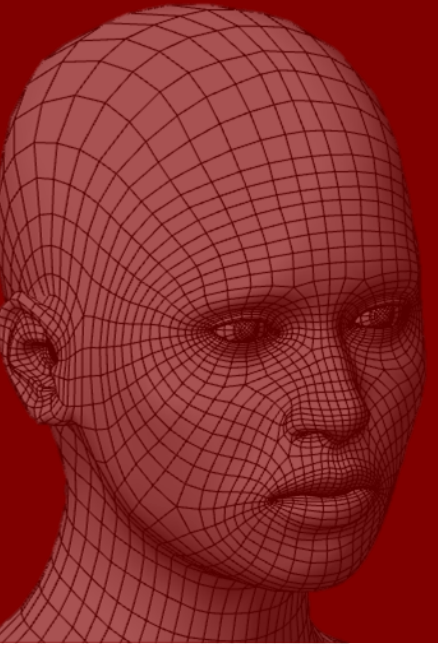

Advanced Image Processing

Lesson 1: How to choose your algorithm of image segmentation ?

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PARIS-EST CRÉTEIL
VAL DE MARNE

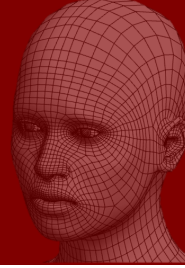
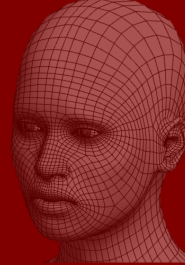


Image Segmentation

- Image segmentation is the process of **isolating objects** of interest from the rest of scene (Castleman).
- Image segmentation is the process of partitioning an image into **non-intersecting regions** such that each region is homogeneous and the union of the no two adjacent regions is homogenous. (Pal)
- Image segmentation is to divide an image into parts that have a **strong correlation with objects or areas of the real word** contained in the image. (Watt)



In Brief :

- Image segmentation is the **partition** of the image space into a set of **non-overlapping regions** whose union is the image.
- decompose the data set into a series of **meaningful** components. However....
- there is a problem in telling a computer what a 'meaningful segmentation' is.

Image processing flow based on image segmentation

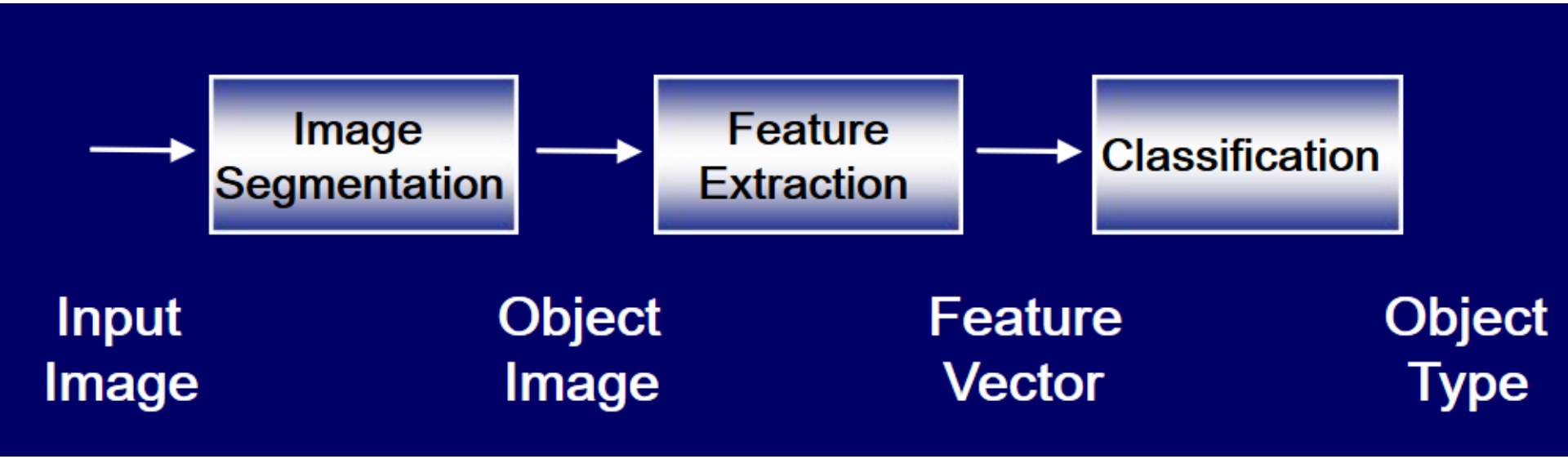
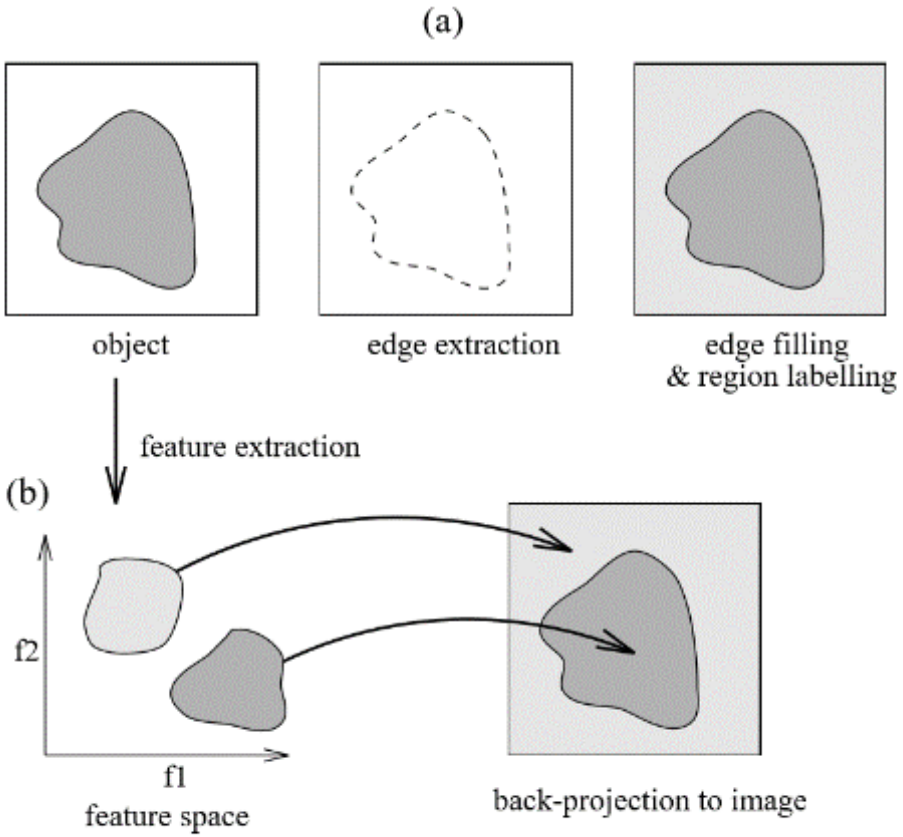
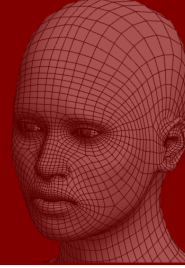


