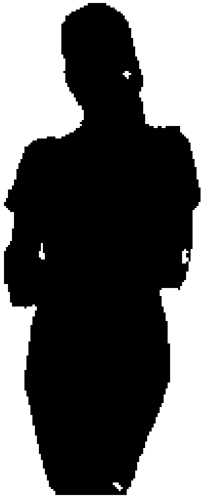
Introduction

- What is image segmentation?
  - Technically speaking, image segmentation refers to the decomposition of a scene into different components (thus to facilitate the task at higher levels such as object detection and recognition)
  - Scientifically speaking, segmentation is a hypothetical middle-level vision task performed by neurons between low-level and high-level cortical areas
- There is no ground truth to a segmentation task (an example is given in the next slide)

Dilemma

input

result 1



result 2

What do we mean by “DIFFERENT” objects?

Another example: when we look at trees at a close distance, we consider each of them as a different object; but as we look at trees far away, they merge into one coherent object (woods)

Applications: Finding tumors, veins, etc. in medical images, finding targets in satellite/aerial images, finding people in surveillance images, summarizing video, etc.

• Methods: Thresholding, K-means clustering, etc.

Overview of Segmentation Techniques

- Edge-based
- Color-based
- Texture-based
- Disparity-based
- Motion-based

- Document images
- Medical images
- Range images
- Biometric images
- Texture images

Segmentation strategy

Edge-based

- Assumption: different objects are separated by edges (grey level discontinuities)
- The segmentation is performed by identifying the grey level gradients
- The same approach can be extended to color channels

Region-based

- Assumption: different objects are separated by other kind of perceptual boundaries
  - neighborhood features
- Most often texture-based
  - Textures are considered as instantiations of underlying stochastic processes and analyzed under the assumptions that stationarity and ergodicity hold
- Method
  - Region-based features are extracted and used to define "classes"

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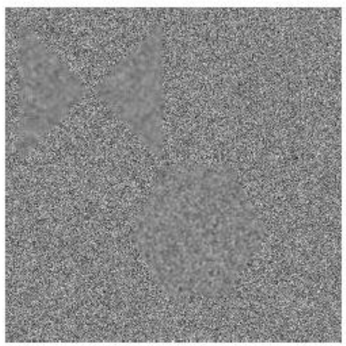
Edge-based Techniques

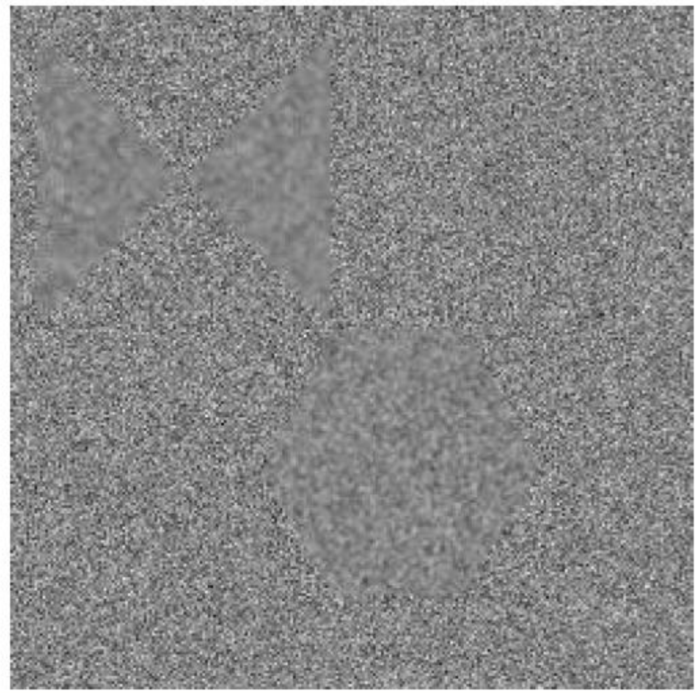
→ Edge detection → Segmentation by boundary detection → Classification and analysis →

Examples

original

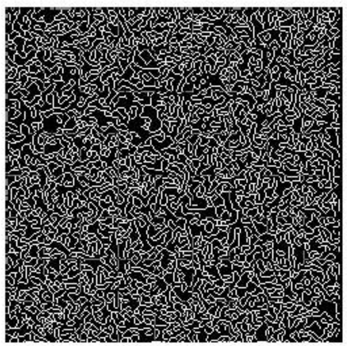


zoomed

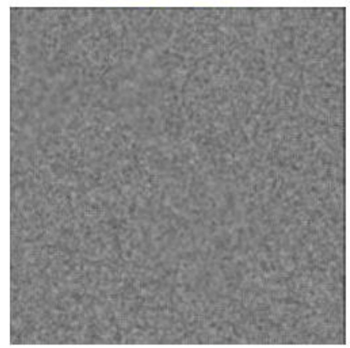


Examples

Canny



block mean



block std

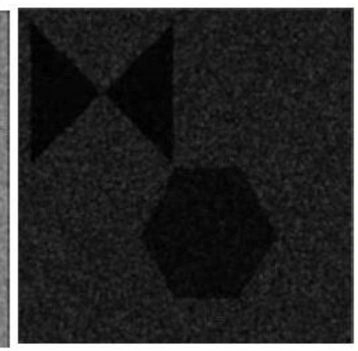


Image Segmentation

Contour-based

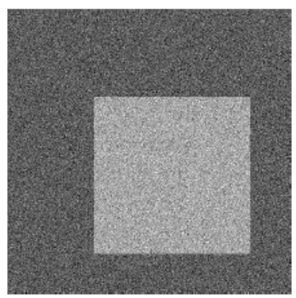
- Discontinuity
  - The approach is to partition an image based on *abrupt changes* in gray-scale levels.
  - The principal areas of interest within this category are detection of isolated points, lines, and edges in an image.

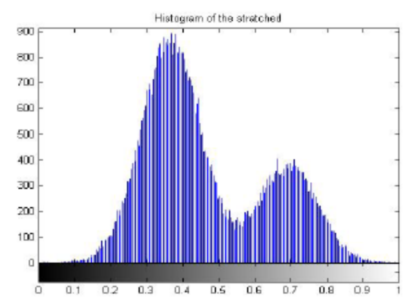
Region-based

- Similarity, homogeneity
- The principal approaches in this category are based on
  - thresholding,
  - region growing
  - region splitting/merging
  - clustering in feature space

Thresholding

- Image model
  - The objects in the image differ in the graylevel distribution
    - Simplest: object(s)+background
  - The spatial (image domain) stochastic parameters (i.e. mean, variance) are sufficient to characterize each object category
    - rests on the ergodicity assumption
  - Easily generalized to multi-spectral images (i.e. color images)





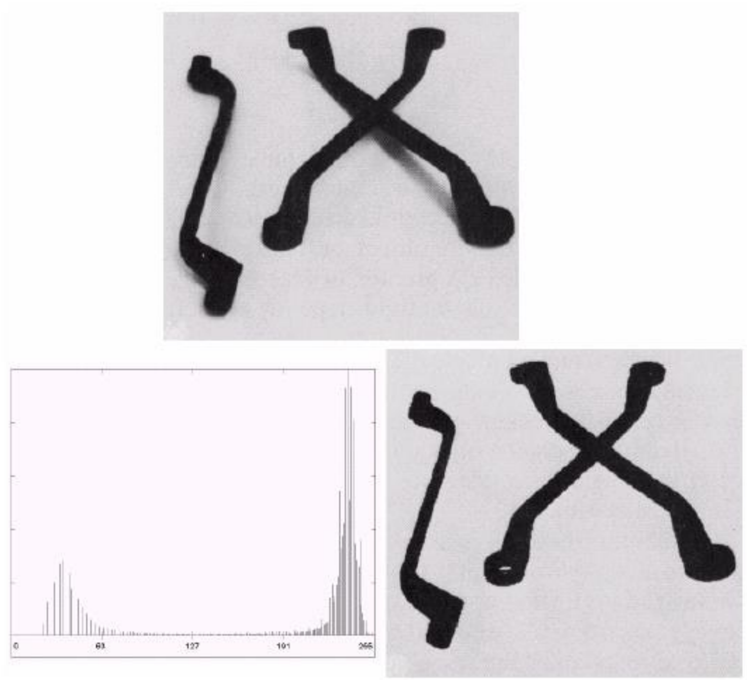
7

Thresholding

- Individual pixels in an image are marked as “object” pixels if their value is greater than some threshold value and as “background” pixels otherwise → *threshold above*
  - assuming an object to be brighter than the background
  - Variants
    - *threshold below*, which is opposite of threshold above;
    - *threshold inside*, where a pixel is labeled "object" if its value is between two thresholds
    - *threshold outside*, which is the opposite of threshold inside
  - Typically, an object pixel is given a value of “1” while a background pixel is given a value of “0.” Finally, a binary image is created by coloring each pixel white or black, depending on a pixel's label.

8

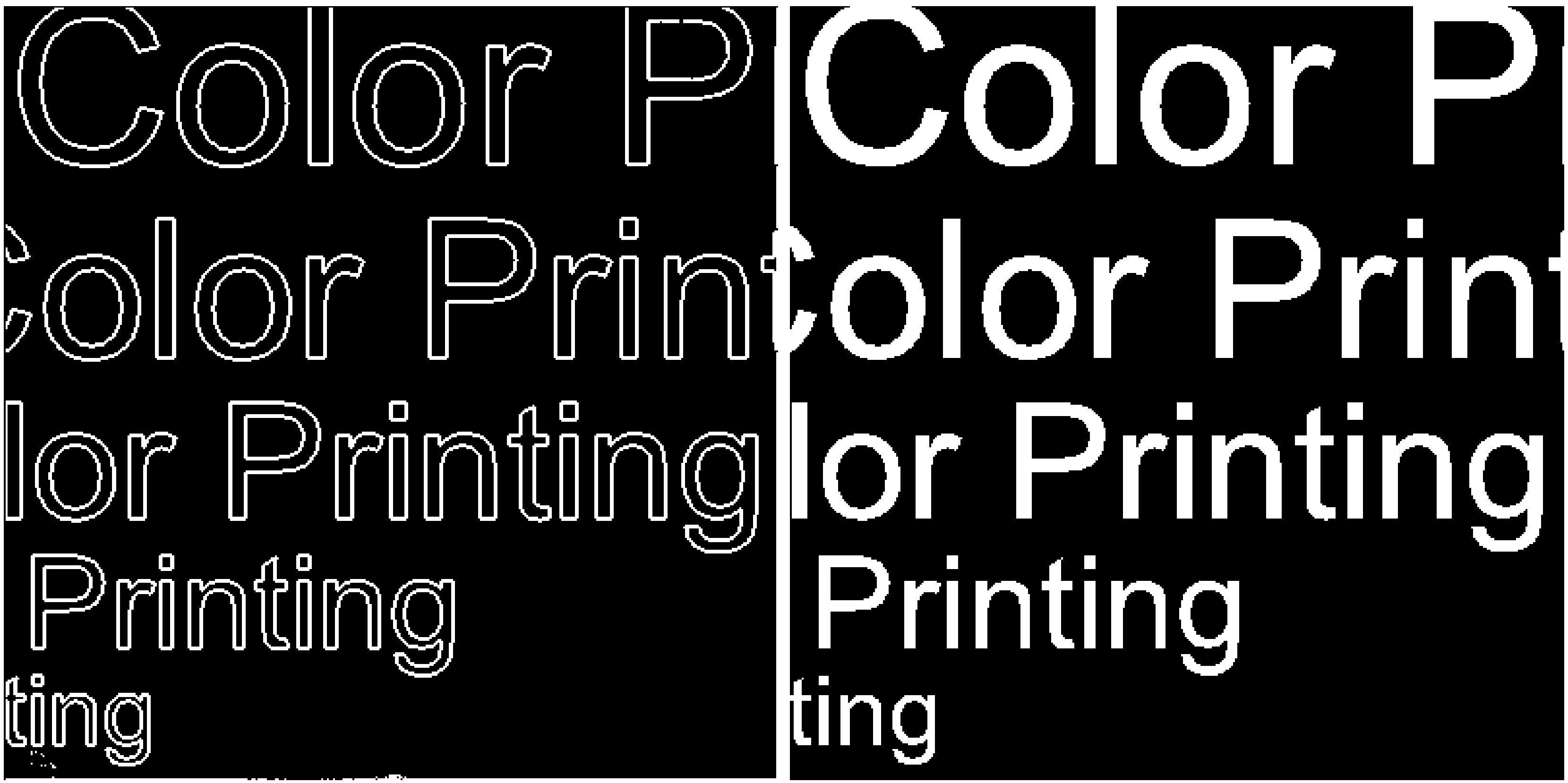
Thresholding



a
b c

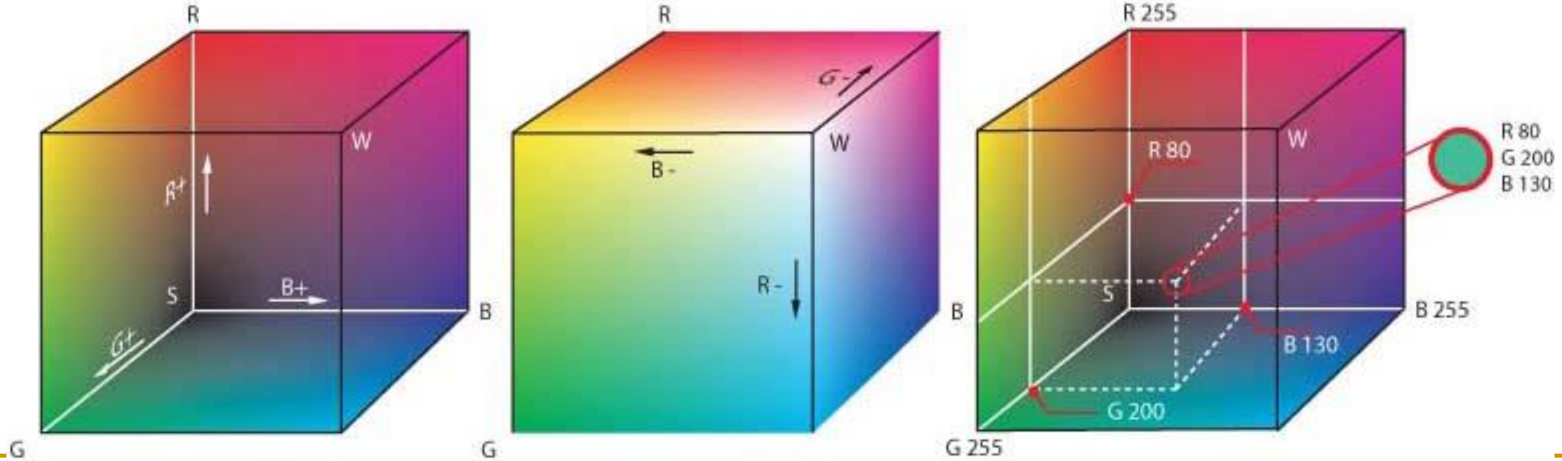
FIGURE 10.28 (a) Original image. (b) Image histogram. (c) Result of global thresholding with *T* midway between the maximum and minimum gray levels.

