Imperial College London

9 - Segmentation

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What is Segmentation?

- Segmentation is the **division** of an image into **spatial region**.
- This is achieved by **grouping pixels with similar visual characteristics** into regions.
- If R represent the entire spatial region, and R_i, R_j represents two separate regions $i \text{ and } j$, image segmentation is defined by the following five conditions:

a) Every pixel must be in the region R: $\bigcup_{i=1}^{n} R_i = R.$

b) R_i is a region where pixels are connected (i.e. in connected set).

c) Region R_i must be disjoint: $R_i \cap R_j = \emptyset$ for all $i \text{ and } j, i \neq j$.

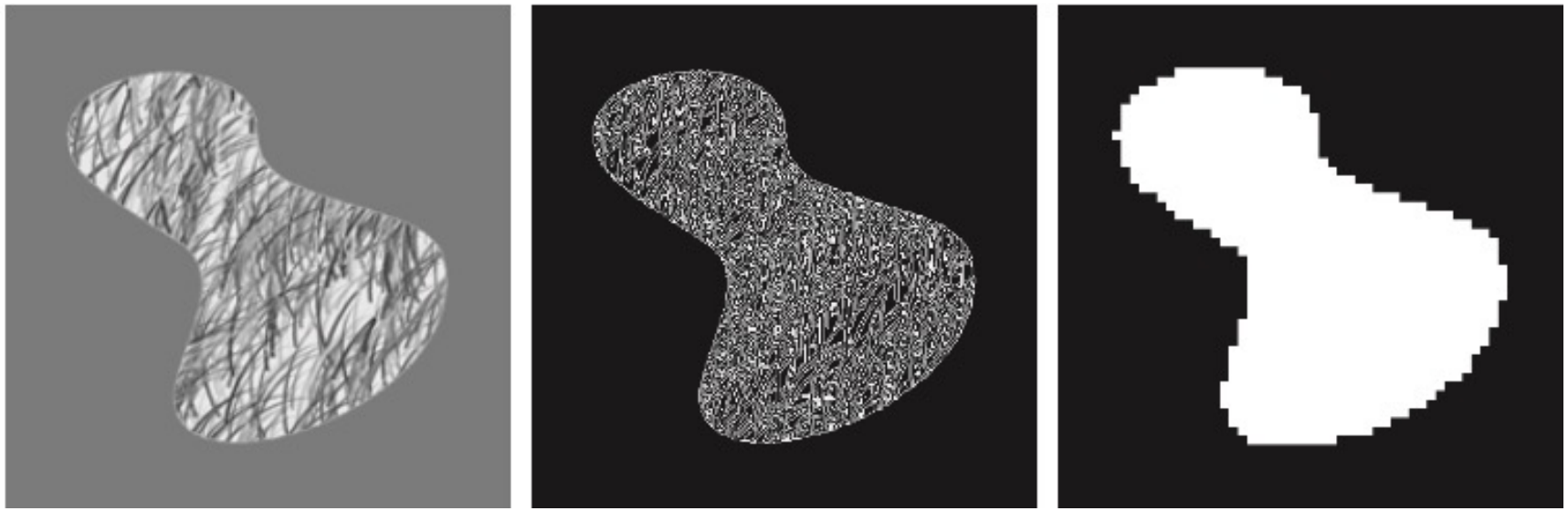
d) All pixels must share some common properties Q: $Q(R_i) = TRUE \text{ for all pixels in } R_i$.

e) Two adjacent regions R_i and R_j must be different in some properties Q.

Segmentation based on discontinuity

Intensity based segmentation

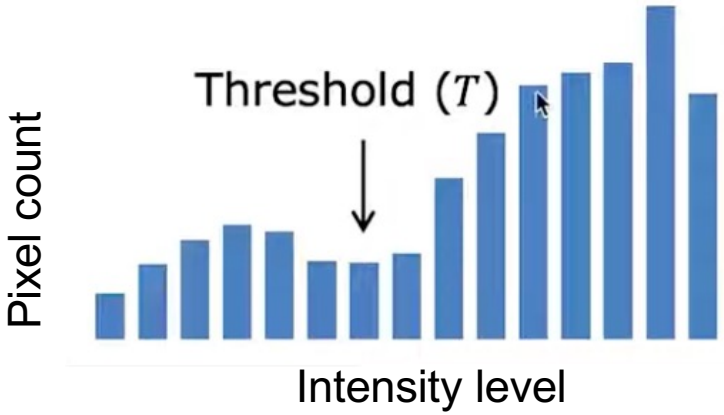
Texture based Segmentation (8 x 8 patch)