Image processing flow based on image segmentation

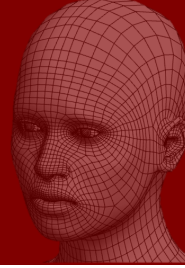


An example of image segmentation: Observation space (a) and feature space (b) segmentation.



I. What are the algorithmes of images segmentation you know ?

II. Which kind of images can segment ?

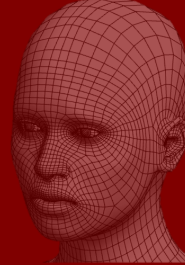


No standard or generic approach of segmentation

Aiming to perform an objective comparison of methods, Chenouard et al. (2014) gathered the community and organized an open competition in which participating teams applied their own methods **independently** to a **commonly defined data set** including **diverse scenarios**.

Performance was assessed using commonly defined measures. ***Although no single method performed best across all scenarios, the results revealed clear differences between the various approaches***, leading to notable practical conclusions for users and developers.

[1]: Chenouard, N., Smal, I., De Chaumont, F., Maška, M., Sbalzarini, I. F., Gong, Y., ... \& Cohen, A. R. (2014). Objective comparison of particle tracking methods. Nature methods, 11(3), 281-289.
[2]: A. Othmani, S. Basu, A. N. Shrivastava, S. Aslan, F. De Carli, A. D. Afua, Asm Shihavuddin and A. Nait-Ali (2017): Cellular Imaging to Biometrics. In Hidden Biometrics: when biometrics meets biomedical engineering, Springer, October 2017 (accepted).

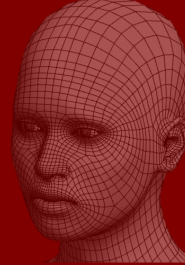


No standard or generic approach of segmentation

- No standard approach of segmentation.
- It is specific to the application
- Segmentation approaches incorporate a prior knowledge of the domain.
- The performance of segmentation methods depends on how high is the SNR (Signal to Noise Ratio)
- Some approaches performs better than others with overlapped and touching objects.

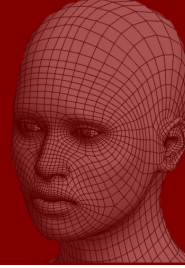
[1]: Chenouard, N., Smal, I., De Chaumont, F., Maška, M., Sbalzarini, I. F., Gong, Y., ... \& Cohen, A. R. (2014). Objective comparison of particle tracking methods. Nature methods, 11(3), 281-289.

[2]: A. Othmani, S. Basu, A. N. Shrivastava, S. Aslan, F. De Carli, A. D. Afua, Asm Shihavuddin and A. Nait-Ali (2017): Cellular Imaging to Biometrics. In Hidden Biometrics: when biometrics meets biomedical engineering, Springer, October 2017 (accepted).



- Image analysis methods seem to be locked in a stalemate where **new techniques are proposed by the hundreds every year** and yet are **only applicable to the specific data they were developed** on. [2]

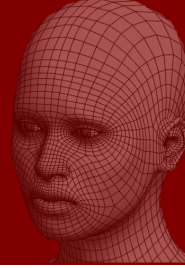
[2]: A. Othmani, S. Basu, A. N. Shrivastava, S. Aslan, F. De Carli, A. D. Afua, Asm Shihavuddin and A. Nait-Ali (2017): Cellular Imaging to Biometrics. In Hidden Biometrics: when biometrics meets biomedical engineering, Springer, October 2017 (accepted).