Region-Filling



Color-Based Techniques

- Color representations
  - Device dependent: RGB (displaying) or CMYK (printing)
  - Device independent: CIE XYZ or CIELAB (L*a*b*)



Color Space Conversion

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \frac{1}{b_{21}} \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} = \frac{1}{0.17697} \begin{bmatrix} 0.49 & 0.31 & 0.20 \\ 0.17697 & 0.81240 & 0.01063 \\ 0.00 & 0.01 & 0.99 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

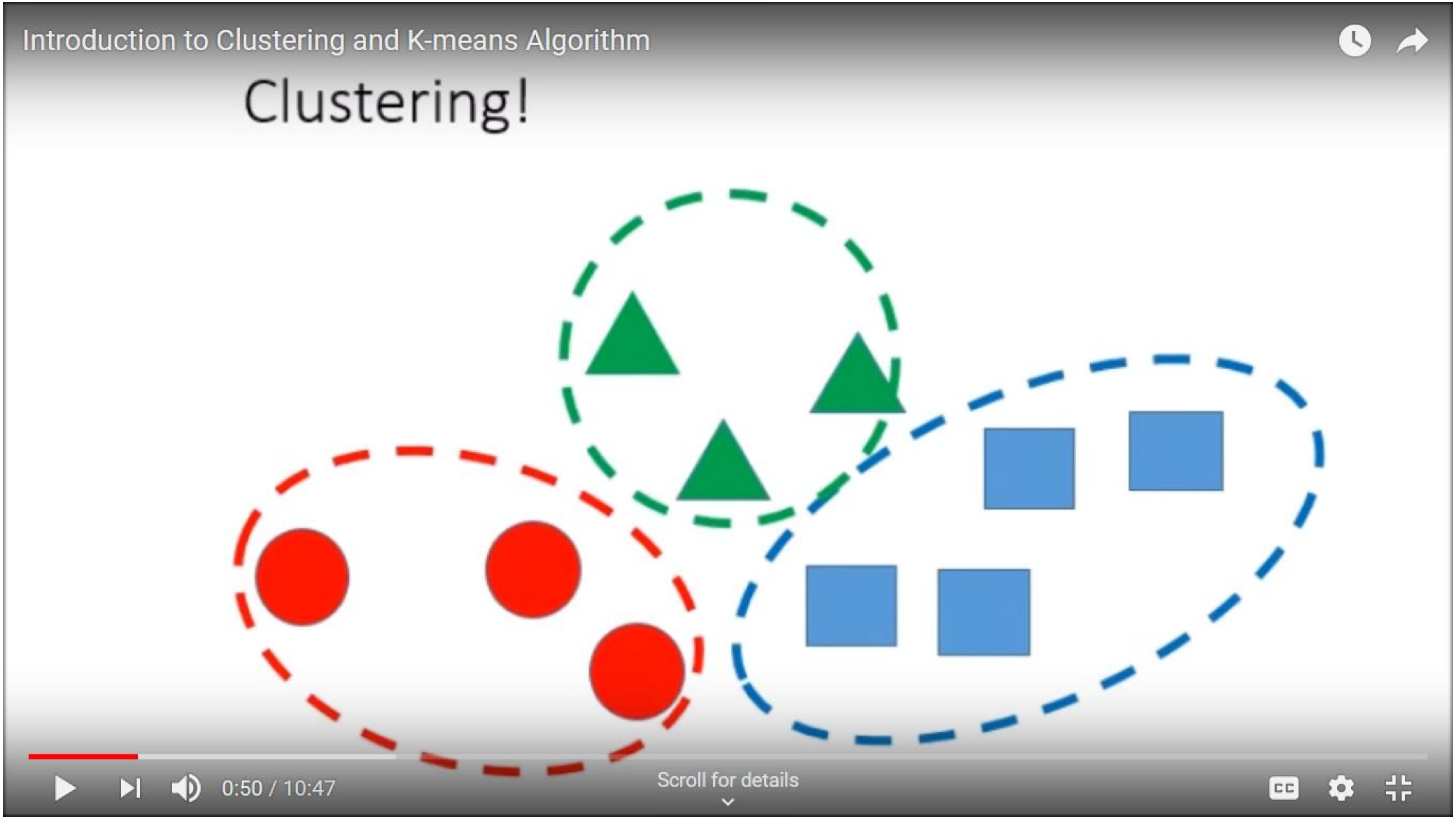
Analog TV

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.595716 & -0.274453 & -0.321263 \\ 0.211456 & -0.522591 & 0.311135 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Digital TV(MPEG)

$$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51499 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Clustering: Clustering is a grouping



Cont.

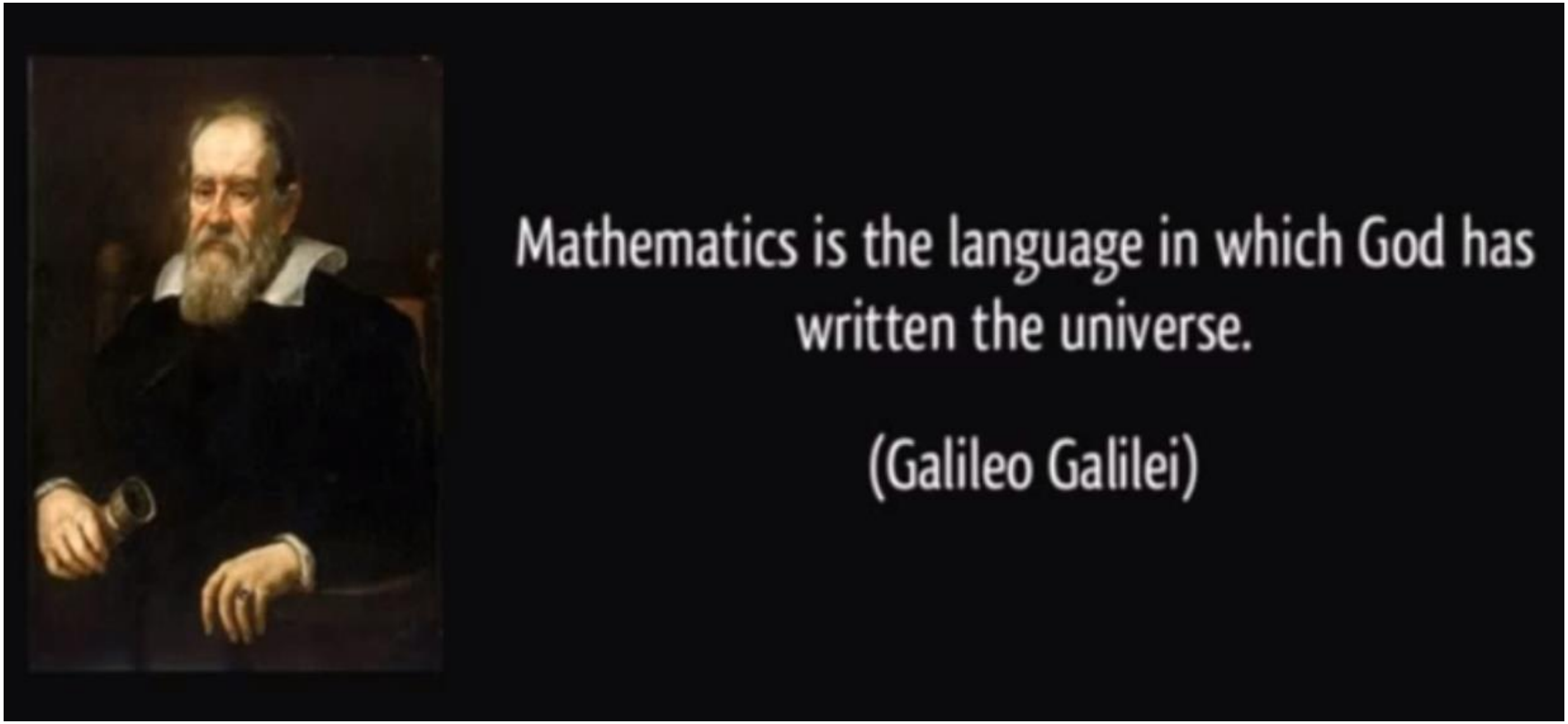
- "You need to know the question you are trying to answer"

  - Jason Bell (2015)

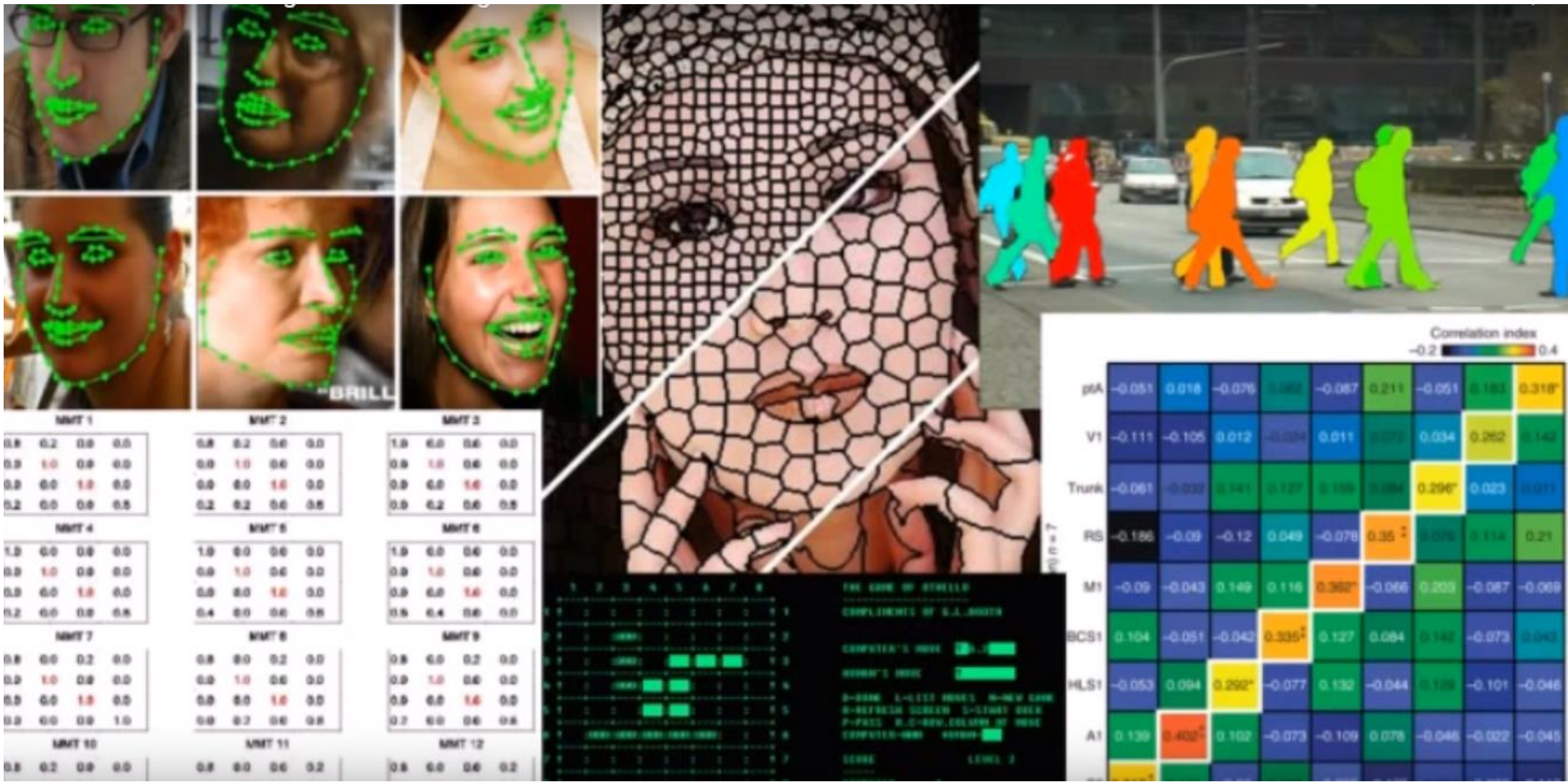
[1] Bell, 2015, Machine Learning: Hands-On for Developers and Technical Professionals