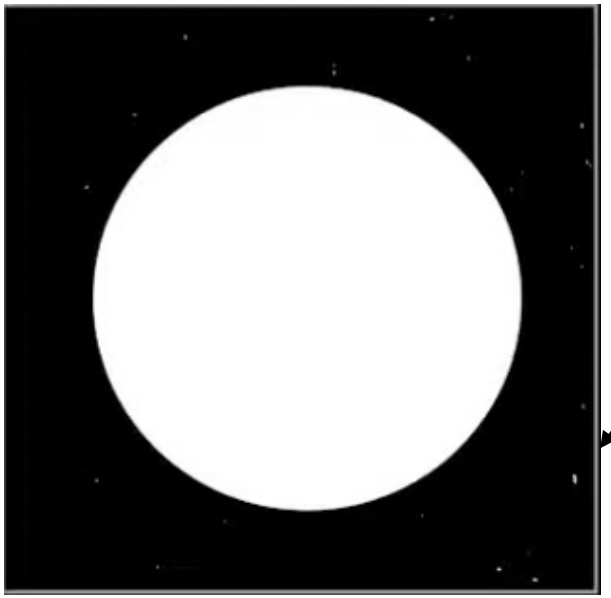
Segmentation using Thresholding

$f(x, y)$

Histogram

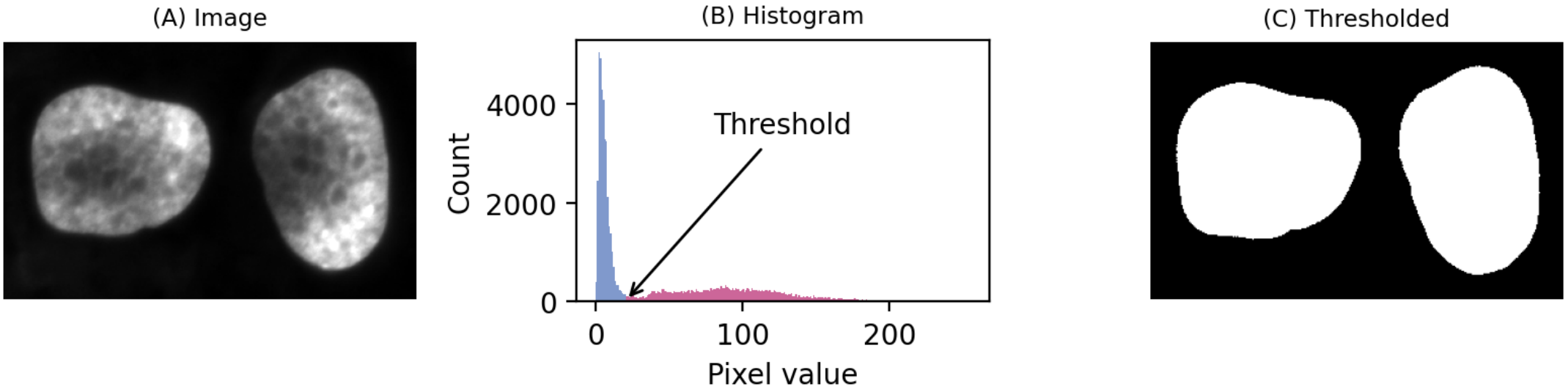


Binary image



$g(x, y)$

Histogram can be a guide

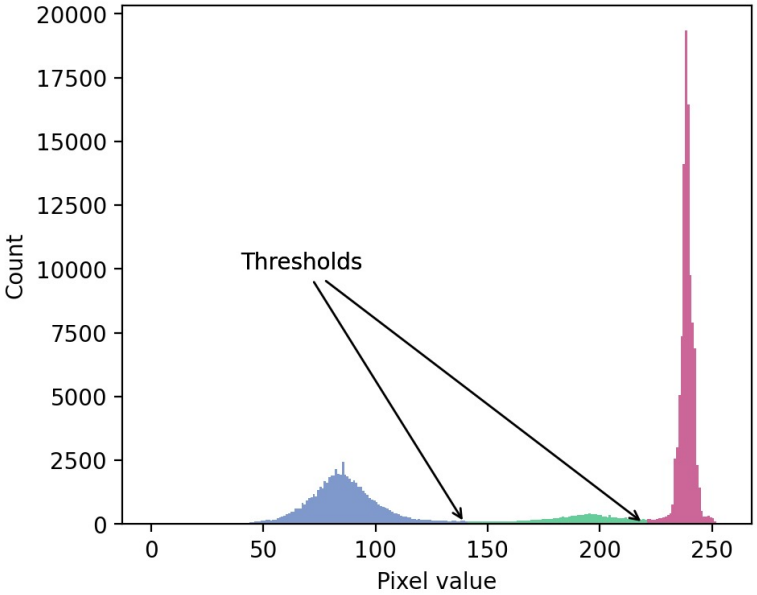


- The left image is to be segmented.
- Histogram is bimodal - the background and the object occupying two distinct regions.
- Putting the threshold between the two “hills” will easily segment the image.

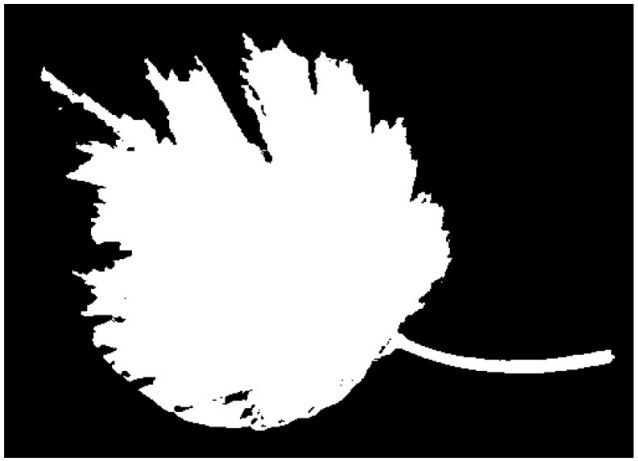
What if it is not bimodal?

(A) Image

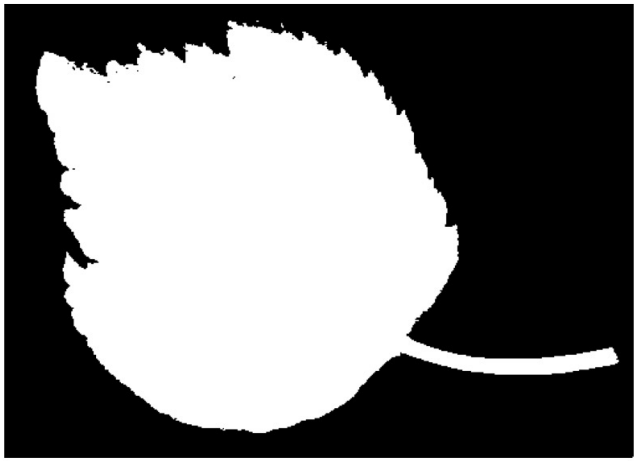
(B) Histogram



(C) Thresholded 140

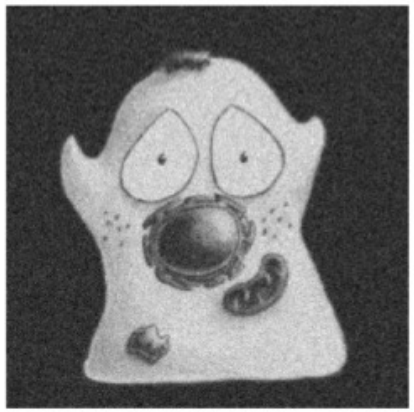


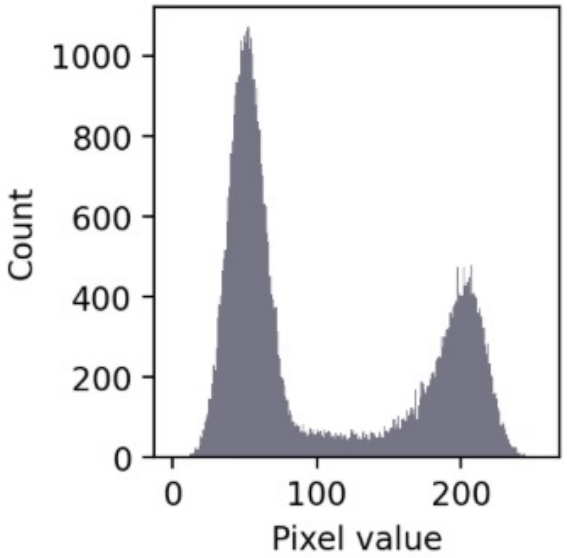
(D) Thresholded 220



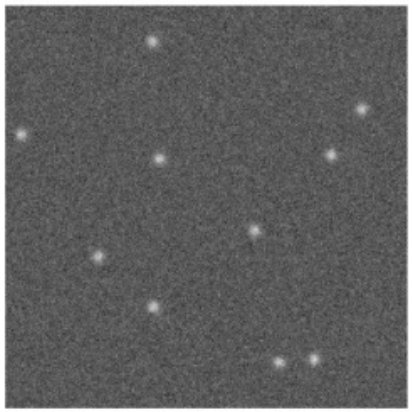
Three Different Type of Images & Histograms