"Reflecting on the developments in the field in the past 50 years, one might wonder what to expect from the next 50 years of research. As early as 1966, researchers already exclaimed that "automation of the acquisition and interpretation of data in microscopy has been a focus of biomedical research for almost a decade," and they concluded that "**many facets of the problem appear to be well within the grasp of present-day technology**," leading them to anticipate that "**modern large-capacity, high-speed data facilities at last provide the ability to manipulate the hitherto unmanageable quantities of optical information contained within all but the simplest images**" [9]. **On one hand, it may feel embarrassing to admit that today, half a century down the road, very similar remarks still apply**". [1]

[1]: Meijering, E. (2012). Cell segmentation: 50 years down the road [life sciences]. IEEE Signal Processing Magazine, 29(5), 140-145.

How to choose the image segmentation adapted algorithm ?



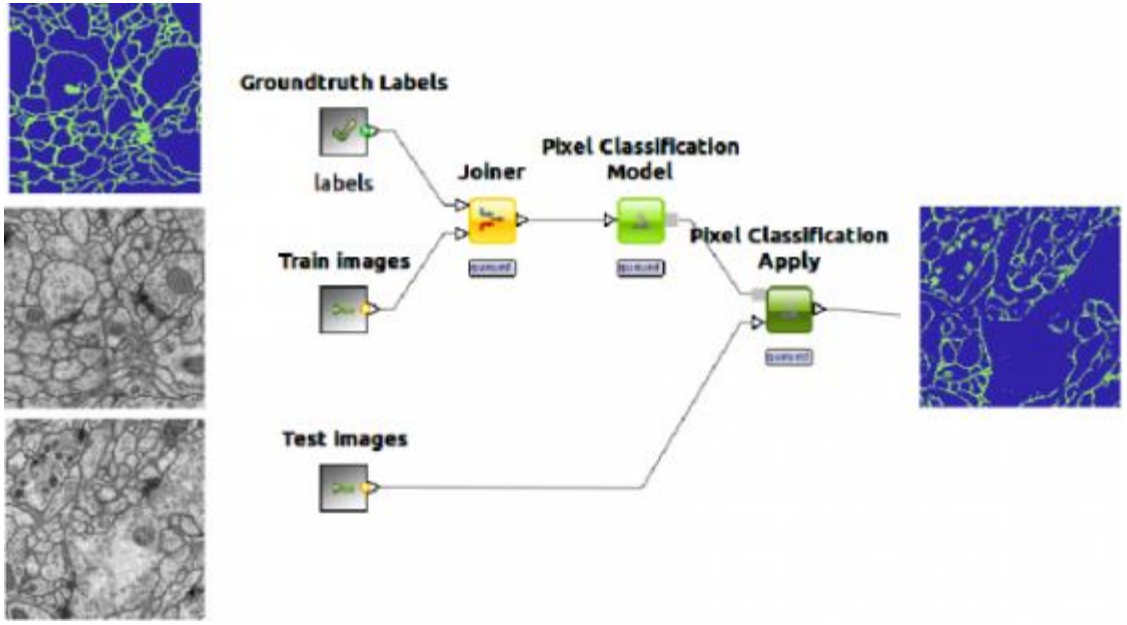
- Narrowly define the context, **make assumptions** !
  - the number of objects to segment,
  - noise estimation,
  - does your image contain overlapped objects ?
  - does the objects you segment have the same shape, same texture or same color ?
  - does the objects to segment present an inter-class variability/correlation ?
  - does the objects to segment present an intra-class variability/correlation ?

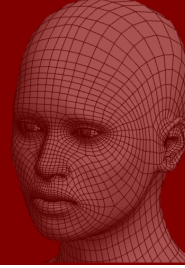
→ To make a good choice 'quickly' is a matter of Knowledge and experience.

Supervised vs. Unsupervised Image Segmentation Methods

Supervised learning: predicting an output variable (class label of each pixel) from high-dimensional observations (labelled images = Ground truth).

Supervised learning consists in learning the link between two datasets: the observed data X and an external variable y that we are trying to predict, usually called “target” or “labels”.



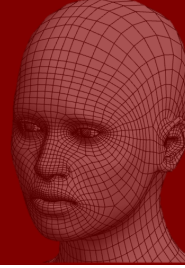


Supervised vs. Unsupervised Image Segmentation Methods

Unsupervised learning: is a type of machine learning algorithm used to draw inferences from datasets consisting of input data **without labeled responses**.

→ **No training data**

- **Grouping (or clustering)**
  - collect together tokens that "belong together"
- **Model Fitting**
  - associate a model with tokens
  - issues
    - which model?
    - which token goes to which element?
    - how many elements in the model?



