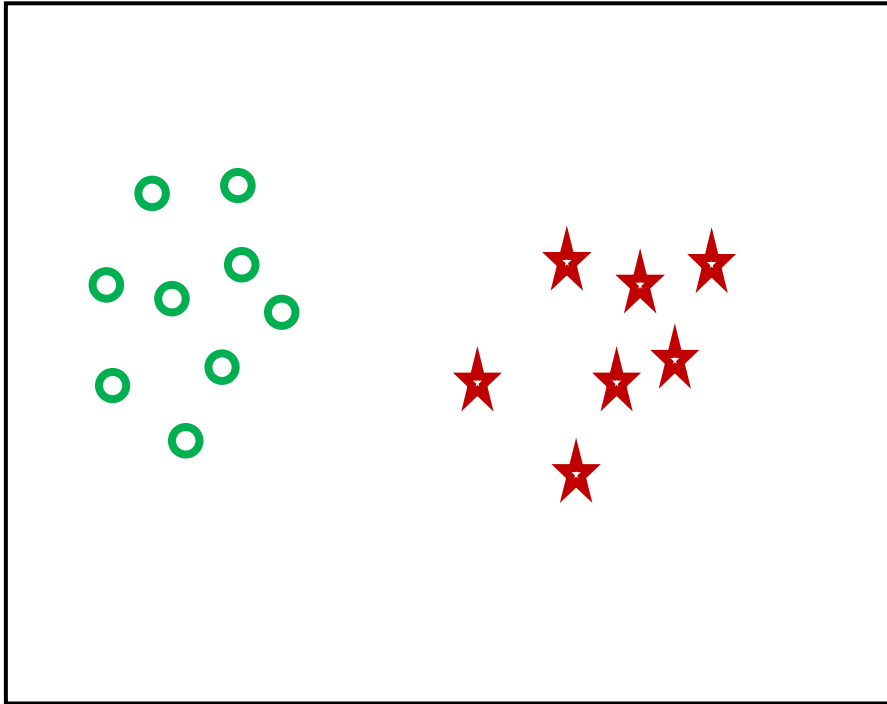# Deep Learning (CS 470, CS 570)
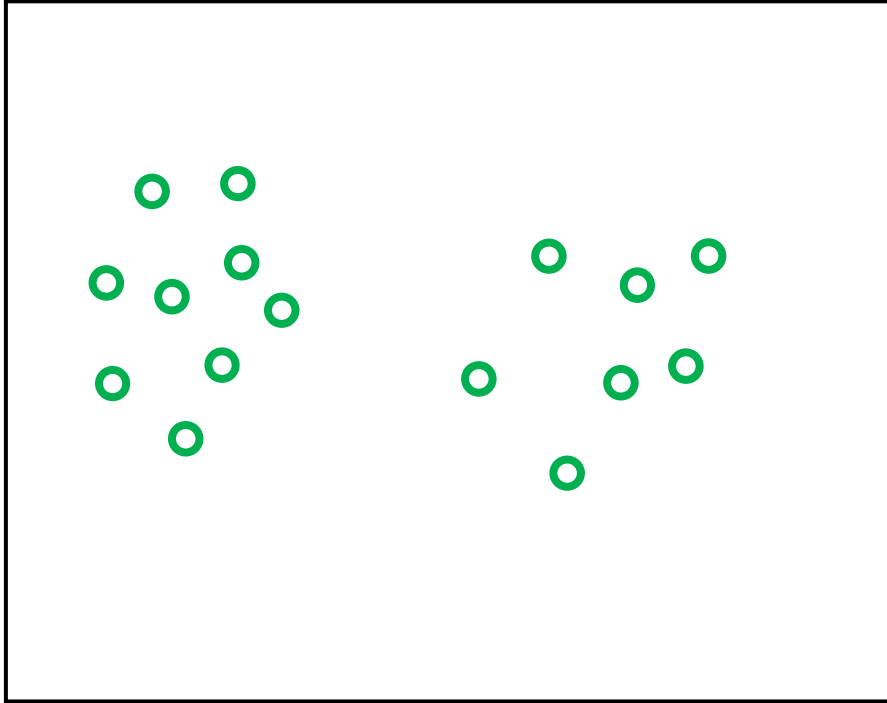
Module 2, Lecture 3: Unsupervised Learning

Unsupervised Learning

In case of supervised learning such as classification and regression, we know the class labels or output value of the training data points. The respective ML algorithms learns based on the training data points input and output values.

Unsupervised Learning

Sometimes labels for the data points are not available.

Unsupervised learning can work on no-ground-truth data and provide useful insight.

Why !

For some problems we do not know how many/what classes are present.

Example: Number of segments in an image

Solution: clustering

Clustering is grouping of similar data points

Other unsupervised examples

Learning a low dimensional representation of data

Reason: handling data in high dimension is difficult

Solution: Principal Component Analysis, Autoencoder

Image Segmentation: K-means Clustering

Clustering is a technique that allows to segment a set of data points into similar groups based on the characteristics/features of the points. For example if we cluster image pixels based on gray values, we will get groups of pixels with similar gray values. The example in the next slide illustrates that.