- *How to make computer do this automatically for us?*

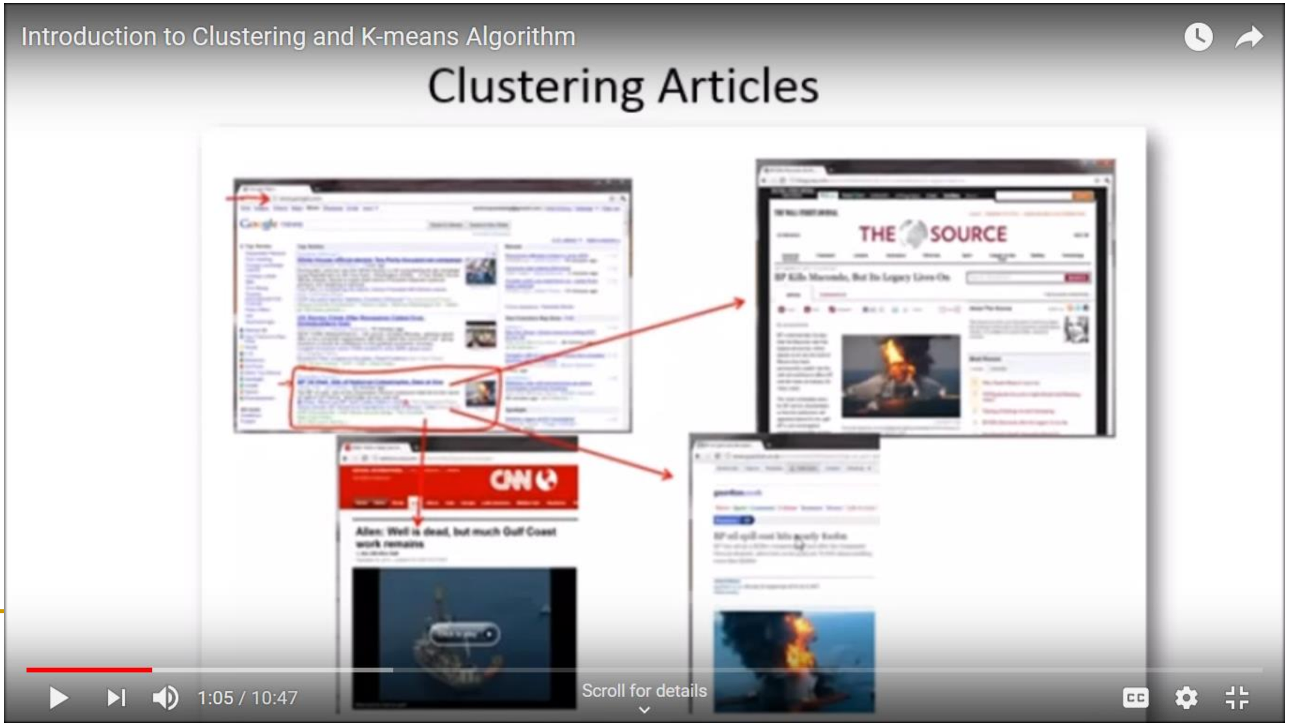
Cont.

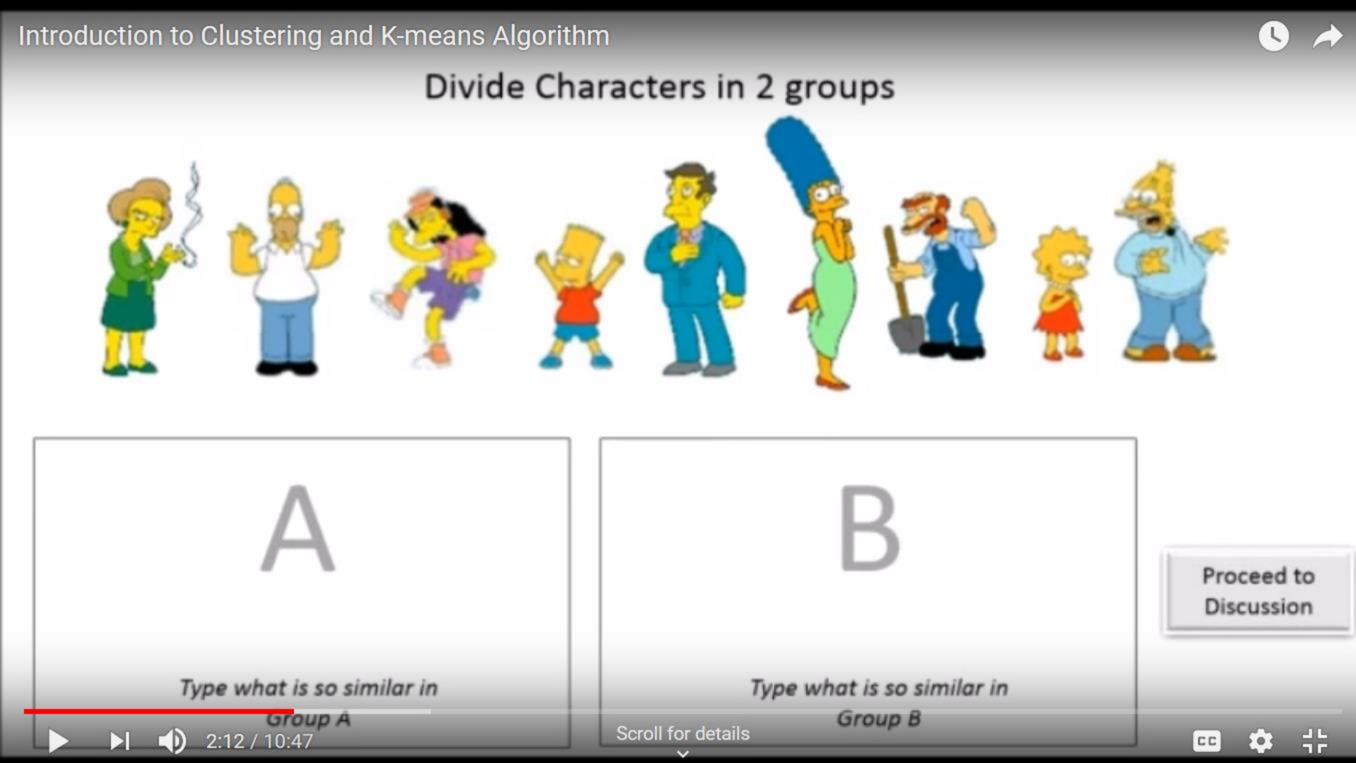

Mathematics is the language in which God has written the universe.
(Galileo Galilei)

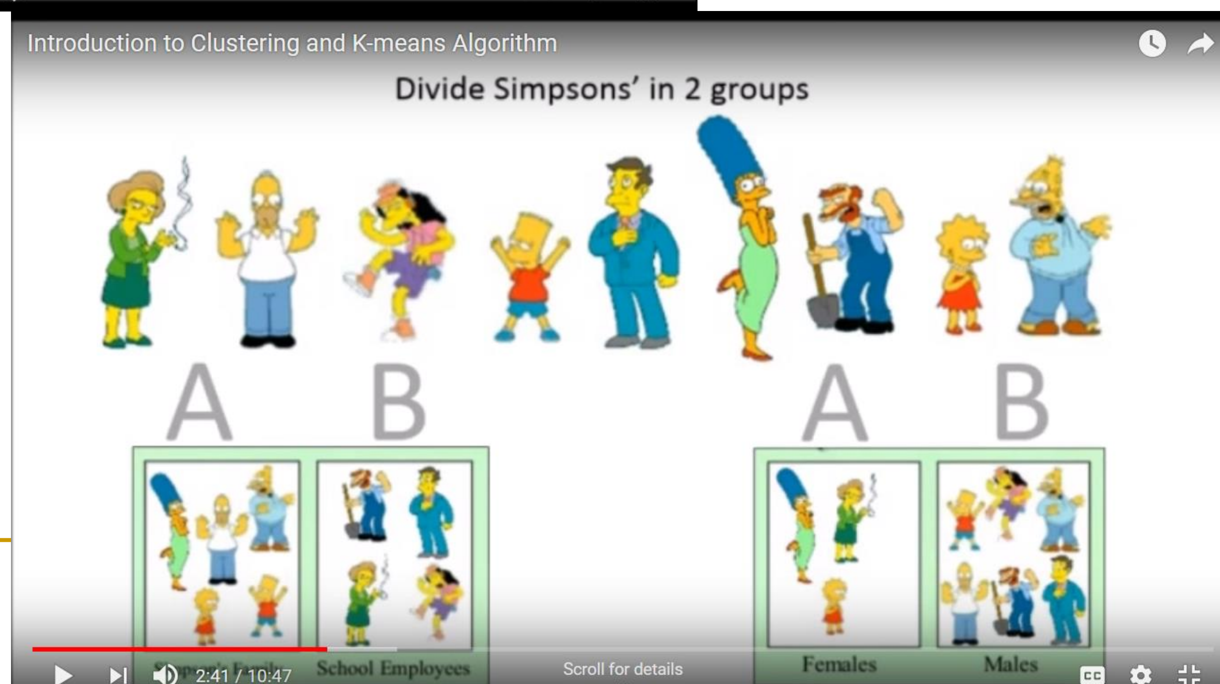
Cont.




Introduction to Clustering and K-means Algorithm
1:01 / 10:47
Scroll for details


Introduction to Clustering and K-means Algorithm
Clustering Articles
THE SOURCE
Allen: Well is dead, but much Gulf Coast work remains
1:05 / 10:47
Scroll for details


Introduction to Clustering and K-means Algorithm
Divide Characters in 2 groups
A
B
Type what is so similar in Group A
Type what is so similar in Group B
Proceed to Discussion
Scroll for details
2:12 / 10:47


Introduction to Clustering and K-means Algorithm
Divide Simpsons' in 2 groups
A
B
A
B
School Employees
Females
Males
Scroll for details
2:41 / 10:47

Data Clustering via Kmeans

K-Means Clustering

1. Partition the data points into K clusters randomly. Find the centroids of each cluster.
2. For each data point:
   – Calculate the distance from the data point to each cluster.
   – Assign the data point to the closest cluster.
3. Recompute the centroid of each cluster.
4. Repeat steps 2 and 3 until there is no further change in the assignment of data points (or in the centroids).