Supervised vs. Unsupervised Image Segmentation Methods

General ideas

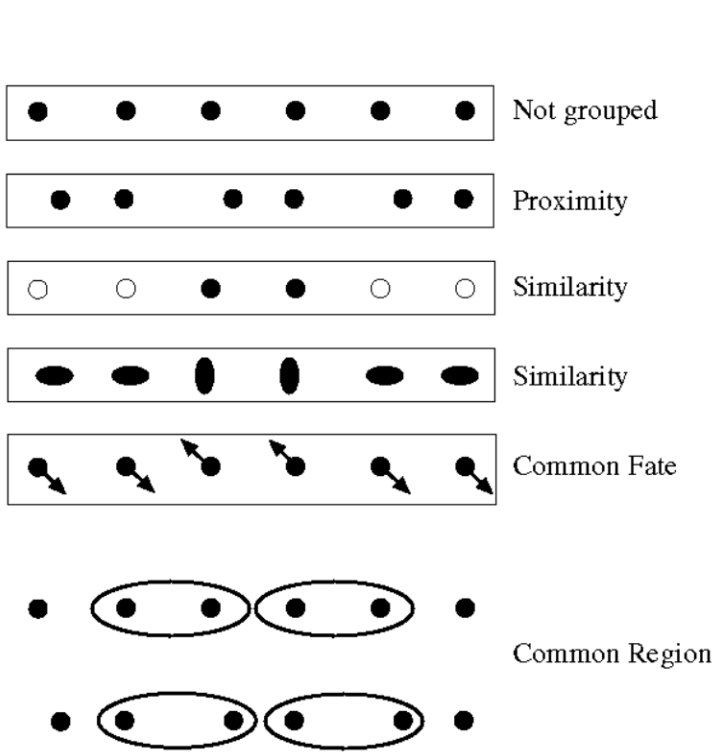
- **tokens**
  whatever we need to group (pixels, points, surface elements, etc., etc.)

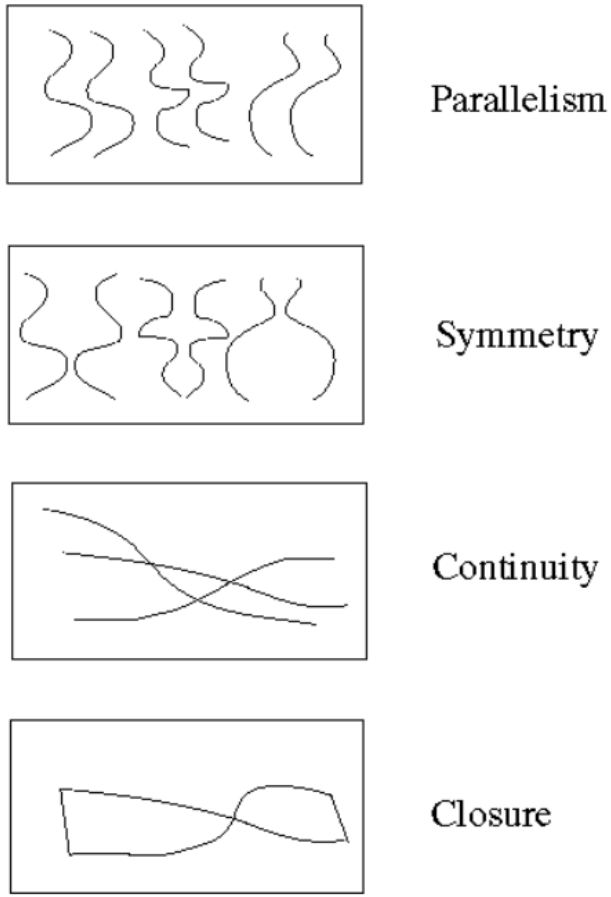
- **top down segmentation**
  tokens belong together because they lie on the same object

- **bottom up segmentation**
  tokens belong together because they are locally coherent

- **These two are not mutually exclusive**
  e.g. symmetries, etc.

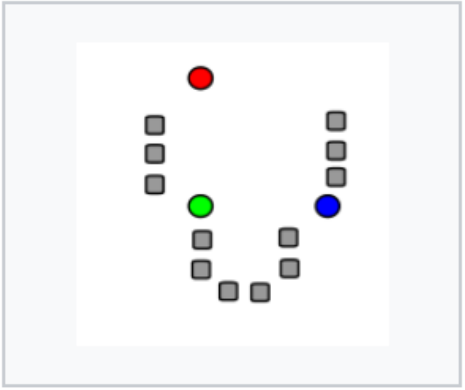
Supervised vs. Unsupervised Image Segmentation Methods



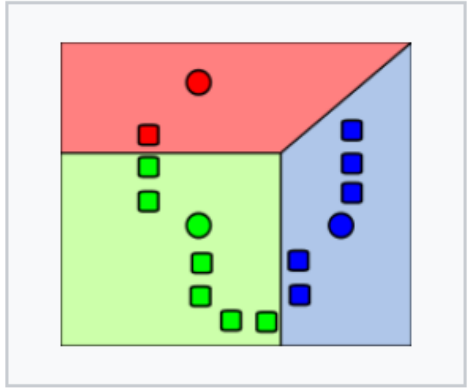


- **Grouping (or clustering)**

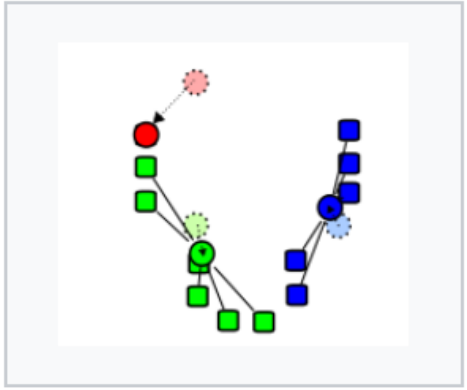
  - *k-Means clustering*: partition data into k distinct clusters based on distance to the centroid of a cluster.