K-means clustering is a powerful and widely used clustering technique that we will use in this lecture for image clustering. Please check the below tutorial for the details on k-means.

Tutorial: k-means
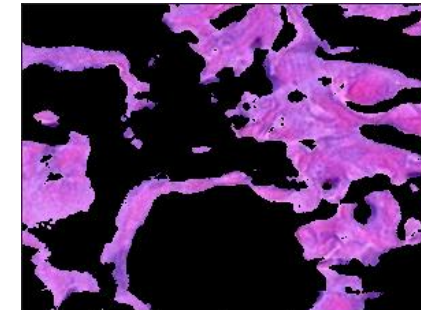
Image Segmentation: K-means Clustering

- Cluster image pixels based on pixel color values
- Number of clusters/image segments are unknown
- K-means clustering, an unsupervised learning method can perform this task
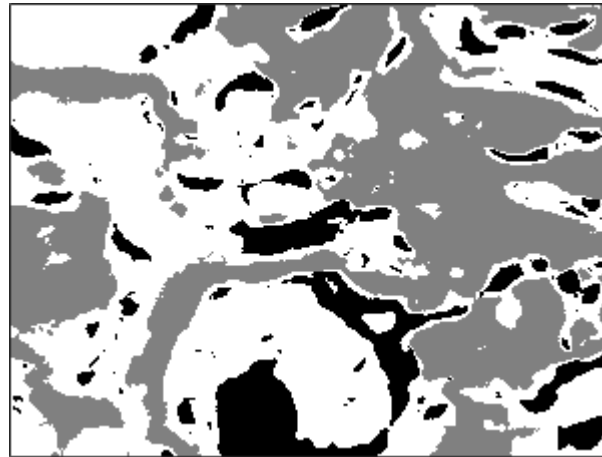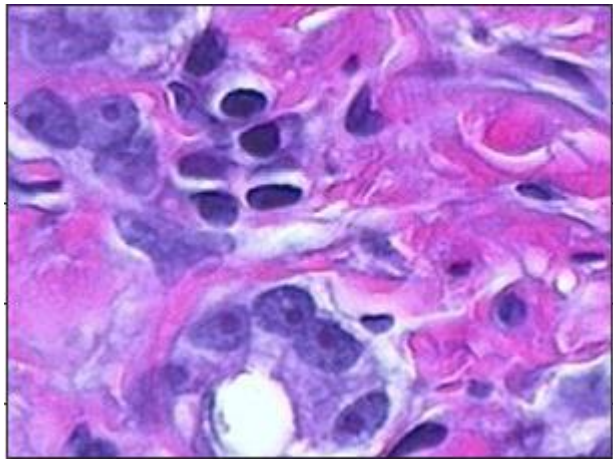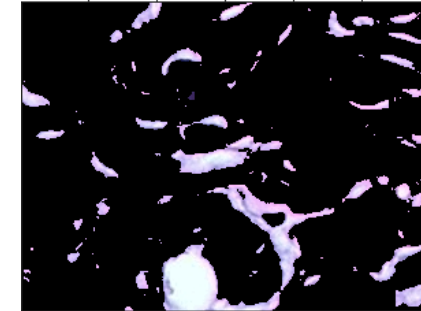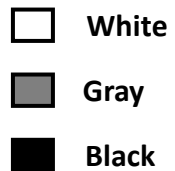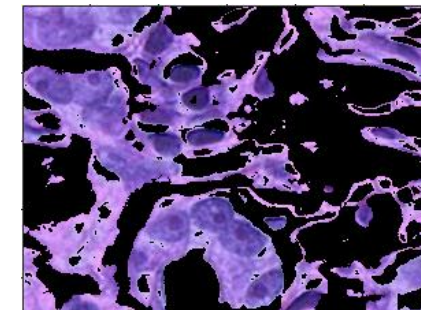

Cluster Black

Cluster Gray

Cluster White

3 Clusters

☐ White

◼ Gray

◼ Black

Unsupervised Learning: K-means

K-means Clustering:

Random initialization of cluster centroids

Assign points to nearest centroids

Unsupervised Learning: K-means

K-means Clustering:

Random initialization of cluster centroids

Assign points to nearest centroids
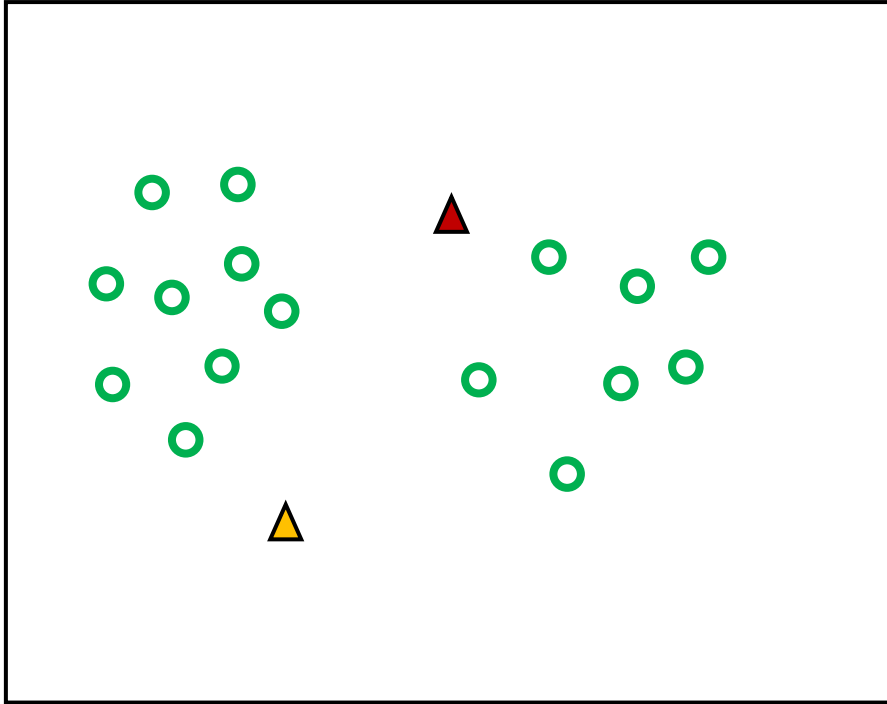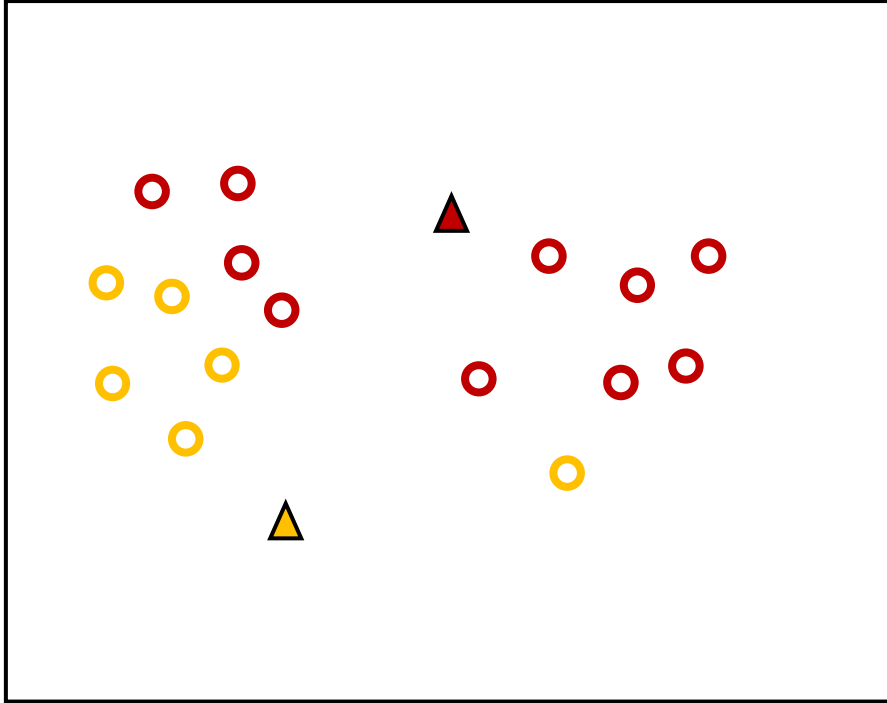
Re-calculate centroids as the mean of the assigned points

Unsupervised Learning: K-means

K- Mean Clustering:

Random initialization of cluster centroids

Assign points to nearest centroids

Re-calculate centroids as the mean of the assigned points

Re-assign the points to the centroids

Unsupervised Learning: K-means

K- Mean Clustering:

Random initialization of cluster centroids

Assign points to nearest centroids

Re-calculate centroids as the mean of the assigned points

Re-assign the points to the centroids

Continue until the algorithm converges
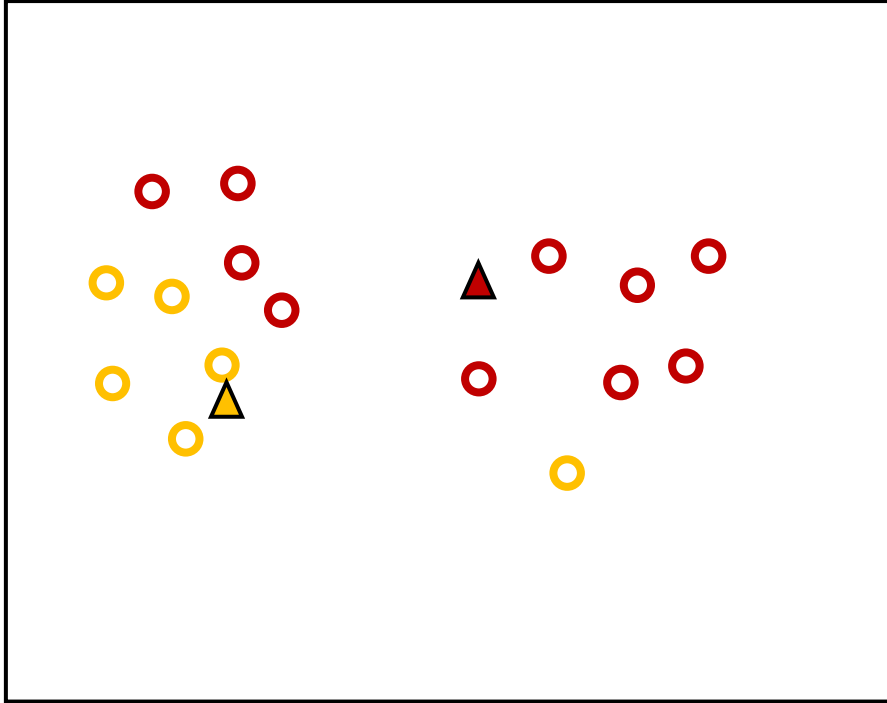
Unsupervised Learning: K-means
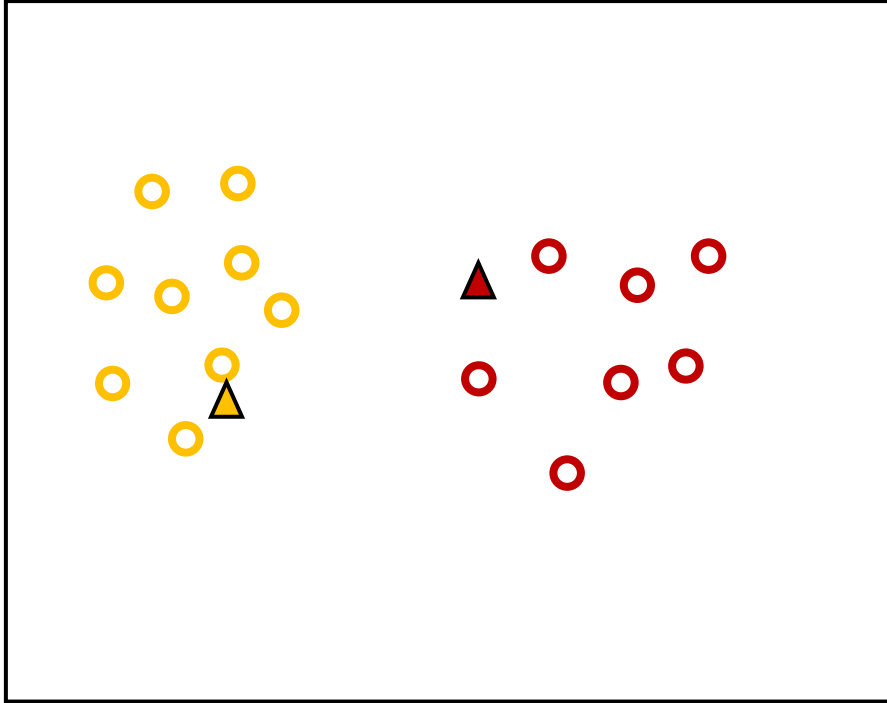
K- Mean Clustering:
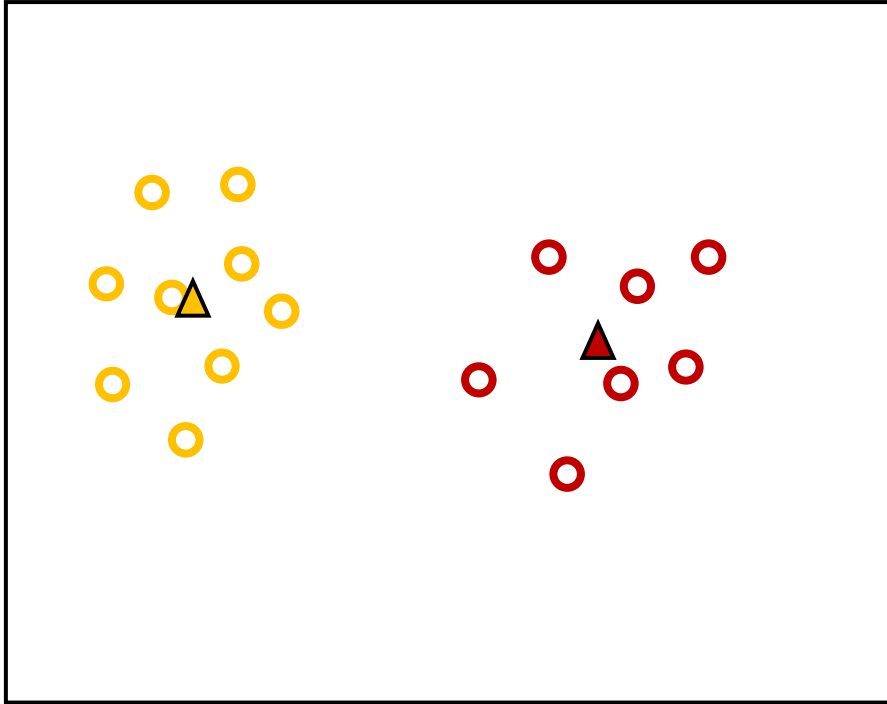
Random initialization of cluster centroids