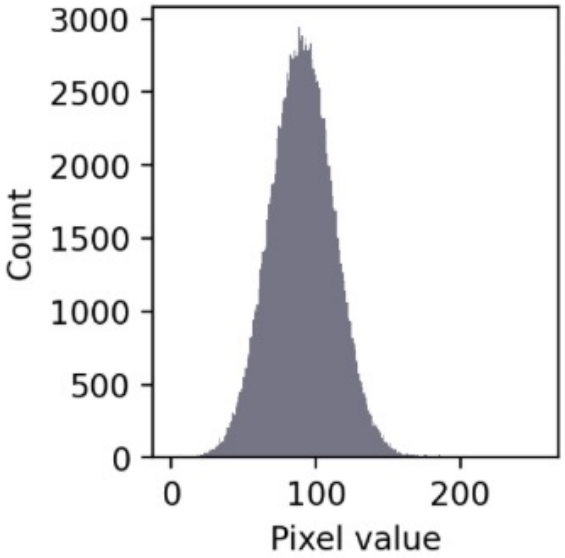
Bimodal



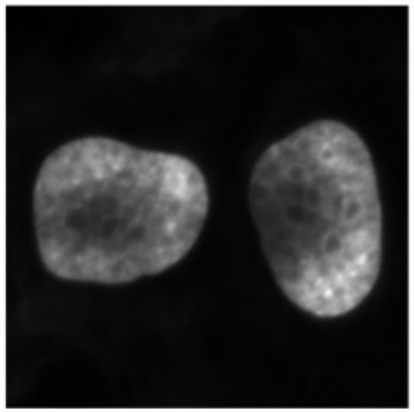


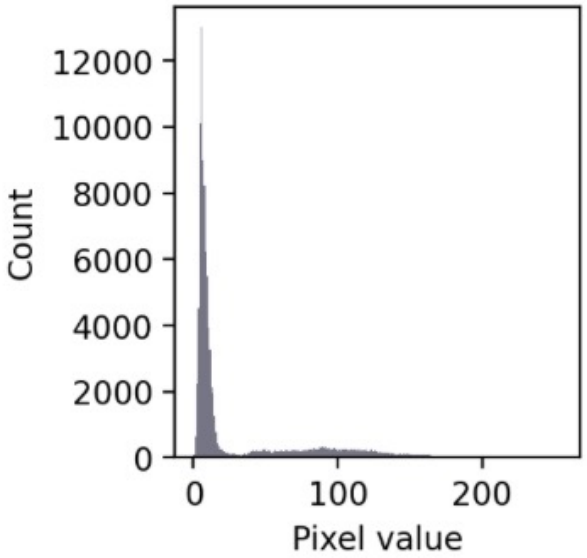
Unimodal





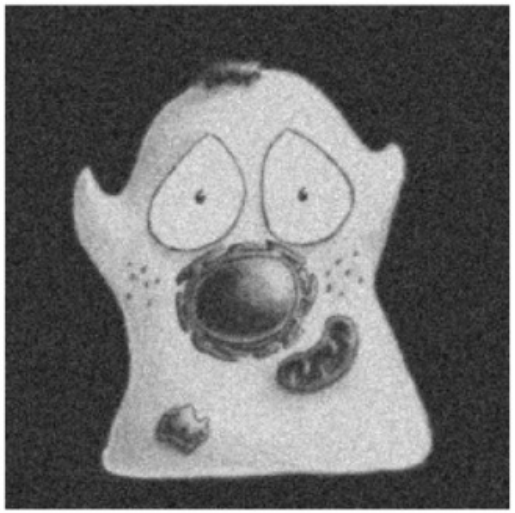
Clear background & object



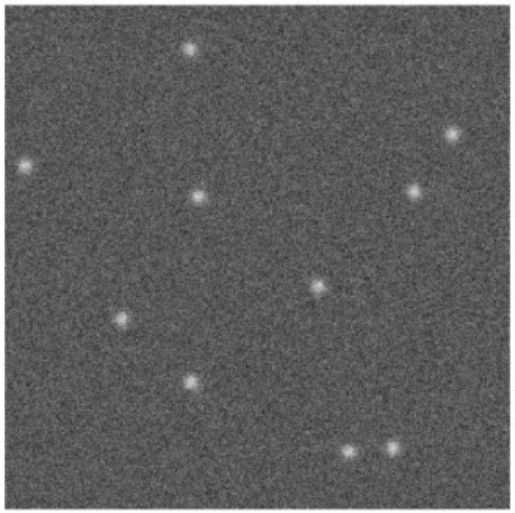


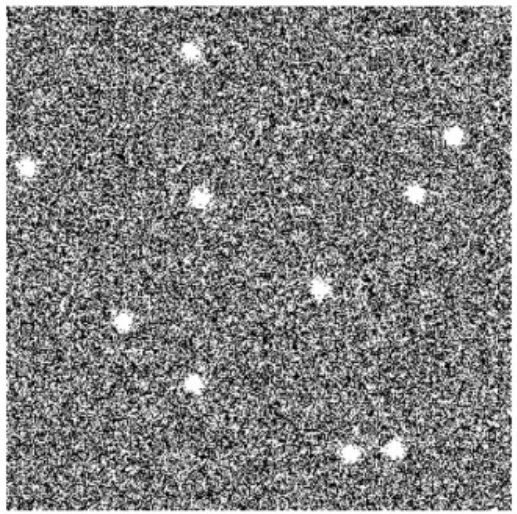
Otsu's method to find threshold

Threshold = 123

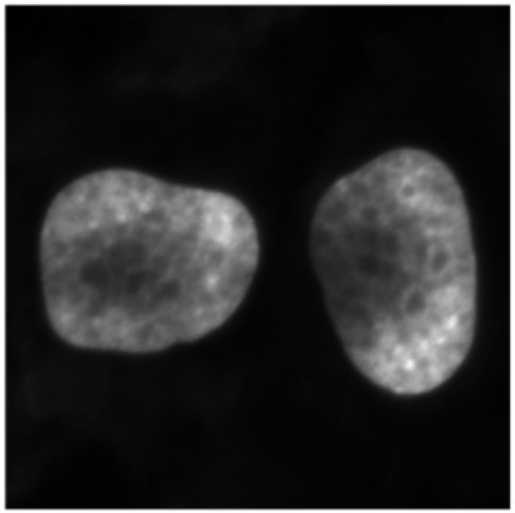


Threshold = 90





Threshold = 59



Variable Thresholding based on local statistics

- Threshold $T_{xy} = a\sigma_{xy} + bm_{xy}$, where σ_{xy} is local standard deviation, m_{xy} is local mean intensity, and a, b are positive constants.