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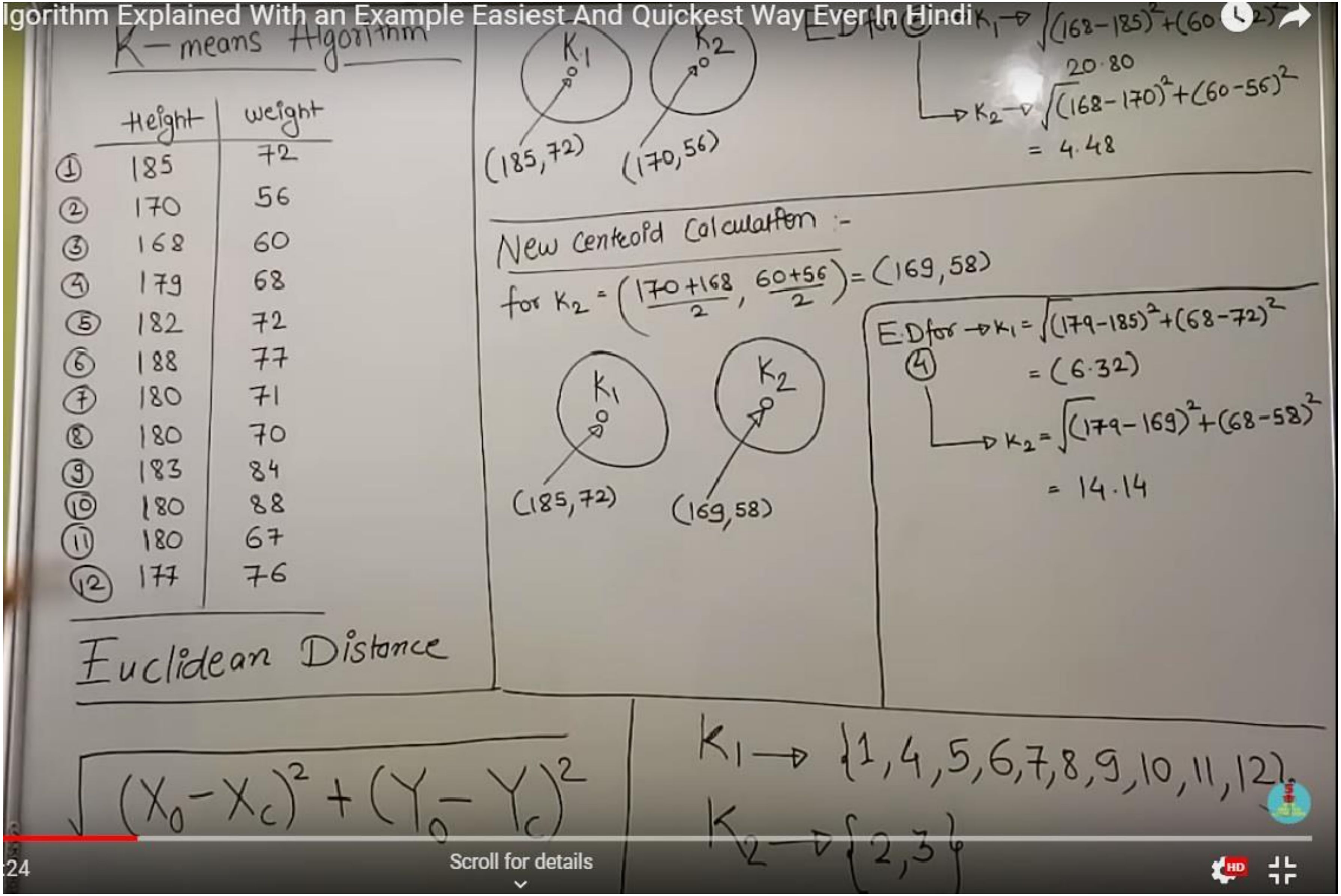
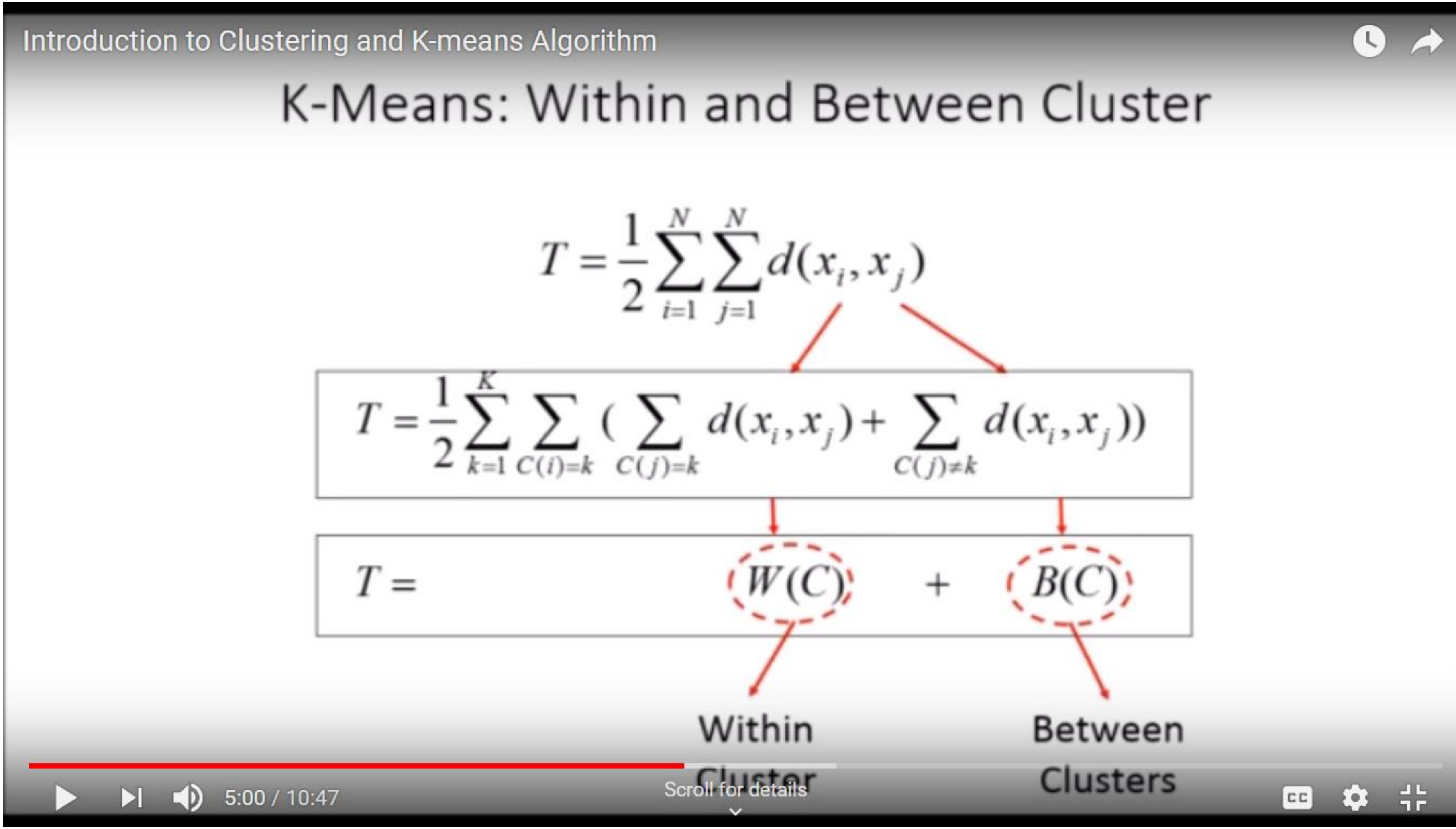
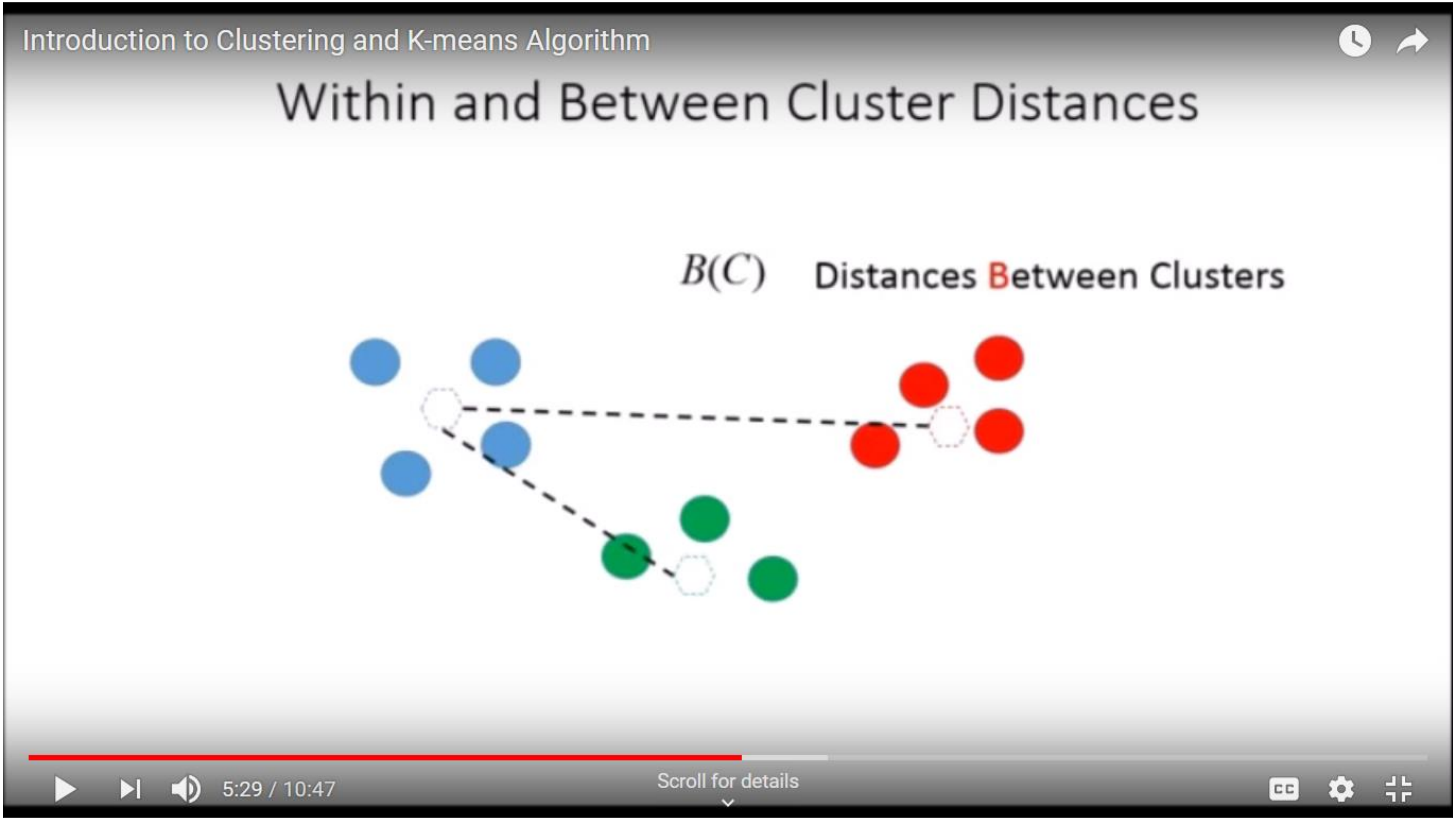
Data Clustering via Kmeans