Assign points to nearest centroids

Re-calculate centroids as the mean of the assigned points

Re-assign the points to the centroids

Continue until the algorithm converges

Minimize objective function:

$$J = \sum_{i=1}^{N} \sum_{k=1}^{K} w_{i,k} \| x^i - \mu_k \|^2$$

K, **N**: Number of clusters and number of data points respectively

μ_k: Cluster center for k_{th} cluster

$w_{i,k}$ = 1, when x^i is assigned to cluster k

$w_{i,k}$ = 0, otherwise

Unsupervised Learning: An Application

Bag of Words (BoW) document classification

Given a document :

Belo Horizonte: Groups of Chilean fans moved about the streets here on the eve of their team's game against Brazil in World Cup. Some were on foot, some rode in packed cars with the red, white and blue flag of Chile fluttering from windows, and many yelled their familiar chant, "Chi Chi Chi, Le Le Le," while locals looked on, distinctly unamused.

The Brazilians have been wonderful in hosting their first World Cup since 1950, but the Chileans are bent on repaying that hospitality with the unthinkable: knocking Brazil out of its own tournament in the Round of 16 on Saturday.

Document type can be classified based on the frequency of occurrences of different words

Unsupervised Learning: An Application

BoW document classification

Dictionary

W_1

W_2

●
●
●

Brazil

●
●
●

World Cup

●
●
●

W_n

Document

Belo Horizonte: Groups of Chilean fans moved about the streets here on the eve of their team's game against Brazil in World Cup. Some were on foot, some rode in packed cars with the red, white and blue flag of Chile fluttering from windows, and many yelled their familiar chant, "Chi Chi Chi, Le Le Le," while locals looked on, distinctly unamused.

The Brazilians have been wonderful in hosting their first World Cup since 1950, but the Chileans are bent on repaying that hospitality with the unthinkable: knocking Brazil out of its own tournament in the Round of 16 on Saturday.

Unsupervised Learning: An Application

BoW document classification

Dictionary

W_1

W_2

•
•
•

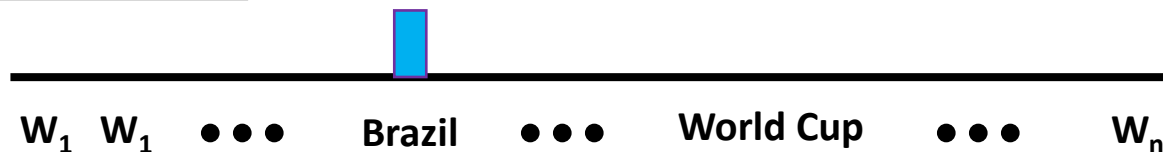**Brazil**

•
•
•

World Cup

•
•
•

W_n

Document

Belo Horizonte: Groups of Chilean fans moved about the streets here on the eve of their team's game against Brazil in World Cup._Some were on foot, some rode in packed cars with the red, white and blue flag of Chile fluttering from windows, and many yelled their familiar chant, "Chi Chi Chi, Le Le Le," while locals looked on, distinctly unamused.

The Brazilians have been wonderful in hosting their first World Cup since 1950, but the Chileans are bent on repaying that hospitality with the unthinkable: knocking Brazil out of its own tournament in the Round of 16 on Saturday.