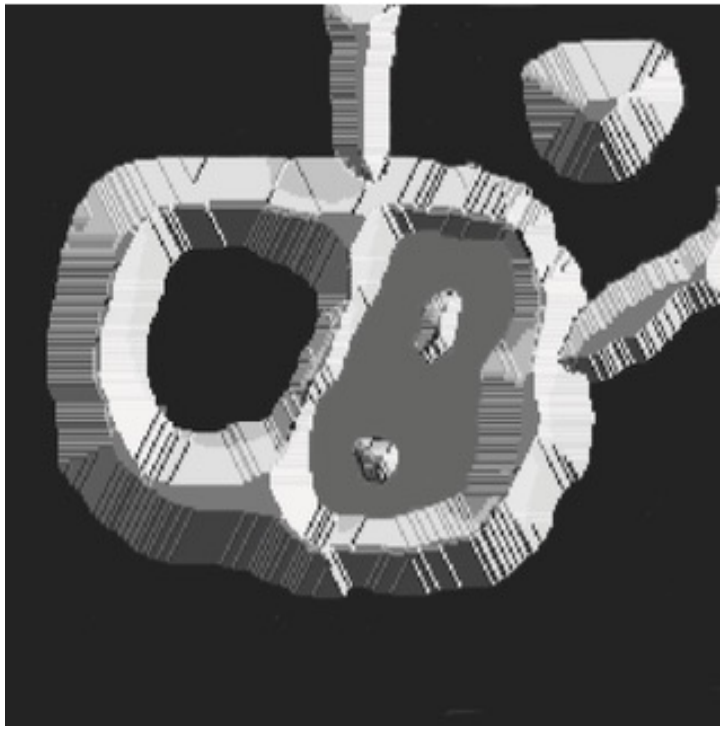
Image of yeast cells

Using dual global thresholds

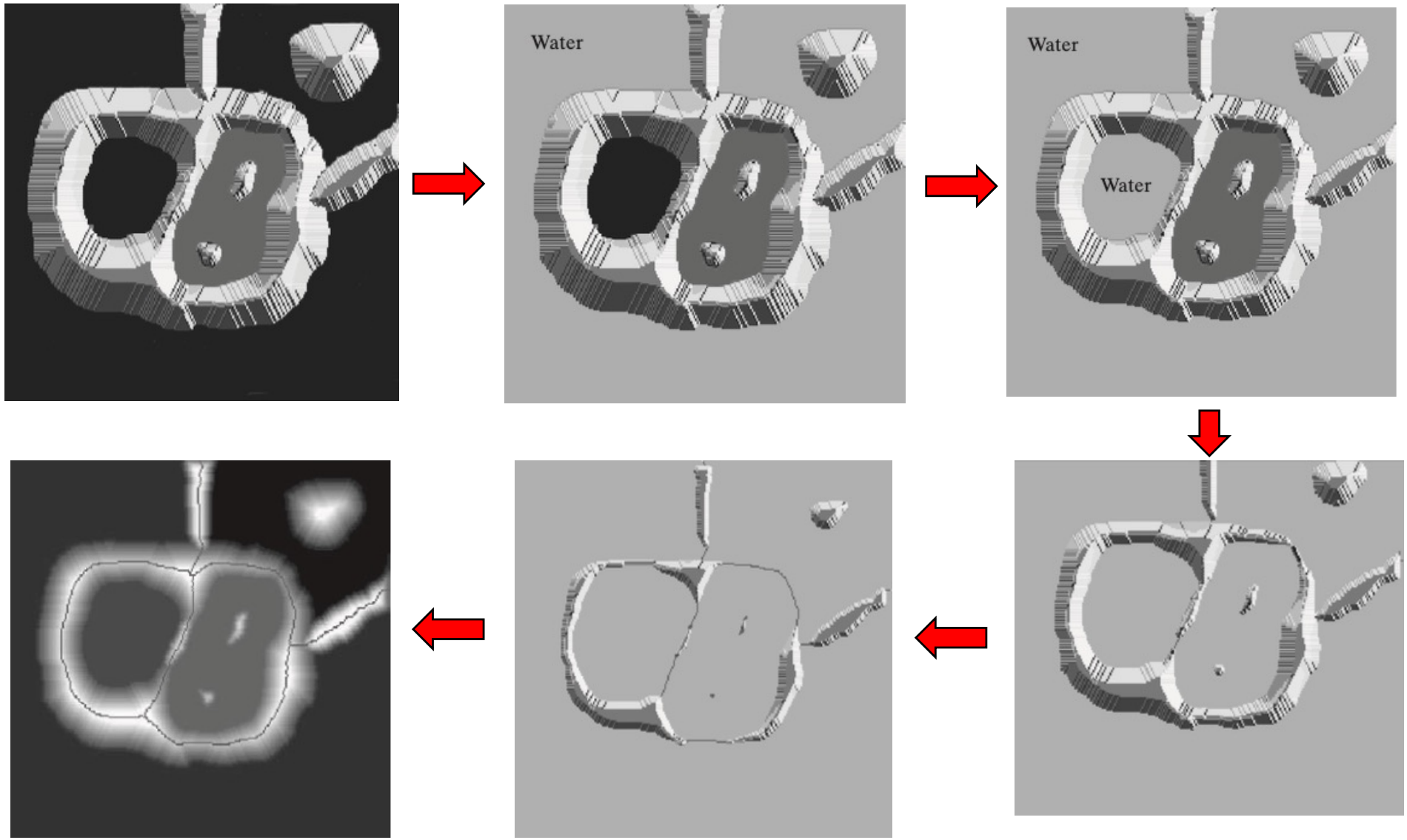
Using local thresholds

Segmentation using Watershed Transform (1)

- A watershed is the ridge that divides areas drained by different river systems.
- A catchment basin is the geographical area draining into a river or reservoir.
- The segmented regions are the basins that catch the rainwater as water rises.
- The watershed ridge line partition the image into regions thus achieving segmentation.