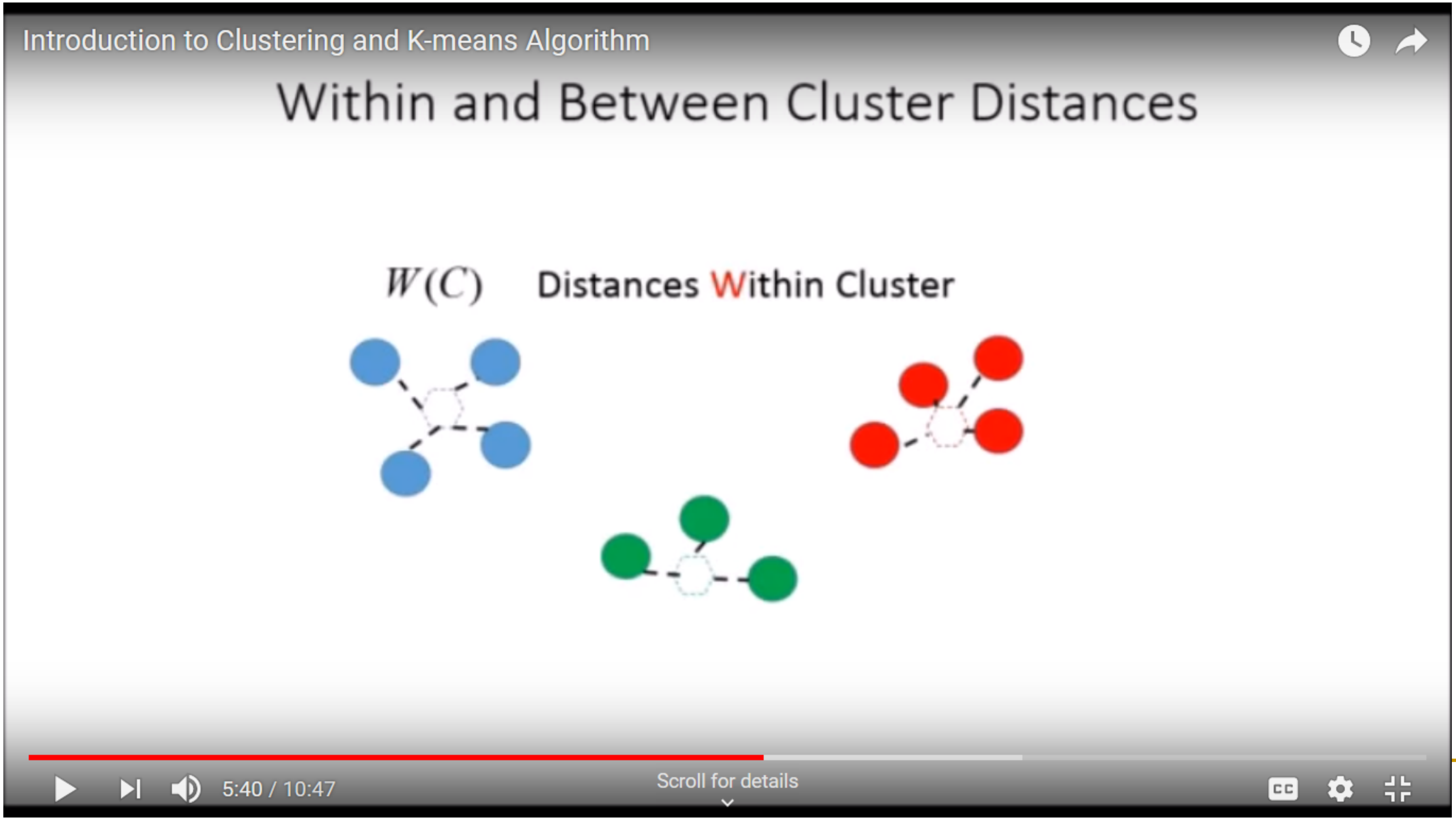


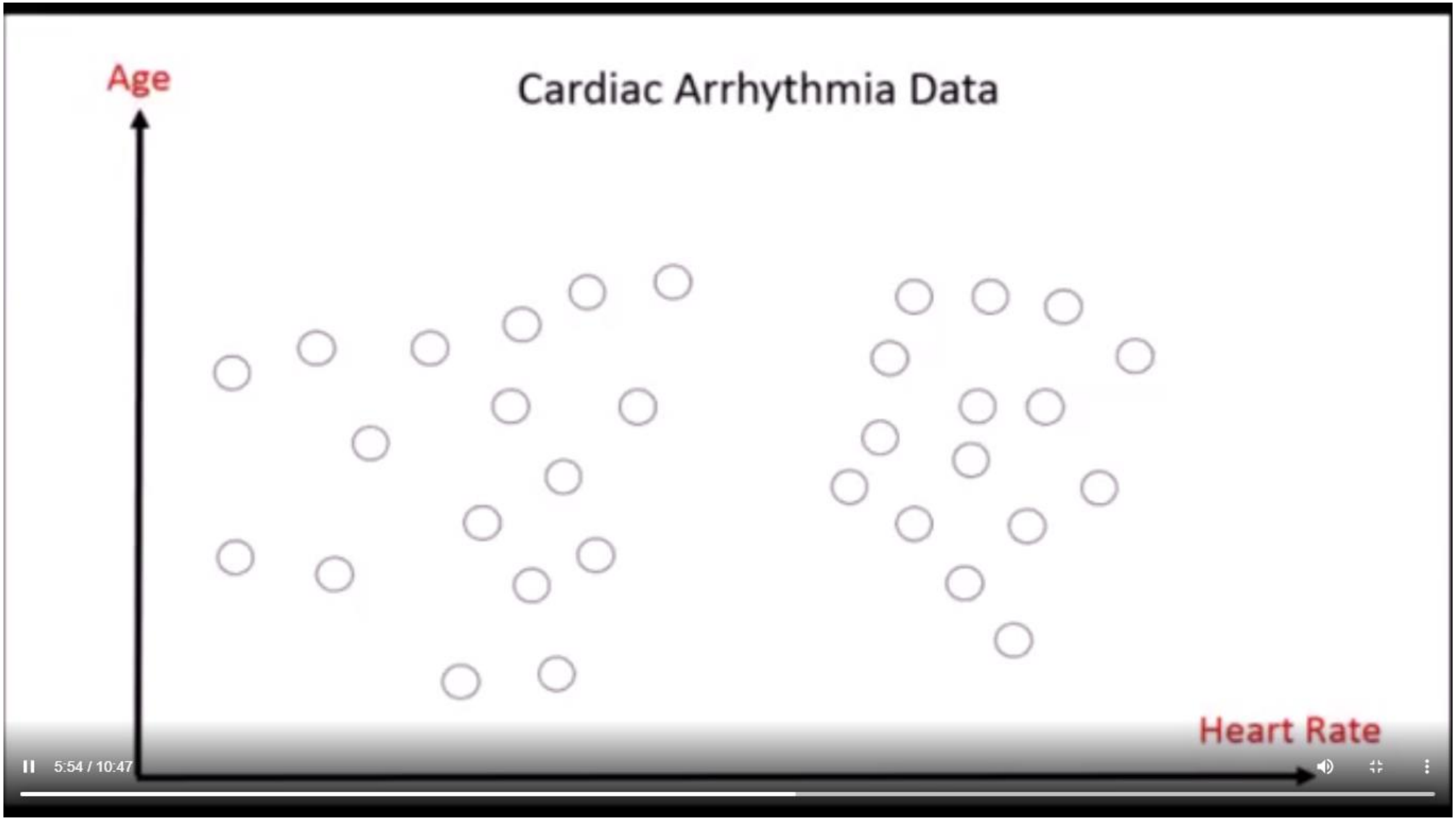

Introduction to Clustering and K-means Algorithm
K-Means: Within and Between Cluster
$T = \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} d(x_i, x_j)$
$T = \frac{1}{2}\sum_{k=1}^{K}\sum_{C(i)=k}\left(\sum_{C(j)=k} d(x_i, x_j) + \sum_{C(j)\neq k} d(x_i, x_j)\right)$
$T = W(C) + B(C)$
Within Cluster
Between Clusters
5:00 / 10:47
Scroll for details

