b_i \\ b_i/a_i - 1 & \text{if } a_i > b_i \end{cases}$$

Silhouette coefficient

$$s_i = \frac{b_i - a_i}{\max\{a_i, b_i\}}$$

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So $s_i \in [-1, 1]$

Silhouette coefficient

s_i near 1 $\iff d_i$ well clustered

s_i near 0 $\iff d_i$ on the border between two clusters

s_i near -1 $\iff d_i$ poorly clustered

Silhouette coefficient

Consider \bar{s}_i over $i \in c_j$ for cluster c_j

Silhouette coefficient

Consider \bar{s}_i

video time

Anomaly Detection

Introduction to Anomaly Detection

- Supervised
- Unsupervised

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Supervised anomaly detection:

- Training data: normal, abnormal
- Train a classifier

So reduced to existing problem of supervised classification.

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Unsupervised anomaly detection:

- Mostly, this is clustering
- Increasingly, this is neural networks in advanced applications

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Applications:

- Intrusion detection (physical or electronic)
- Fraud detection
- Health monitoring (people, animals, machines)

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Techniques:

- Density: kNN, local outlier factor
- SVM
- Clustering: k -Means

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kNN techniques and variations

- Voronoi diagrams
- aNN

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LOF

- Measure average density using kNN
- Points with low local density are suspect outliers
- There is no good thresholding technique

Introduction to Anomaly Detection

k-Means

Examples

ping times

Examples

httpd response times

Examples

single/multiple host access abuse (DOS/DDOS)

Examples

bank card fraud

Examples

spam



questions?