Segmentation using Watershed Transform (2)

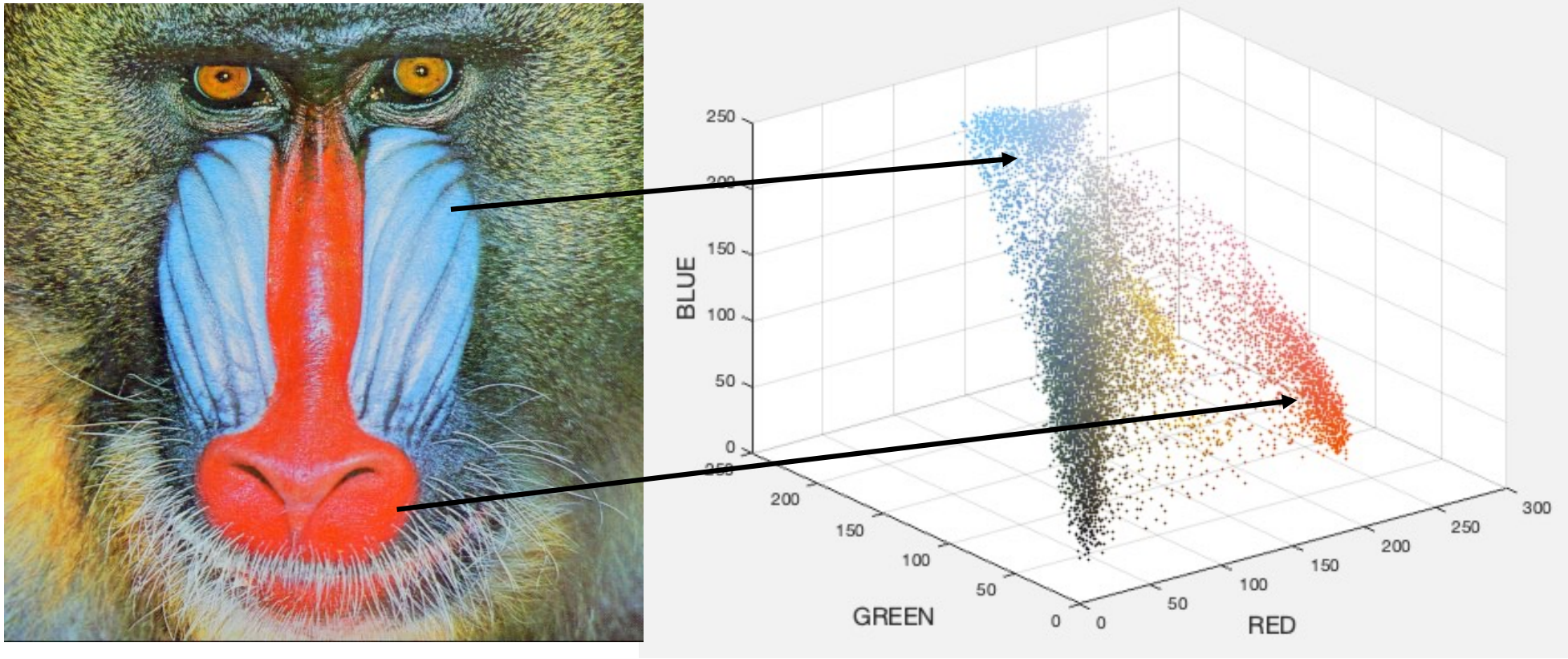


Segmentation based on clustering

- Visual characteristics: Intensity, colour, position, texture, motion, depth
- Each pixel as feature vector: [R, G, B, x, y …..]

Colour image

Pixel colour in feature vector [R G B]

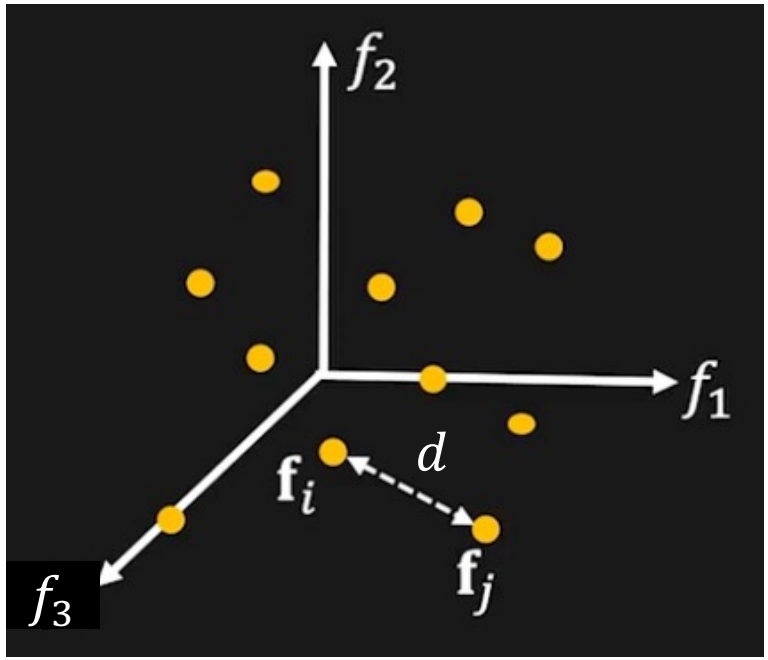


Pixel Similarity Measure

- Let f_i and f_j be the feature vector for pixels i and j respectively.
- The **Euclidian distance** between f_i and f_j is given by:

$$d(f_i, f_j) = \sqrt{\sum_k (f_{ik} - f_{jk})^2}$$

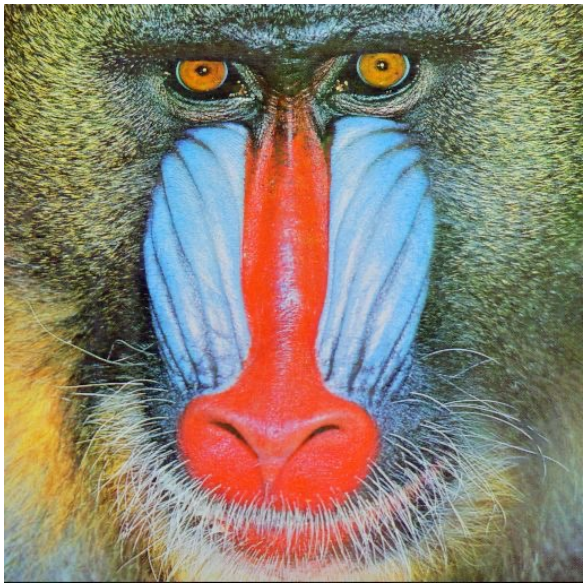
- Smaller the value of d, the greater the similarity.