Data Clustering via Kmeans

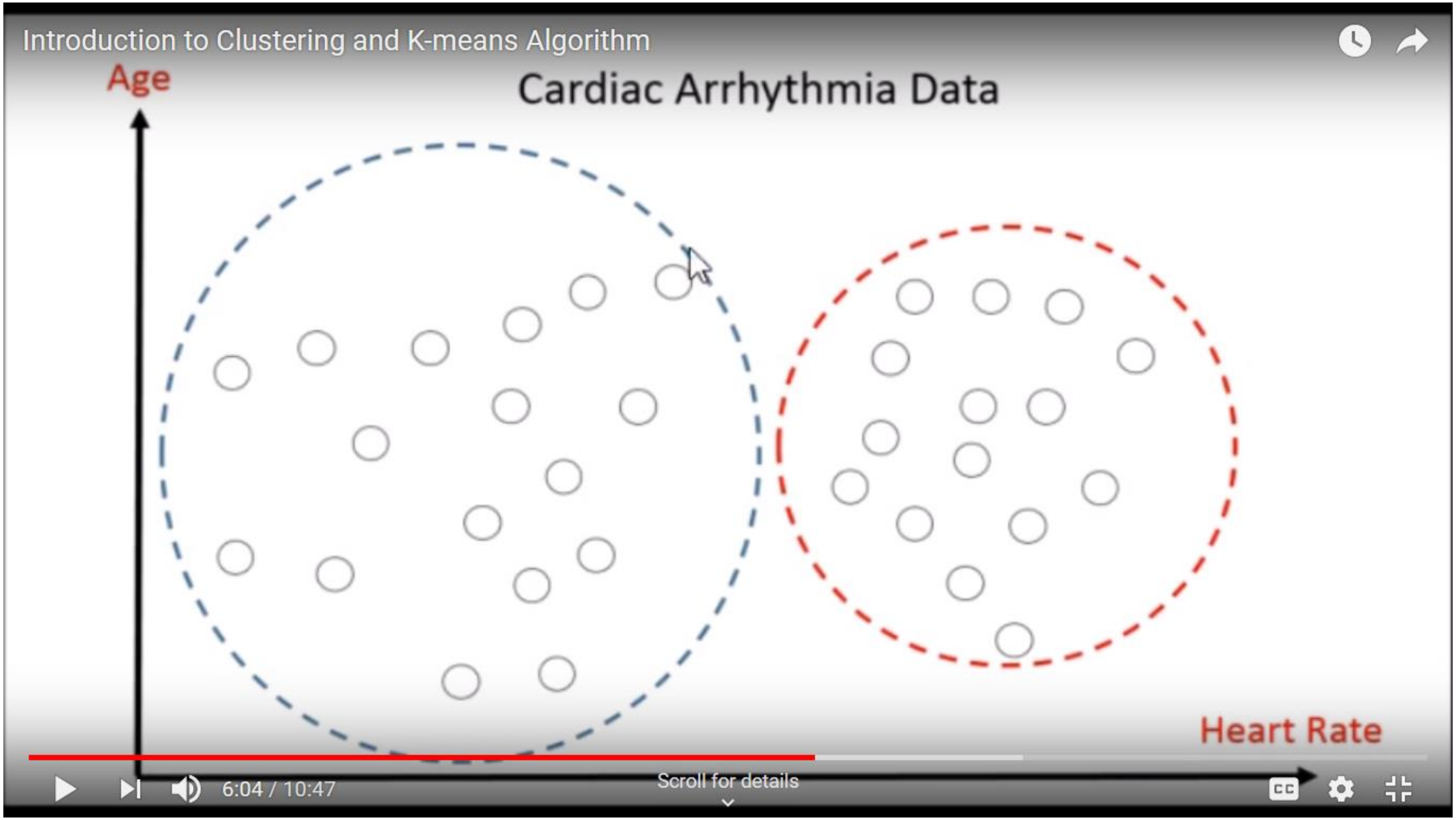


Data Clustering via Kmeans

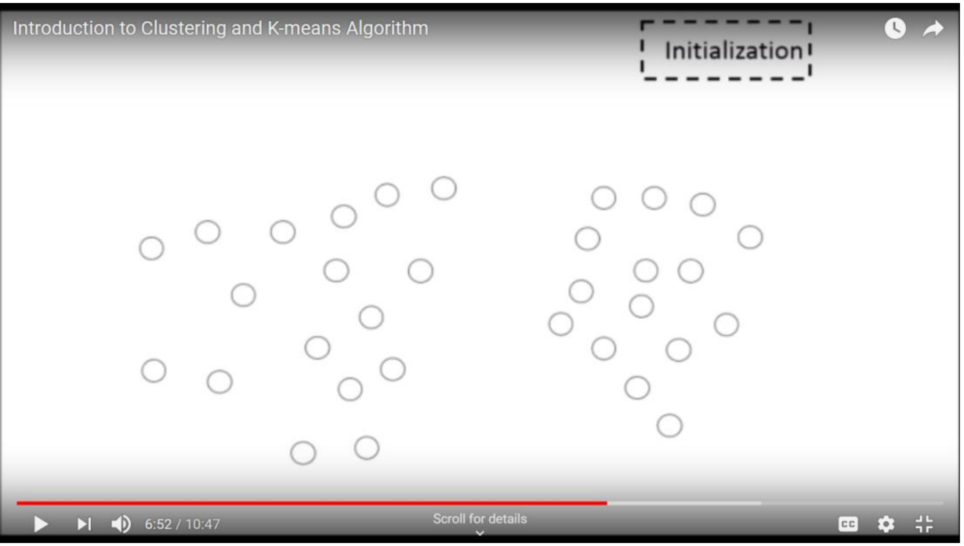


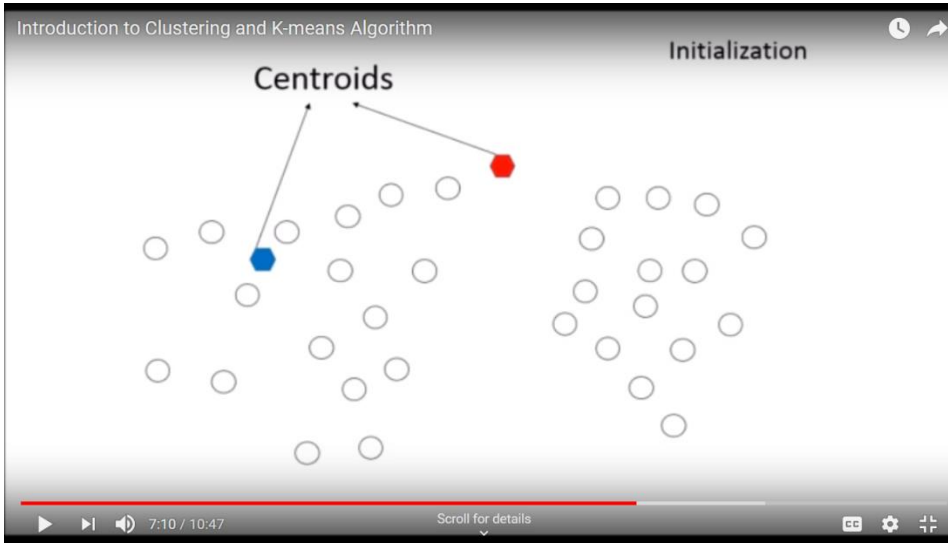

Age
Cardiac Arrhythmia Data
Heart Rate
5:54 / 10:47

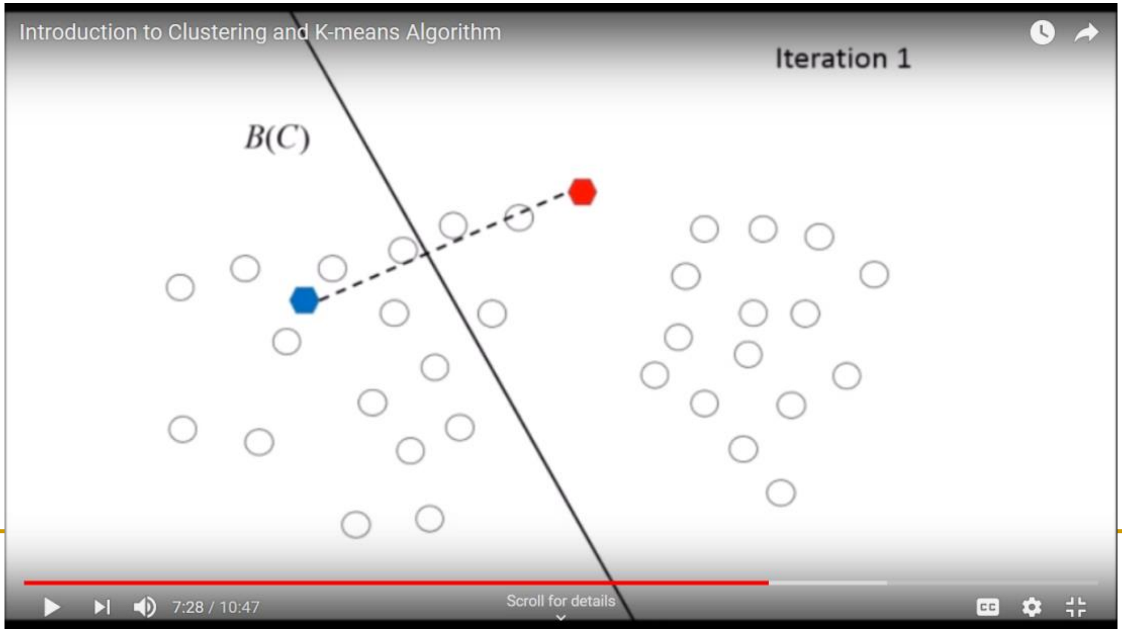
Data Clustering via Kmeans

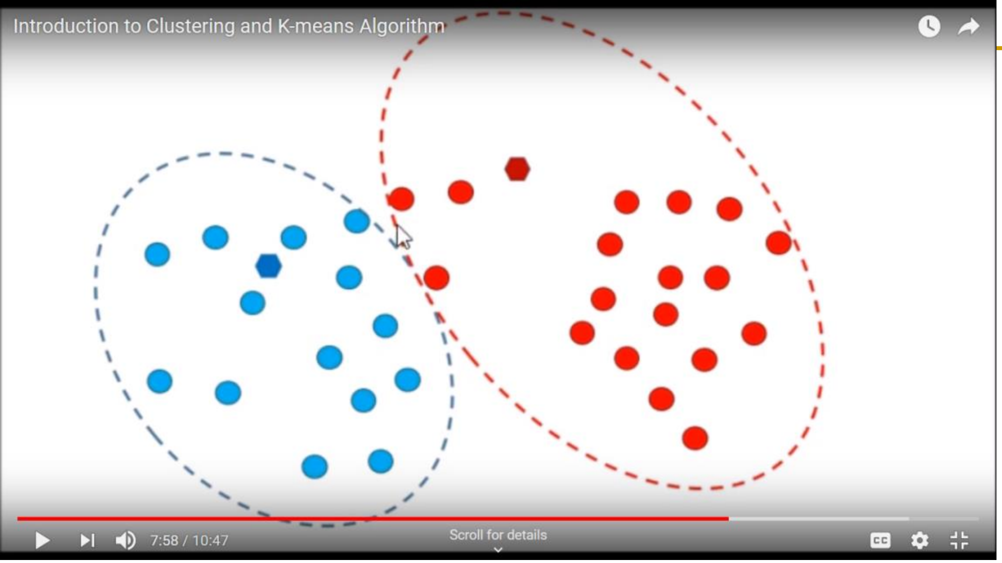


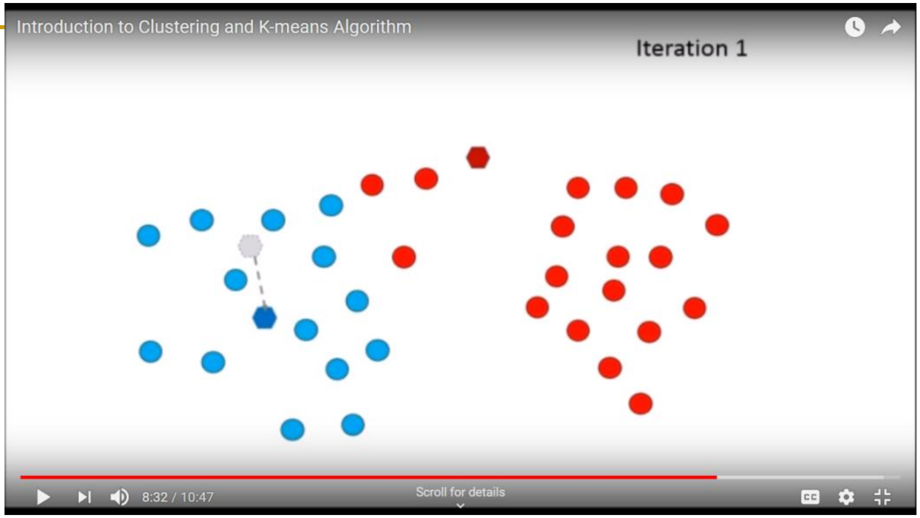
Data Clustering via Kmeans

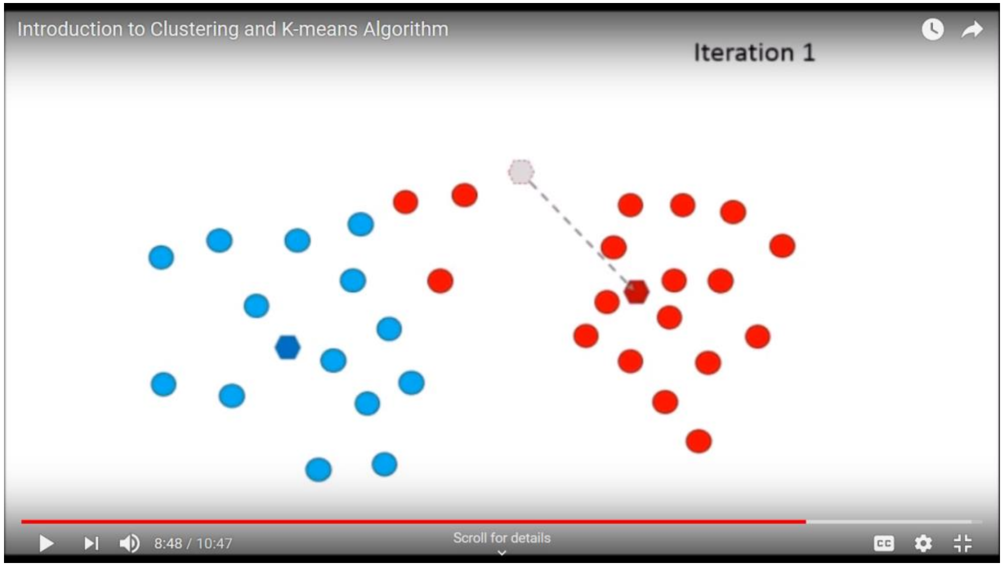


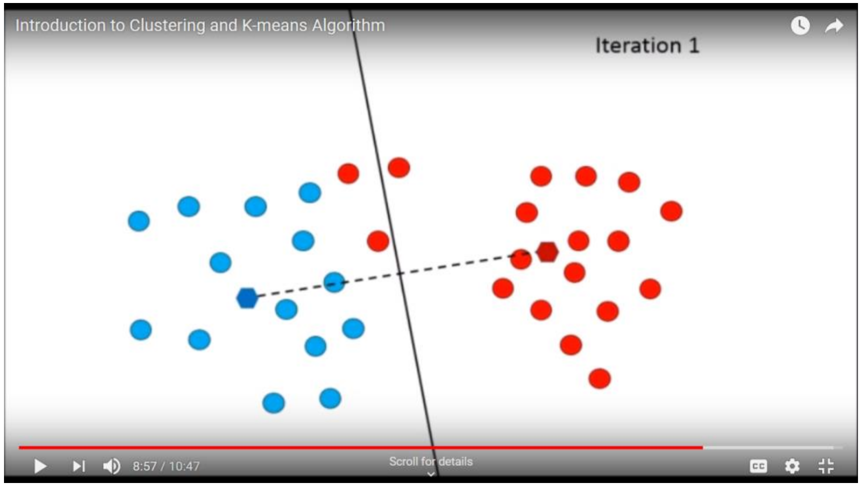


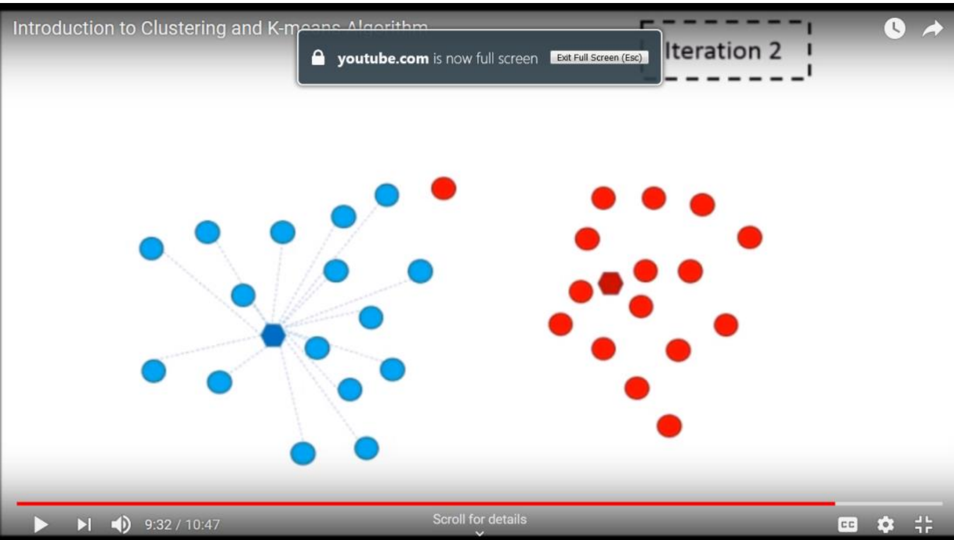


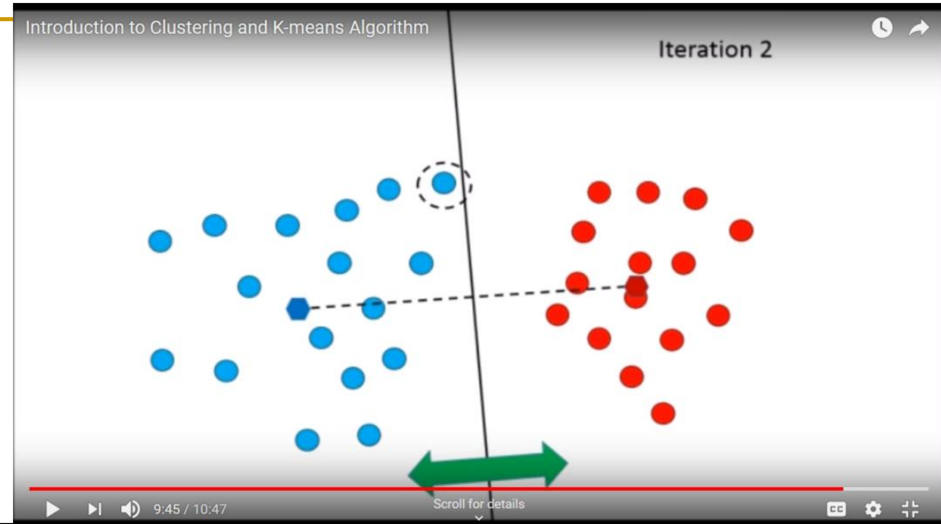

Introduction to Clustering and K-means Algorithm
7:58 / 10:47
Scroll for details

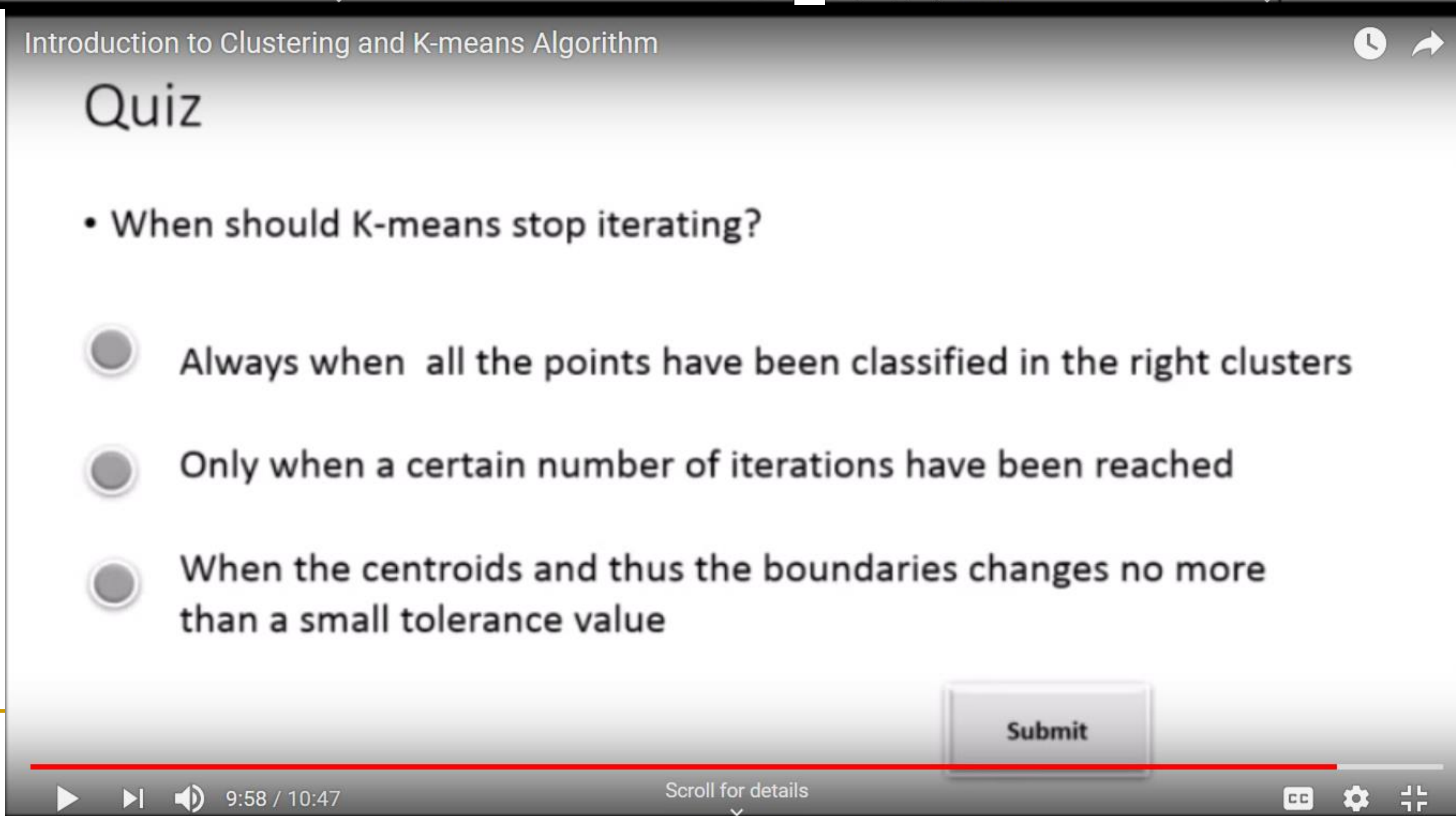

Introduction to Clustering and K-means Algorithm
Iteration 1
8:32 / 10:47
Scroll for details