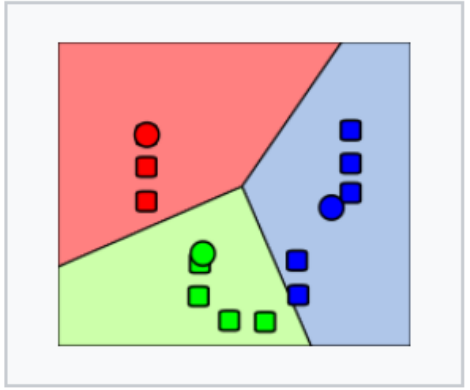
Step1: k initial "means" (in this case k=3) are randomly generated within the data domain (shown in color).



Step2: *k* clusters are created by associating every observation with the nearest mean.



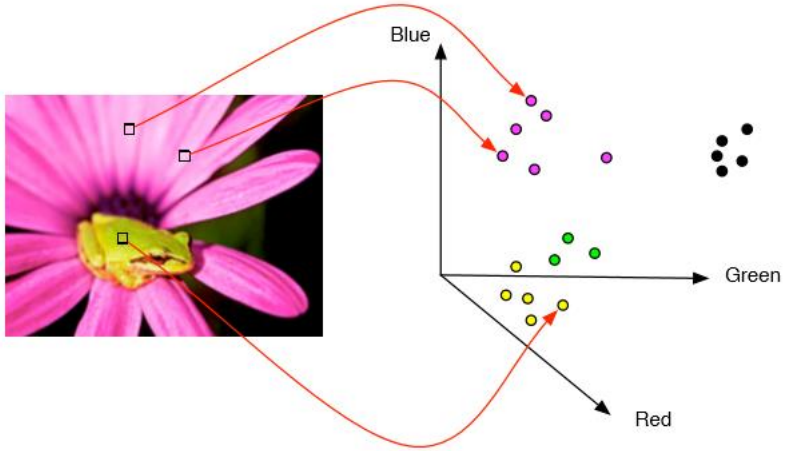
Step3: The centroid of each of the k clusters becomes the new mean.



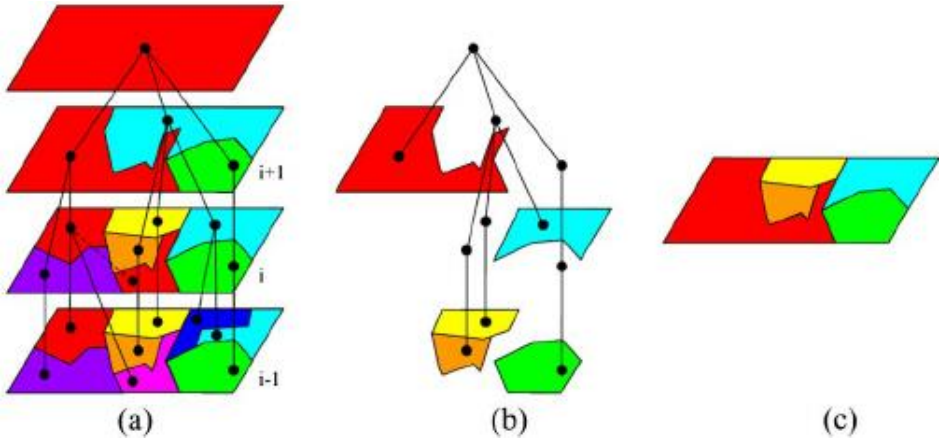
Step4: Steps 2 and 3 are repeated until convergence has been reached.

- **Image segmentation using k-means**

To each pixel of an image is associated its color described in RGB. The image to be segmented can then be represented as a set of points in a 3D data space, as illustrated in the following figure. In case of a grey-level image, the procedure is the same apart from the fact that the image is represented as a set of points in a 1D space.



- **Grouping (or clustering)**
  - *Hierarchical clustering [1, 2]*: builds a multilevel hierarchy of clusters by creating a cluster tree.

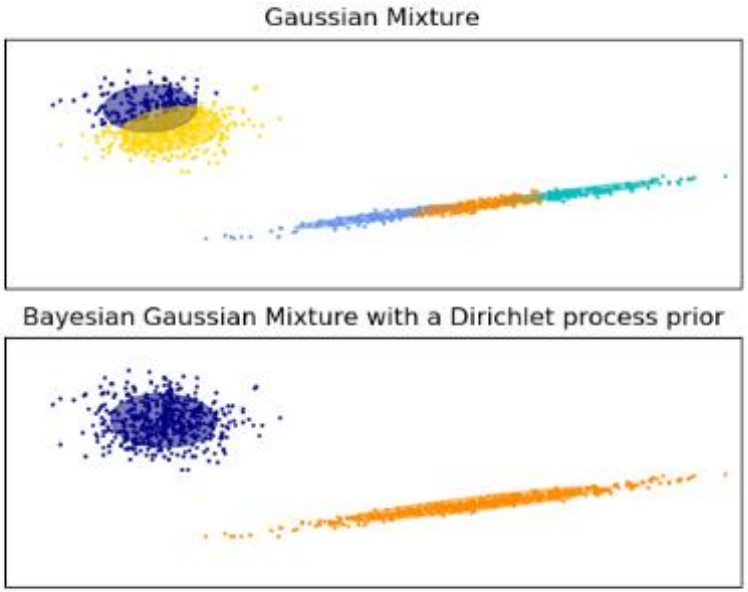


[1]: Johnson, S. C. (1967). Hierarchical clustering schemes. *Psychometrika*, *32*(3), 241-254.
[2]: Wu, Z., & Leahy, R. (1993). An optimal graph theoretic approach to data clustering: Theory and its application to image segmentation. *IEEE transactions on pattern analysis and machine intelligence*, *15*(11), 1101-1113.