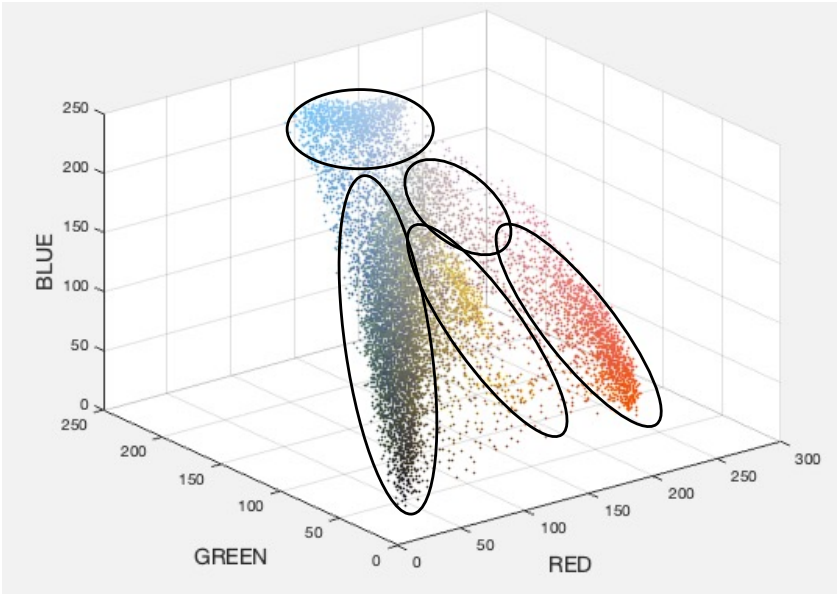
Segmentation by Clustering [R G B] vectors

- Group together those pixels that have high similarity in colour (i.e. short $d(r, g, b)$ distances) to form clusters.
- Assign a “mean” colour to each cluster.
- Now we have a segmented image by colour.

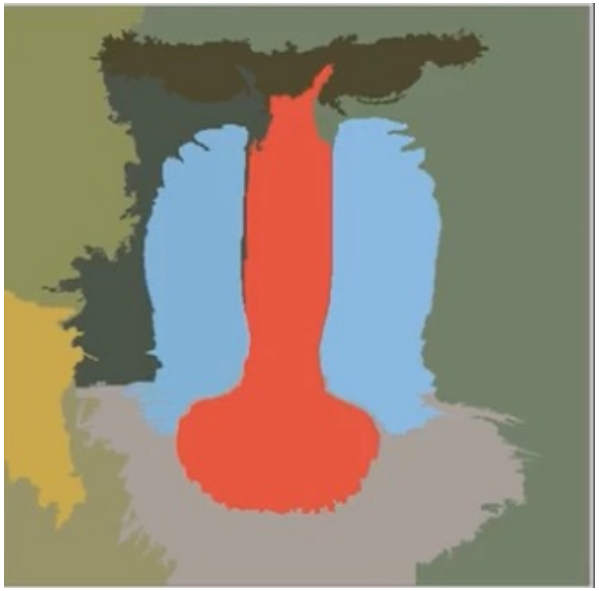
Original image



Features divided into 5 clusters

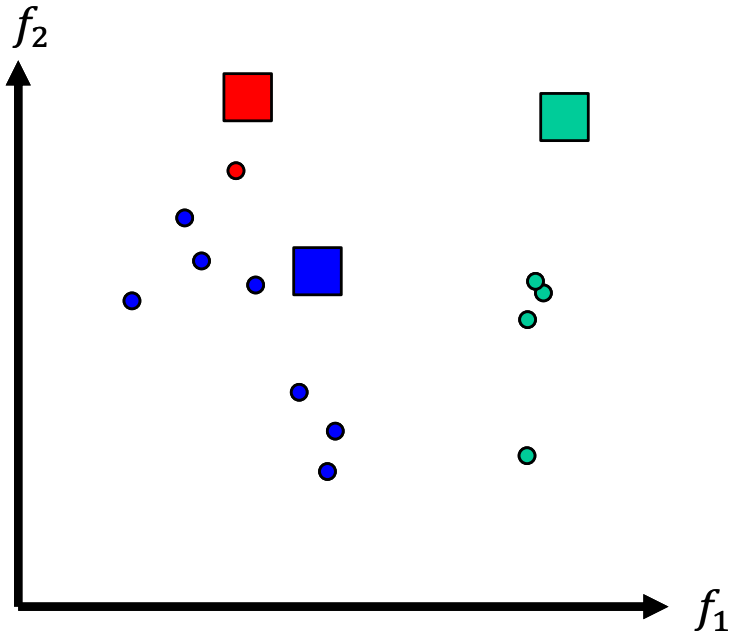


Segmented by colour



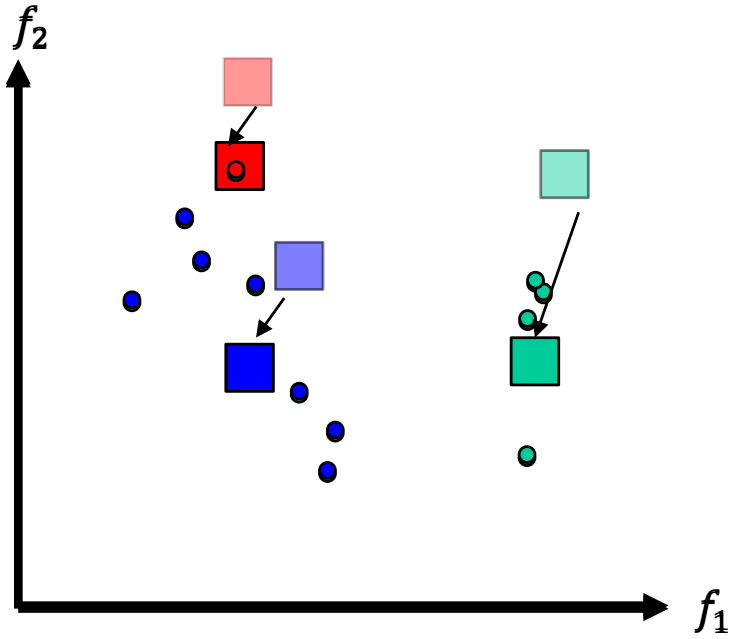
Segmentation by k-Means Clustering (1)

- Segment image into k clusters using pixel characteristics.
  Assume k = 3
- Step 1: Generate 3 random initial means (centroids) in feature space.
- Step 2: Cluster each pixel to the mean with shortest distance to form 3 clusters as shown.