Histogram

W_1 W_1 • • •   **Brazil**   • • •   **World Cup**   • • • W_n

Unsupervised Learning: An Application

BoW document classification

Dictionary

W_1

W_2

$\bullet$
$\bullet$
$\bullet$

Brazil

$\bullet$
$\bullet$
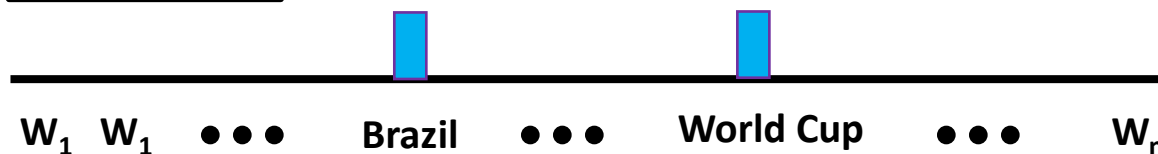$\bullet$

World Cup

$\bullet$
$\bullet$
$\bullet$

W_n

Document

Belo Horizonte: Groups of Chilean fans moved about the streets here on the eve of their team's game against Brazil in World Cup. Some were on foot, some rode in packed cars with the red, white and blue flag of Chile fluttering from windows, and many yelled their familiar chant, "Chi Chi Chi, Le Le Le," while locals looked on, distinctly unamused.
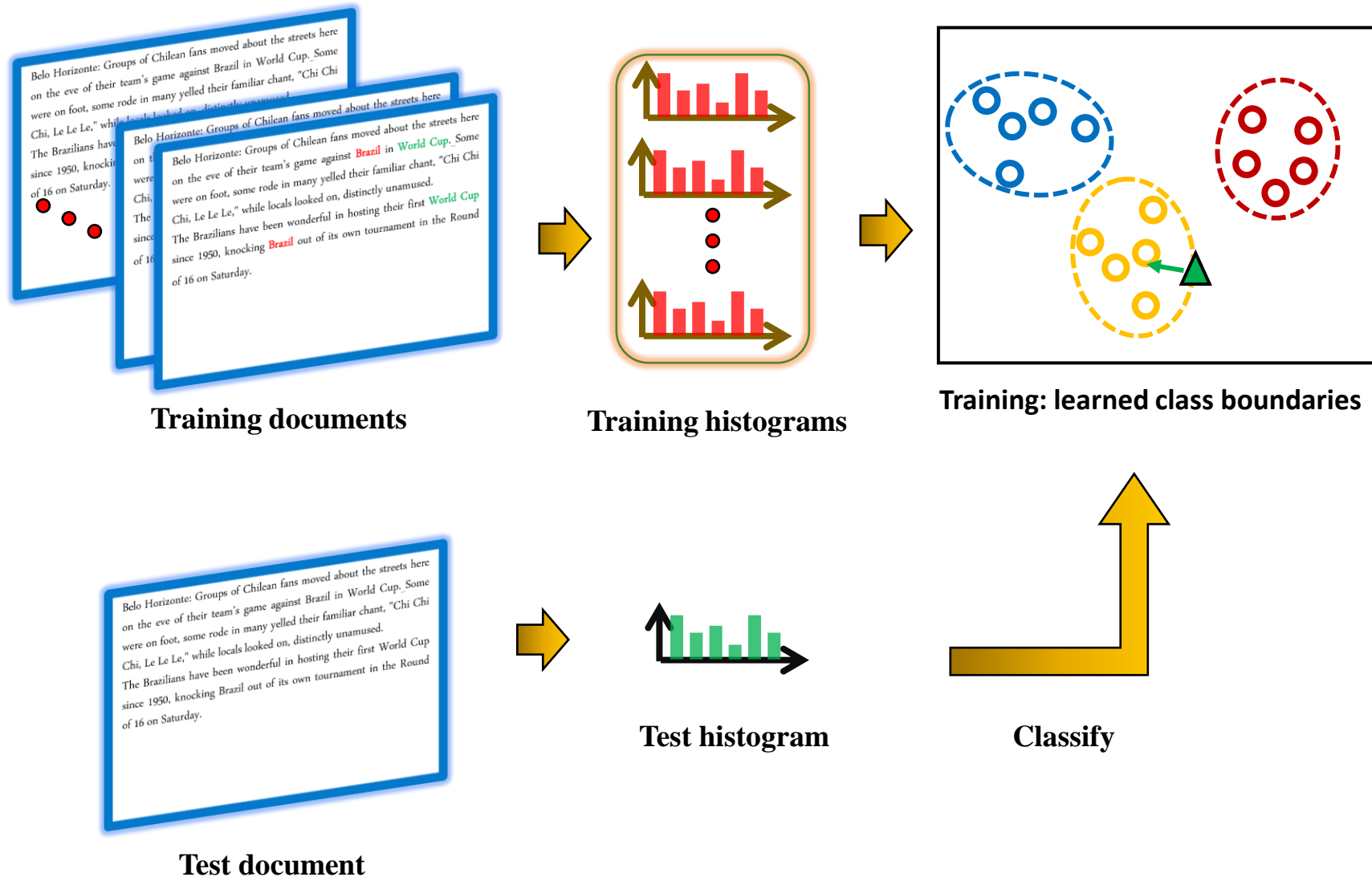
The Brazilians have been wonderful in hosting their first World Cup since 1950, but the Chileans are bent on repaying that hospitality with the unthinkable: knocking Brazil out of its own tournament in the Round of 16 on Saturday.
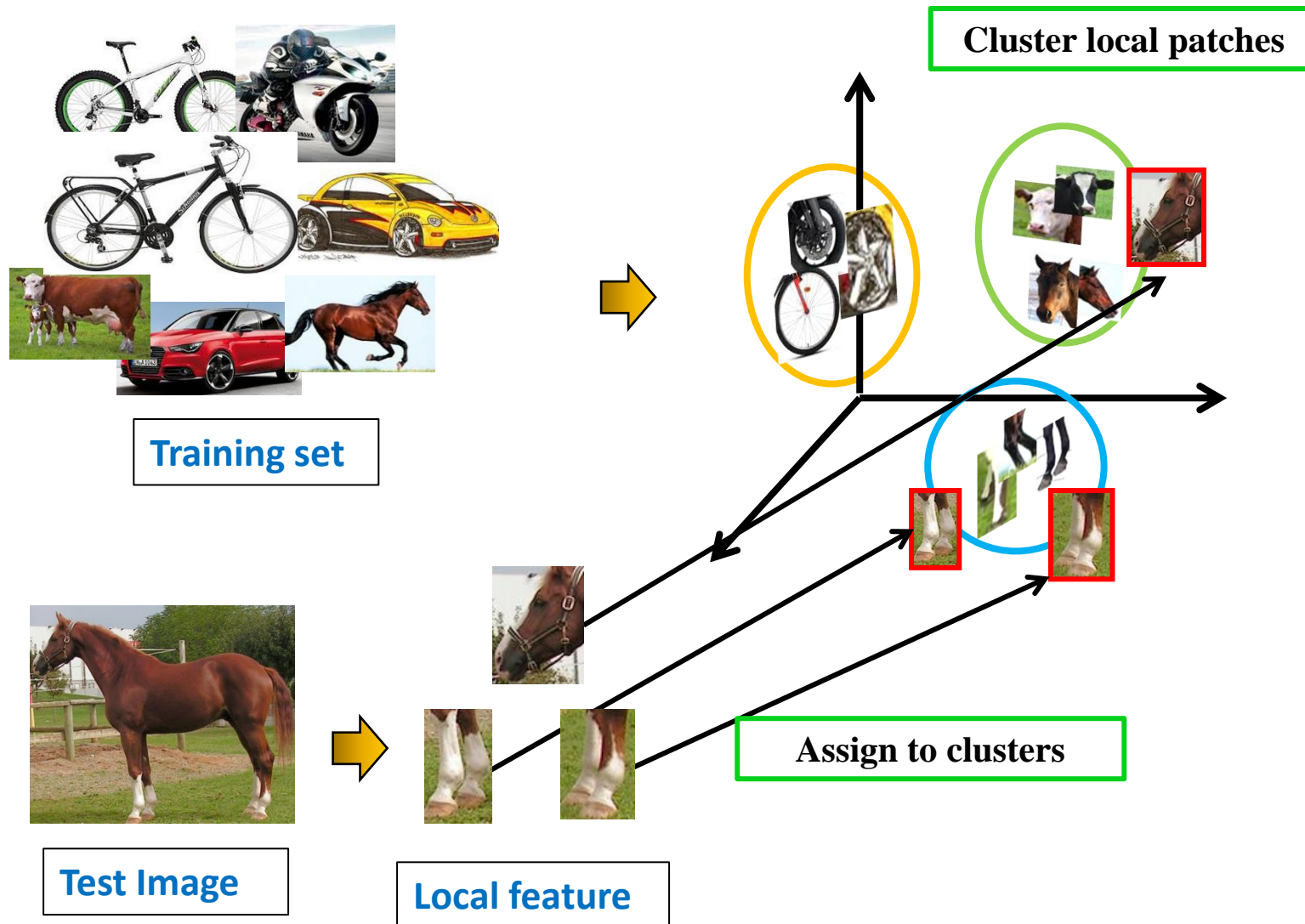
Histogram