- **Model Fitting**

  - **Gaussian mixture models**: models clusters as a mixture of multivariate normal density components.

  - It is a **probabilistic model** that assumes all the data points are generated from a mixture of a finite number of Gaussian distributions with **unknown parameters**.



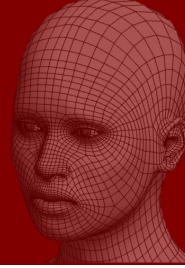


Image segmentation techniques

- Edge based methods
- Region based methods
- Texture based methods
- Color based methods

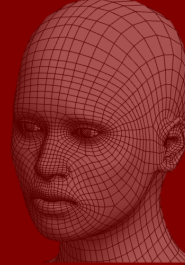
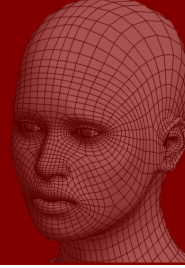


Image Segmentation: Edge-based

- Edge detection (to identify “edges”-edge pixels)
- Find a closed boundary so that an inside and an outside can be defined.
- Rely on edges found in an image by edge detecting operators.
  - Gradient, Laplacian, LoG, Canny filtering, ..



- Edge mark image locations of discontinuities in gray level.
- **Edge is where change occurs.**
- Change is measured by derivative in 1D.
  - Biggest change: first derivative has maximum magnitude or 2nd derivative is zero.
- First-order derivative (Gradient operator)
- Second-order derivative (Laplacian operator)

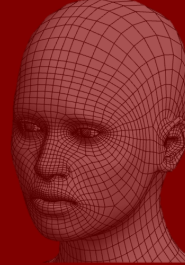
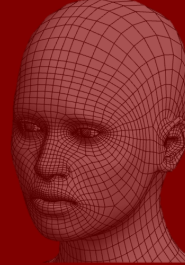


Image Segmentation: Region-based

- Find regions that are « homogeneous » by some criterion.
- There are two families of region-based segmentation:

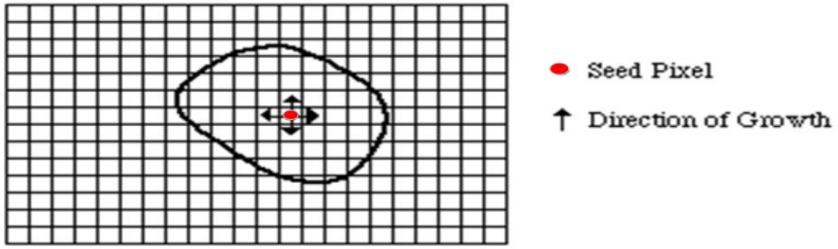
1) Region Growing

2) Region Splitting

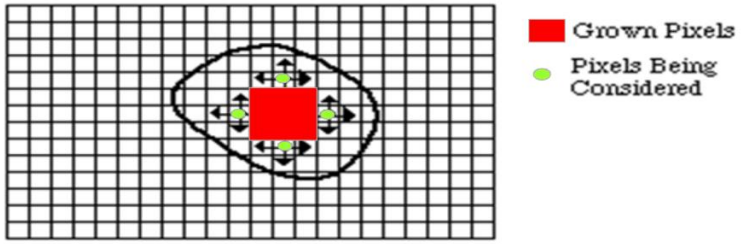


Region Growing

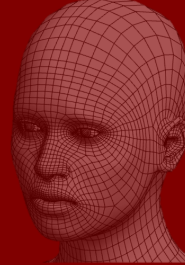
- **Bottom-up** approach
- We start with a set of "**seed**" points
- Growing by appending to each seed's neighbor pixels, if they have **similar properties**, such as specific ranges of gray level, and '**8-connected neighbor**'
- Need initialization, similarity criterion



(a) Start of Growing a Region

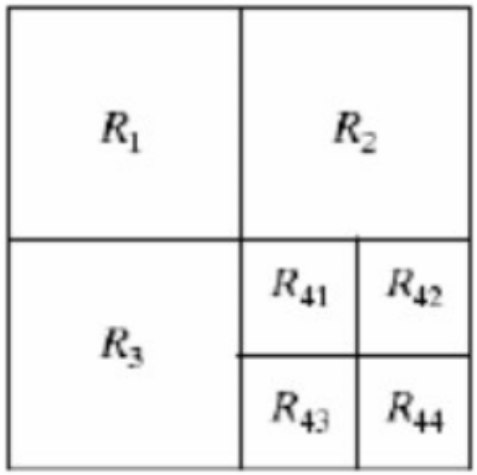


(b) Growing Process After a Few Iterations



Region Splitting

- The opposite approach to region merging.
- A **top-down** approach, it starts with the assumption that the entire image is homogenous.
- If this is not true, the image is split into **sub-images**.
- The splitting procedure is repeated recursively until the image is split into homogenous regions.
- Need homogeneity criterion, split rule.