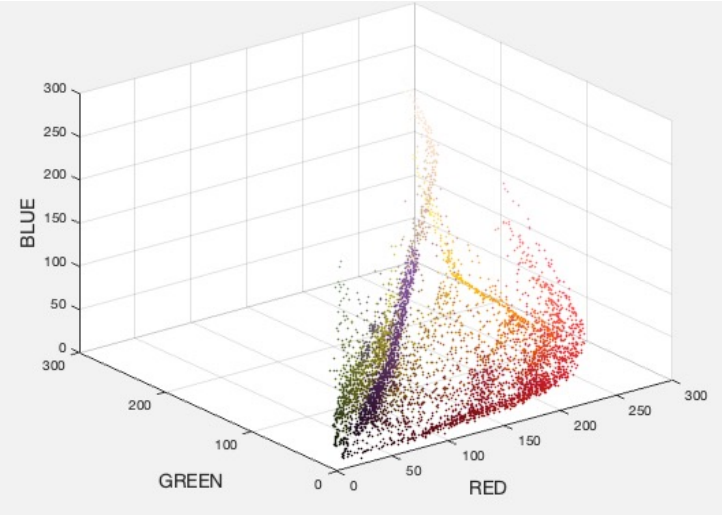


Segmentation by 3-Means Clustering (2)

- Step 3: Recompute the mean of each cluster
- Step 4: Repeat steps 2 and 3 until mean (or centroid) values change below a small margin. Then segmentation is completed and converges to a final solution.
- Needs to determine k. Also need to select initial values.
- Best initial values: Perform k-means clustering on a subset of pixels, and use that solution as initial values.



Example of k-Means Clustering (k = 16)