W_1 W_1 $\bullet\bullet\bullet$ **Brazil** $\bullet\bullet\bullet$ **World Cup** $\bullet\bullet\bullet$ W_n

Unsupervised Learning: An Application

BoW document classification

Training documents

Training histograms

Training: learned class boundaries

Test document

Test histogram

Classify

Unsupervised Learning: An Application

Bag of Visual Words(BoVW) image classification

Cluster local patches

Training set

Test Image

Local feature

Assign to clusters

Training:
- Detect image key points
- Compute local feature descriptors
- Cluster descriptors in the feature space
- Clusters form the visual words
- Now, each image can be represented as the histogram of visual words
- Train the classifier on training histograms

Test:
- Given a test image, identify key points, and compute local feature descriptors
- Assign each descriptors to a visual word cluster to form histogram
- Classify the histogram

Unsupervised Learning: An Application

## Bag of Visual Words(BoVW) image classification

BoVW requires to form visual words dictionary. This needs the following three steps
- Detect image key points
- Compute, local feature descriptors
- Cluster descriptors in the feature space. All the clusters forms the visual word dictionary

Image key points are interesting image points where a local patch around each key point encodes important information that is useful for image classification.

For each key point a **feature descriptor** is computed that encodes the information of the local image patch. In the next slide we explained one such feature descriptor. There are many more feature descriptors.