Top-down vs. Bottom-up Image Segmentation Methods

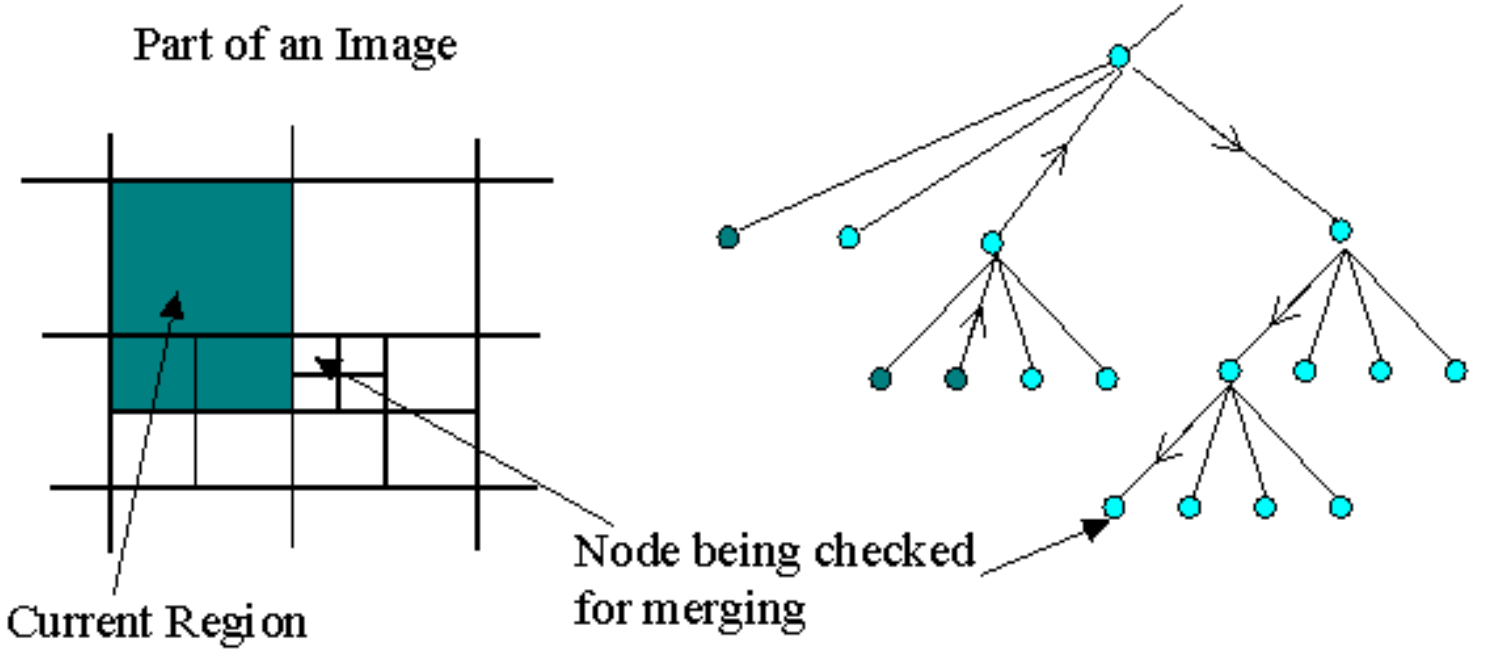


Diagram 2.2: Splitting and Merging with Quadtrees

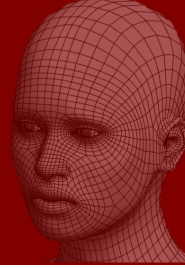


Image Segmentation: Region-based

- Watershed based segmentation
- Toboggan Segmentation
- Superpixels segmentation
- Graph Cut
- Quadtree Image Segmentation
- ..

Image Segmentation: Texture-based

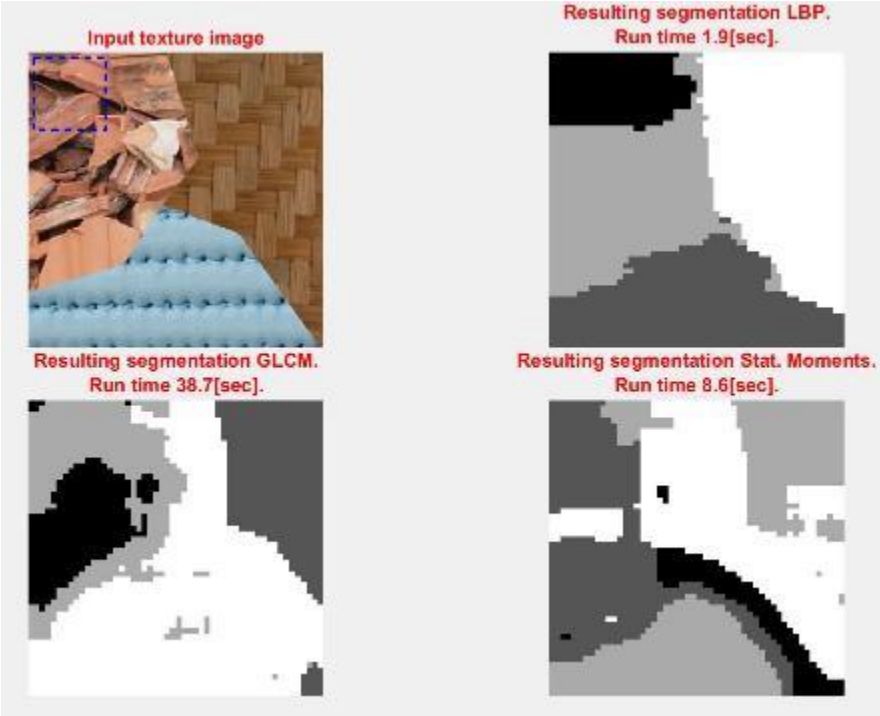
Texture: repetition or quasi repetition of some fundamental image elements or patterns.