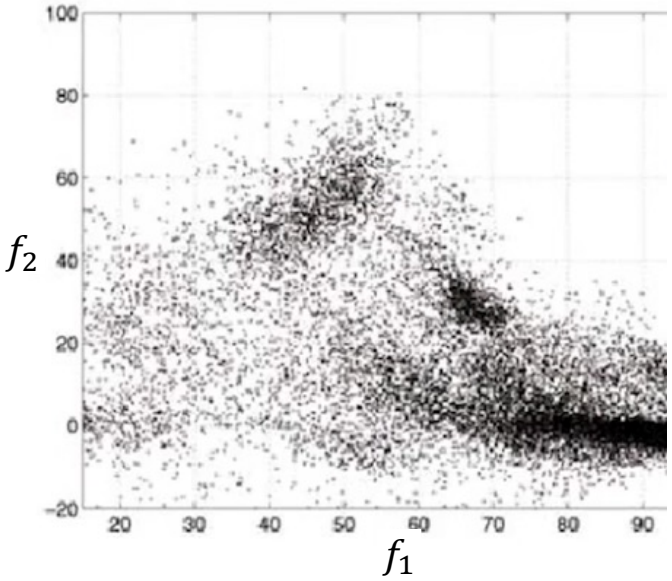


k = 16, {R, G, B} space only

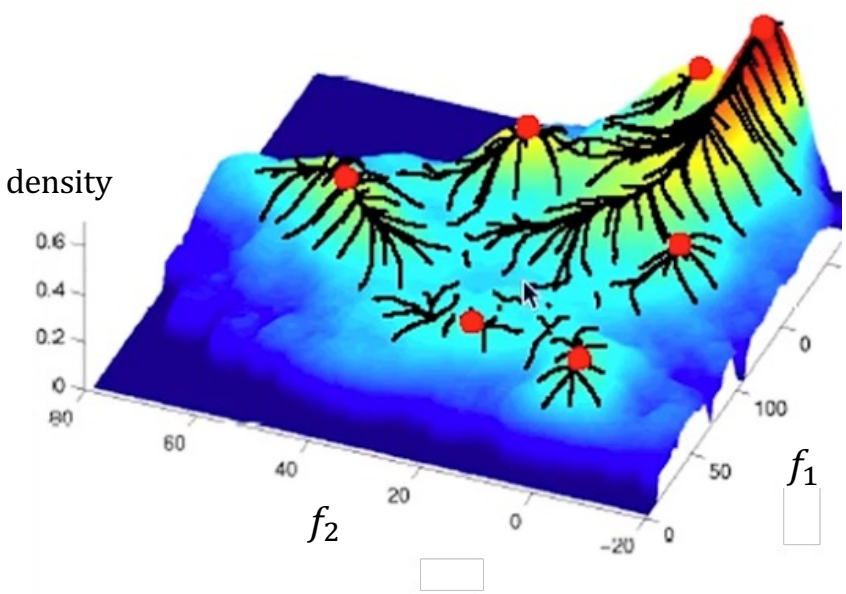
k = 16, {R, G, B, x, y} space

Idea behind Mean Shift Clustering

Pixel feature distribution

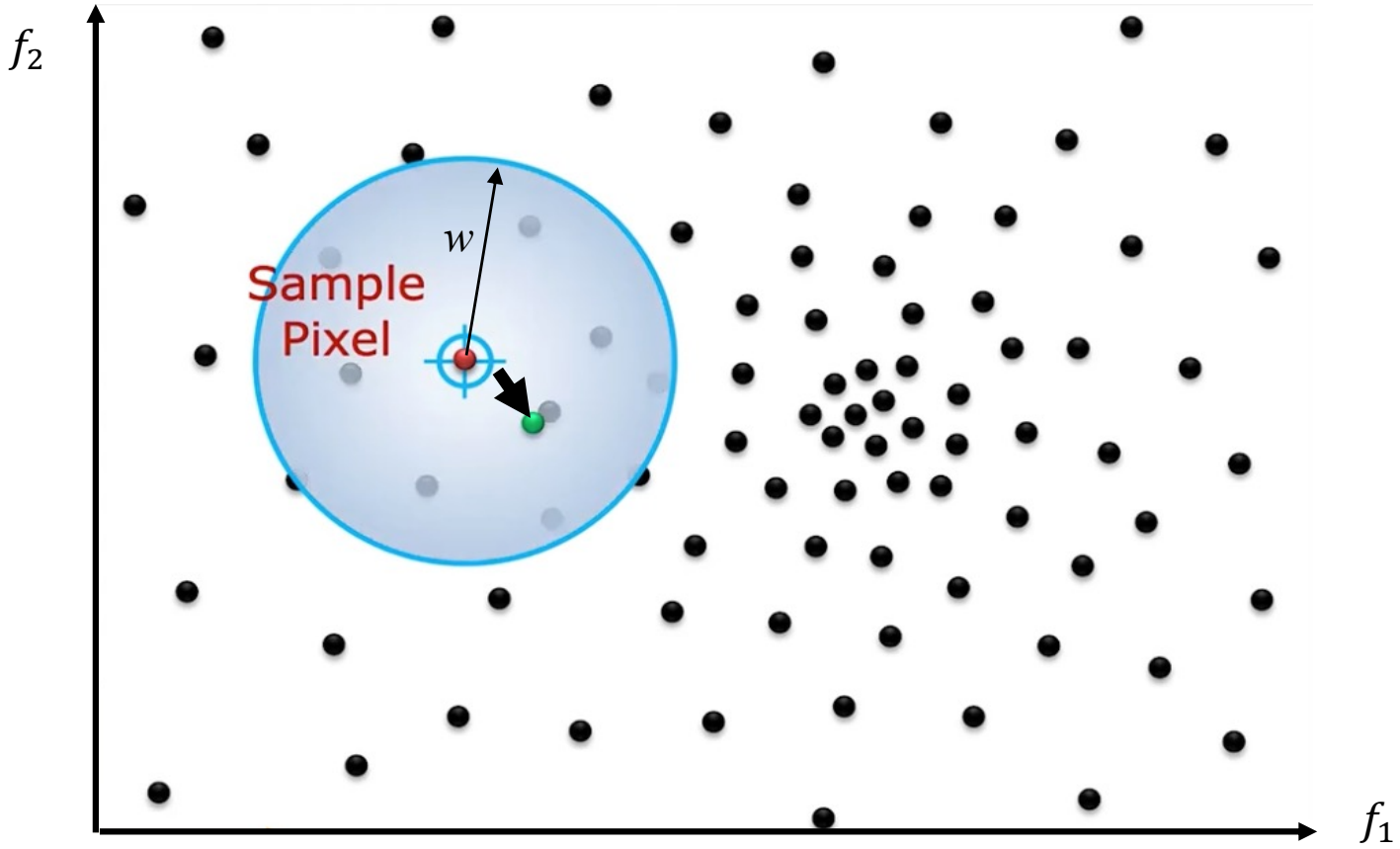


Density (normalized to [0 1])



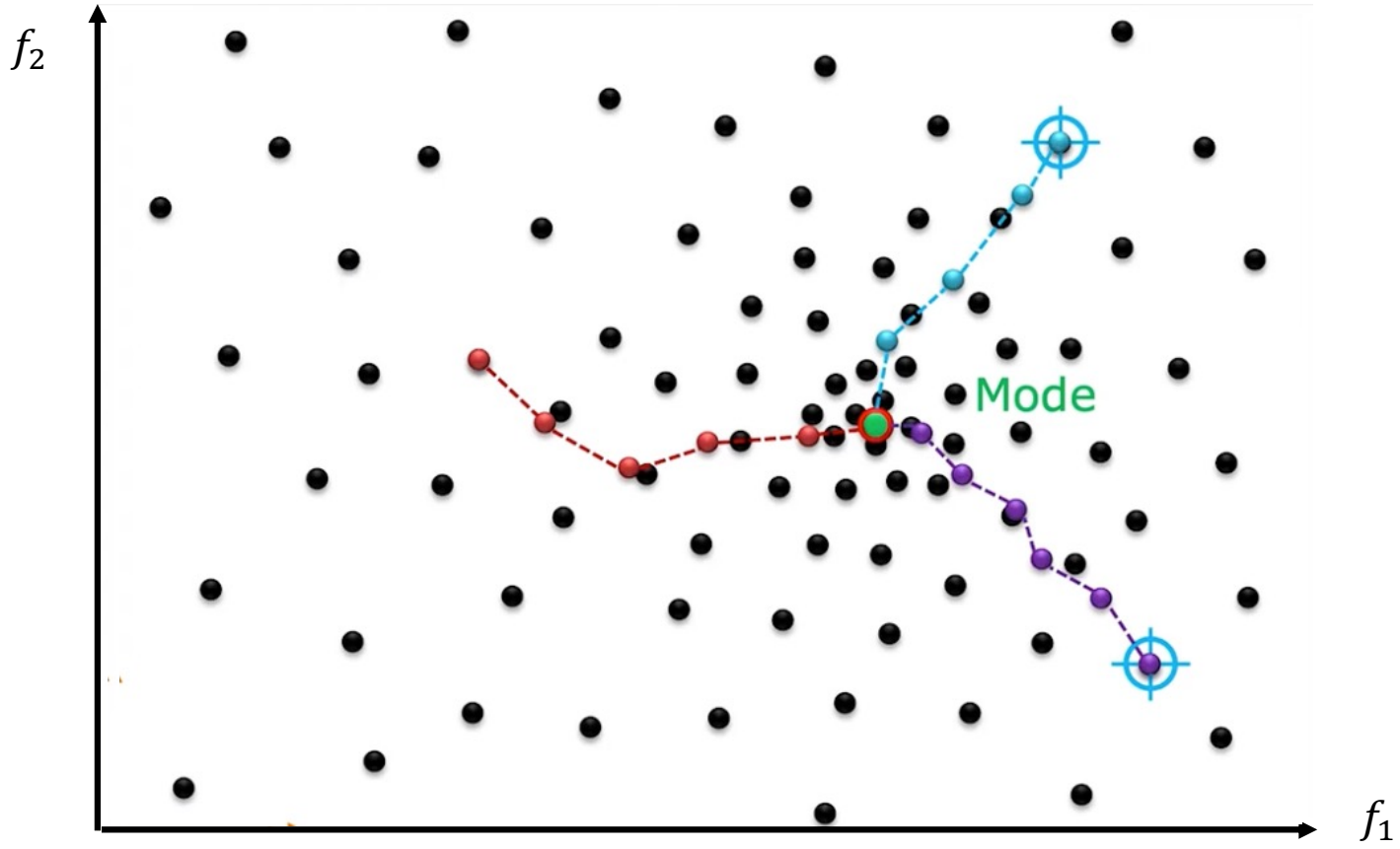
- Mean Shift determines how many clusters automatically depending on image.
- Each hill of the distribution represents a cluster.
- Each peak of the hill represents “mean” or ”centroid” of a cluster.
- Each pixel climbs the steepest hill within its neighbourhood.
- Pixel takes on the peak of the hill in its cluster.

Mean Shift Hill Climbing



- Consider one pixel (red) in feature space. Form a window centred at pixel with with w.
- Calculate the **weighted means** of feature parameters to find a new location in green.
- Shift the original pixel in feature space to the new mean (hence name “mean shift”).
- Keep doing this until there is no shift – we are done for this pixel!

Mean Shift Hill Climbing



- Therefore, the original pixel (in red), successfully climb the hill to the MODE (or peak).
- Other pixels nearby also eventually reach the same peak.
- These are ALL belonging the same cluster. They are then assigned the same feature vector as that of the peak.

Example of Mean Shift Clustering

k-Means (k = 16)

Mean Shift ($w = 21$)