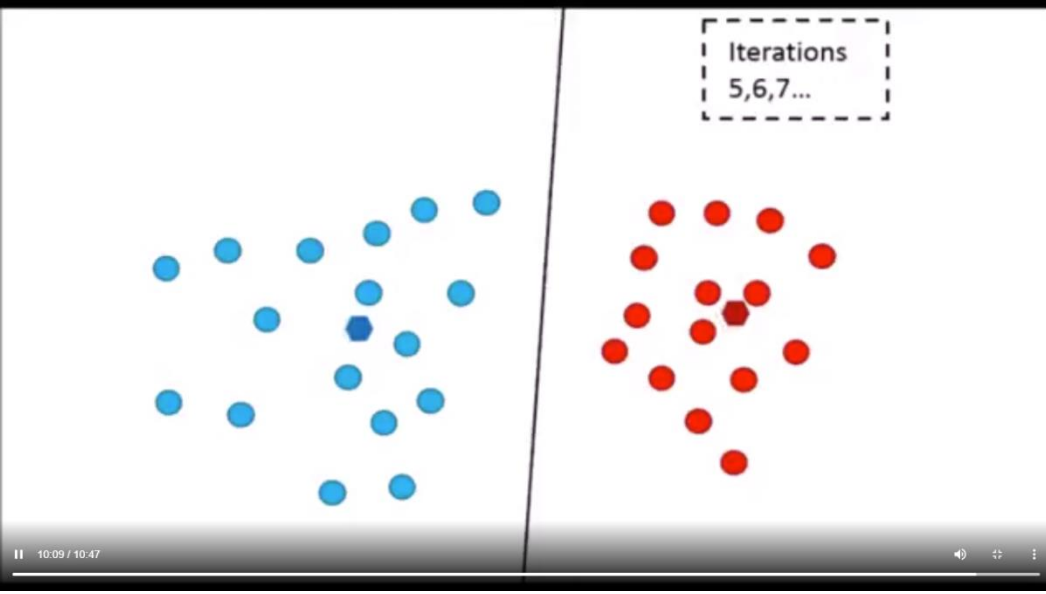

Introduction to Clustering and K-means Algorithm
Iteration 1
8:48 / 10:47
Scroll for details

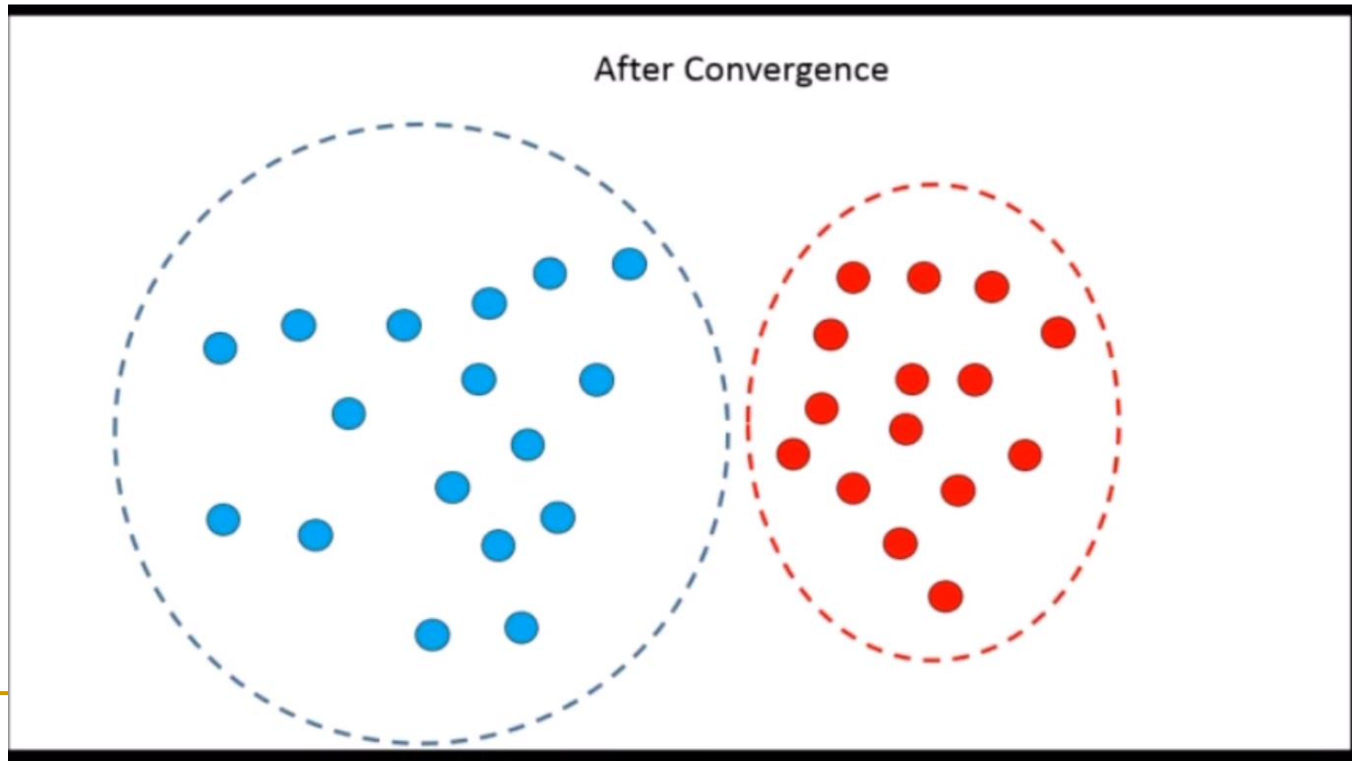

Introduction to Clustering and K-means Algorithm
Iteration 1
8:57 / 10:47
Scroll for details


Introduction to Clustering and K-means Algorithm
youtube.com is now full screen
Exit Full Screen (Esc)
Iteration 2
9:32 / 10:47
Scroll for details


Introduction to Clustering and K-means Algorithm
Iteration 2
9:45 / 10:47
Scroll for details


Introduction to Clustering and K-means Algorithm
Quiz
• When should K-means stop iterating?
Always when all the points have been classified in the right clusters
Only when a certain number of iterations have been reached
When the centroids and thus the boundaries changes no more than a small tolerance value
Submit
9:58 / 10:47
Scroll for details

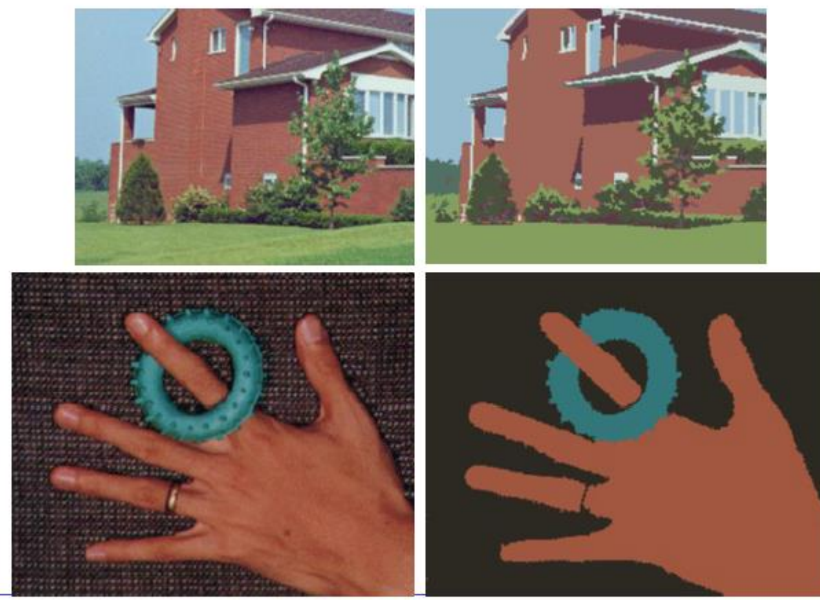

Iterations
5,6,7...
10:09 / 10:47


After Convergence

Data Clustering via Kmeans

Clustering

- Example



D. Comaniciu and P. Meer, *Robust Analysis of Feature Spaces: Color Image Segmentation*, 1997.

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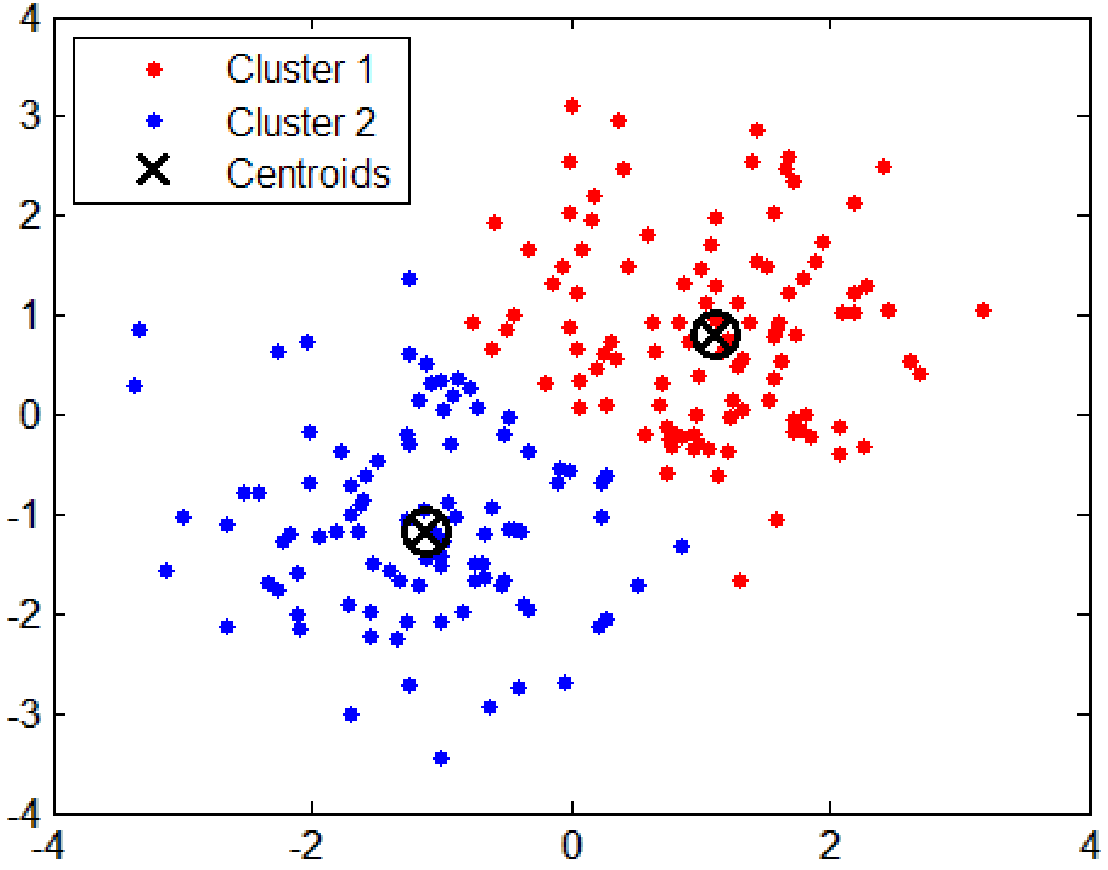
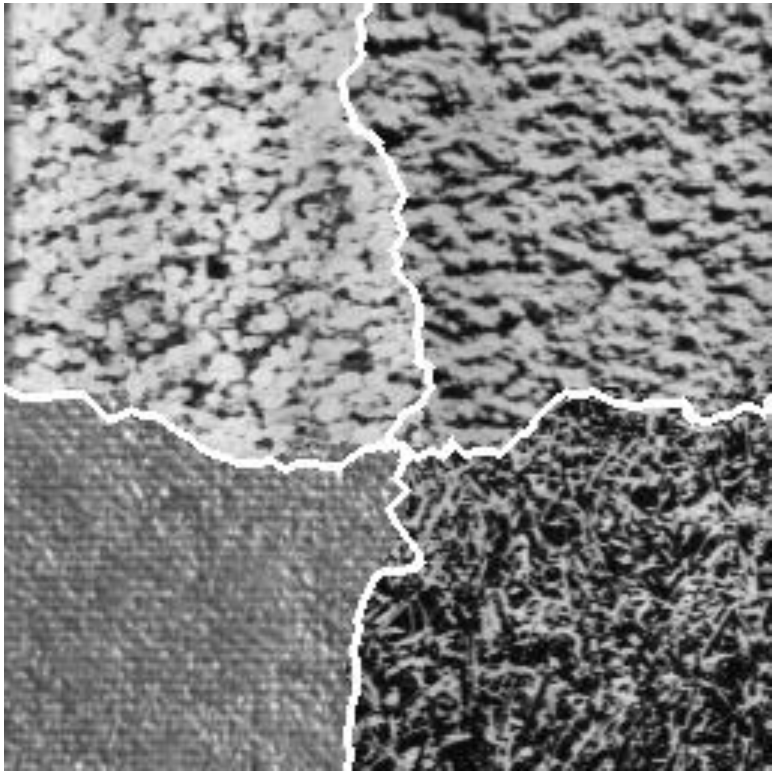
Data Clustering via Kmeans