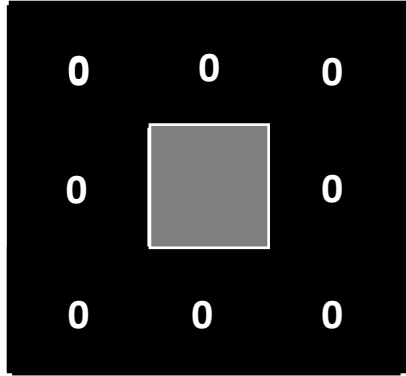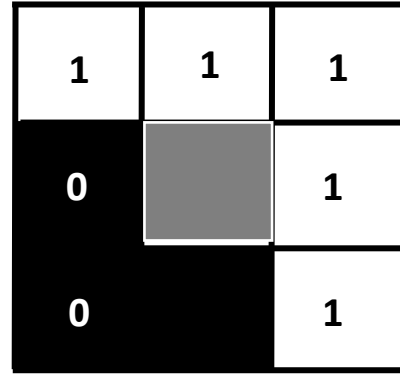# Image Feature: Local Binary Pattern (LBP)
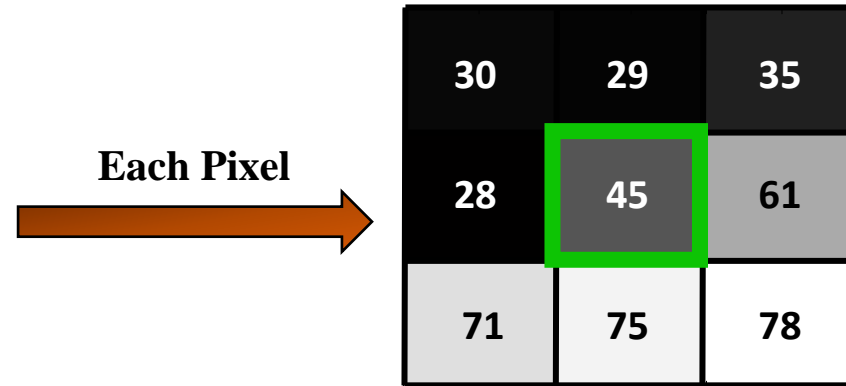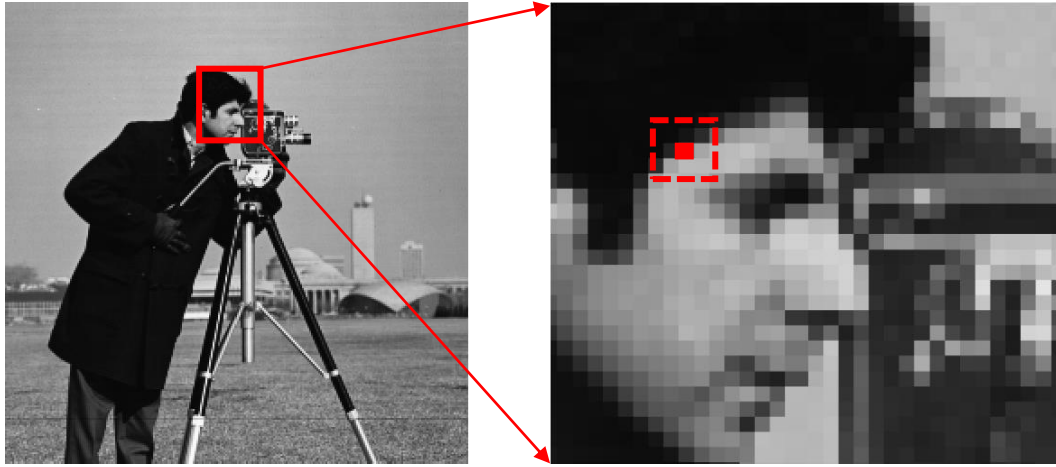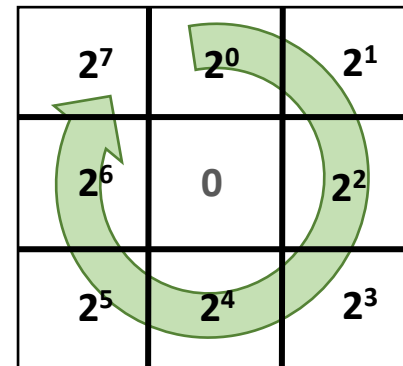
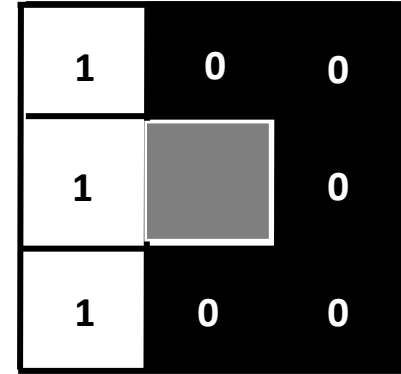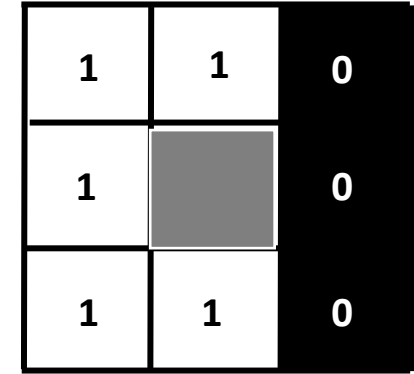# What LBP Captures!

Spot

Corner

Edge

Edge

In total there are 256 different patterns

Additional Reading

[Unsupervised learning](#) optional reading