Instead of 2D, kmeans can be applied to 3D color space RGB or L*a*b*

Texture-based Techniques

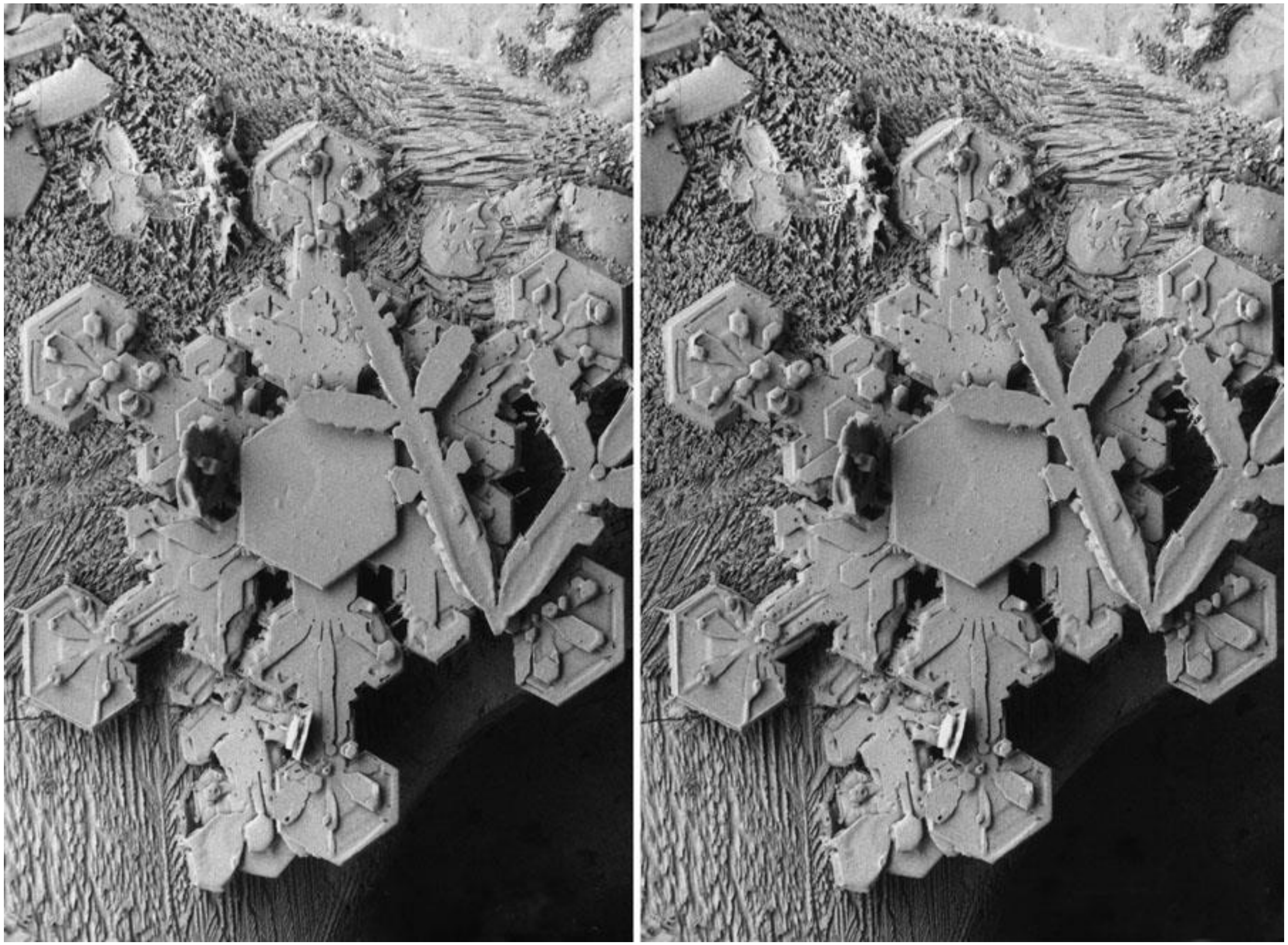


What is Texture?

No one exactly knows.

In the visual arts, **texture**
is the perceived surface quality
of an artwork.

Disparity-based Techniques



Motion Segmentation

Use of Motion In Segmentation

Take the difference between a reference image and a subsequent image to determine the still elements image components.

a b c

FIGURE 10.50 Building a static reference image. (a) and (b) Two frames in a sequence. (c) Eastbound automobile subtracted from (a) and the background restored from the corresponding area in (b). (Jain and Jain.)

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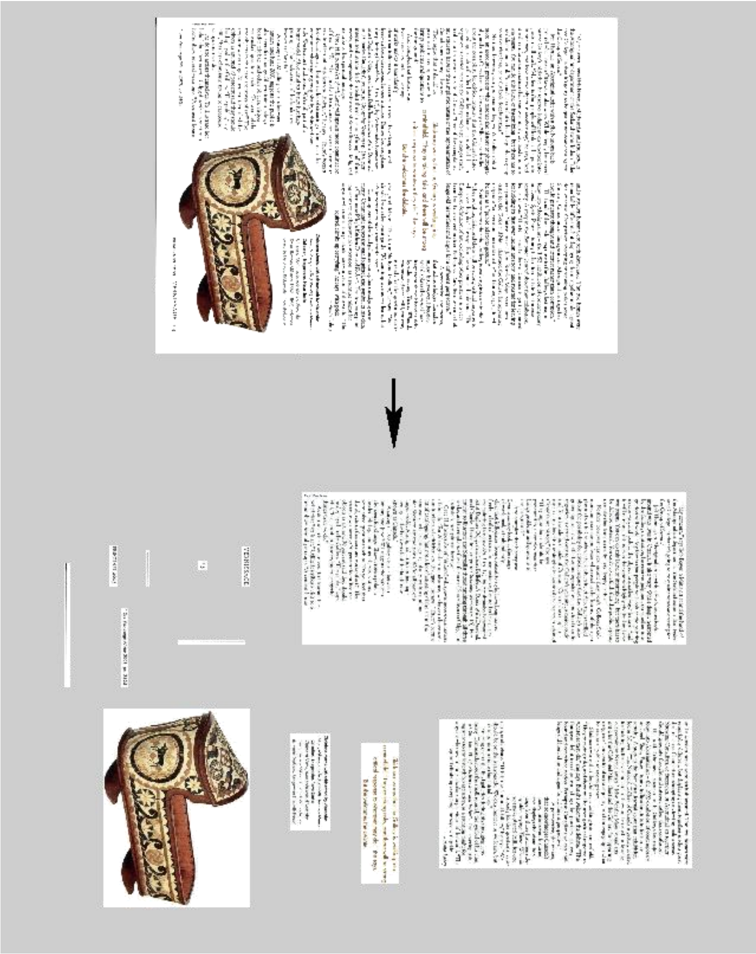
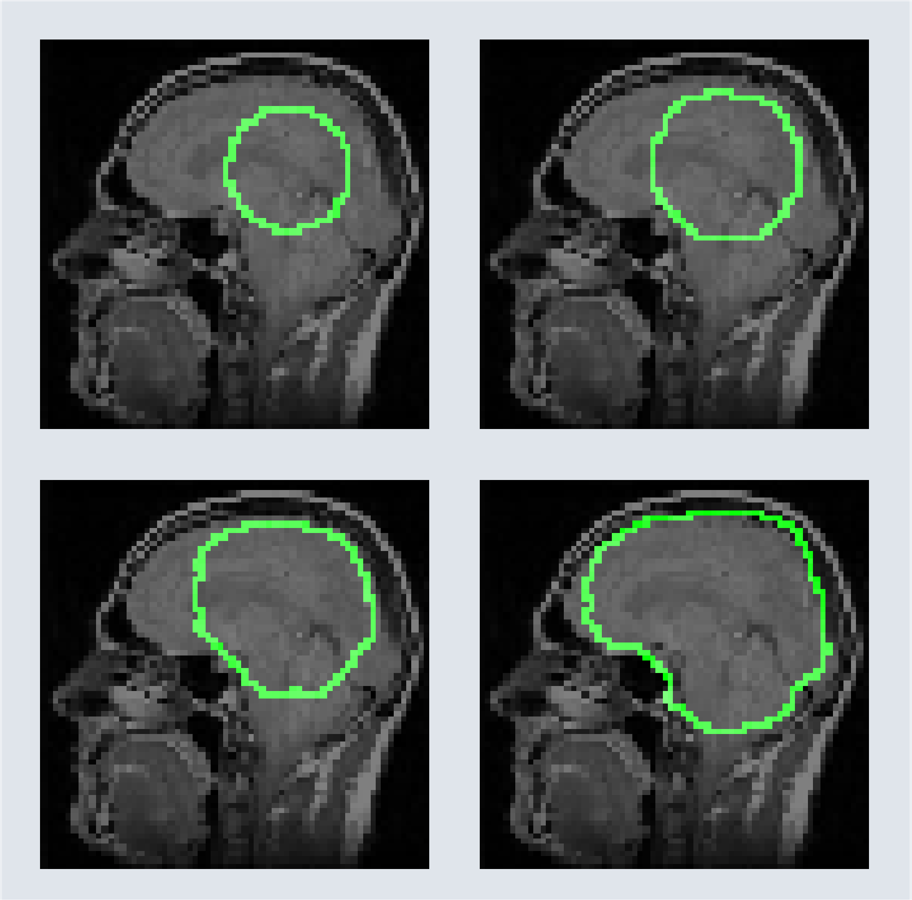
Document Segmentation

- Document images consist of texts, graphics, photos and so on
- Document segmentation is useful for compression, text recognition
- Adobe and Xerox are the major players



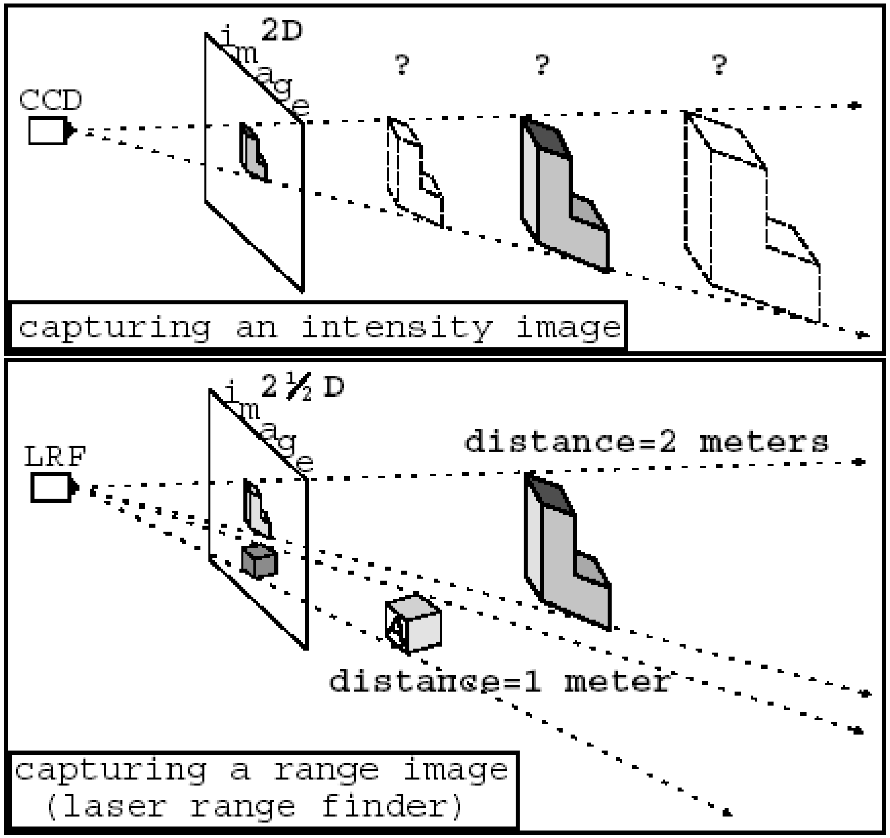
Medical Image Segmentation

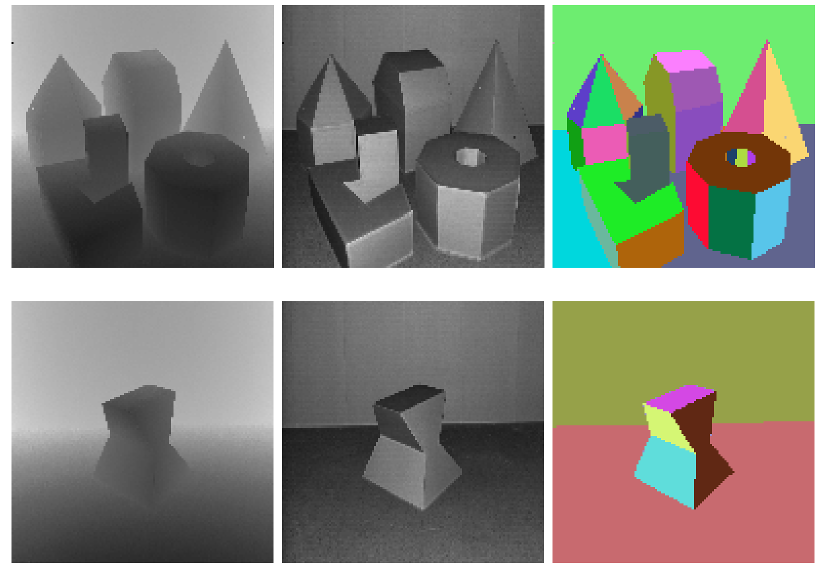
- Medical image analysis can be used as preliminary screening techniques to help doctors
- Partial Differential Equation (PDE) has been used for segmenting medical images



active contour model (snake)

Range Image Segmentation





range intensity ground truth

Biometric Image Segmentation

- For fingerprint, face and iris images, we also need to segment out the region of interest
- Various cues can be used such as ridge pattern, skin color and pupil shape
- Robust segmentation could be difficult for poor-quality images