Information of texture to distinguish between things where **edge of objects in the environment are not defined by clear boundaries.**

Malik, J., Belongie, S., Leung, T., & Shi, J. (2001). Contour and texture analysis for image segmentation. *International journal of computer vision*, *43*(1), 7-27.

Image Segmentation: Texture-based

The simple way to segment textured images is divide the image to sub-images, then compute texture features from each sub-image. Finally, classify each sub-image using its features vector.



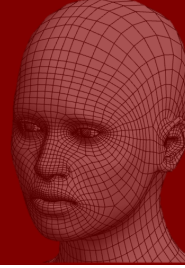


Image Segmentation: Color-based

- Identify or segment different regions by analyzing the colorspace
  - RGB: Red, Green and Blue
  - L*a*b* : ***L*** for lightness and ***a*** and ***b*** for the color opponents green–red and blue–yellow
  - HSV (Hue, Saturation, Value)
  - ..

Image Segmentation: Color-based

H&E image

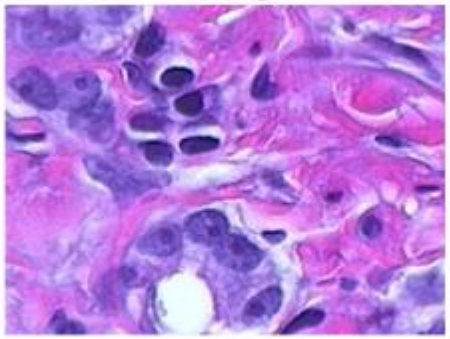
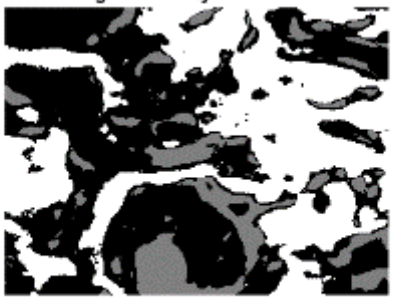


Image courtesy of Alan Partin, Johns Hopkins University

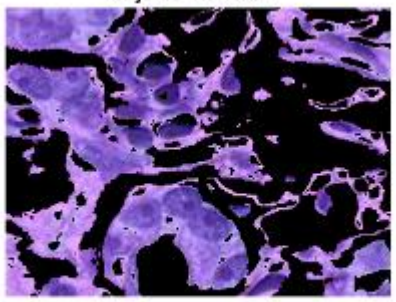
Convert Image from RGB Color Space to L*a*b* Color Space

image labeled by cluster index

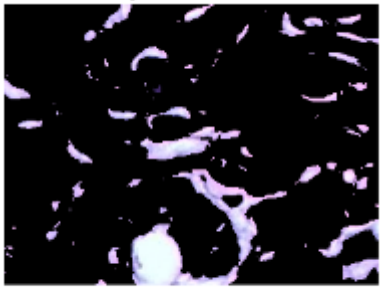


Classify the Colors in 'a*b*' Space Using K-Means Clustering

objects in cluster 1



objects in cluster 2



objects in cluster 3

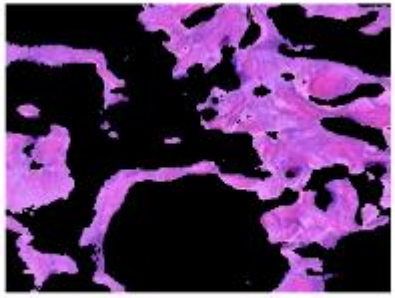


Image Segmentation: Color-based

Segment the Nuclei into a Separate Image:

- you can separate dark blue from light blue using the 'L*' layer in the L*a*b* color space.
- The cell nuclei are dark blue.
- Recall that the 'L*' layer contains the brightness values of each color.
- Find the cluster that contains the blue objects.
- Extract the brightness values of the pixels in this cluster and threshold them with a global threshold.

H&E image

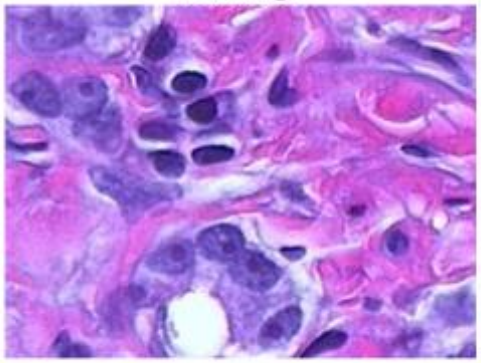
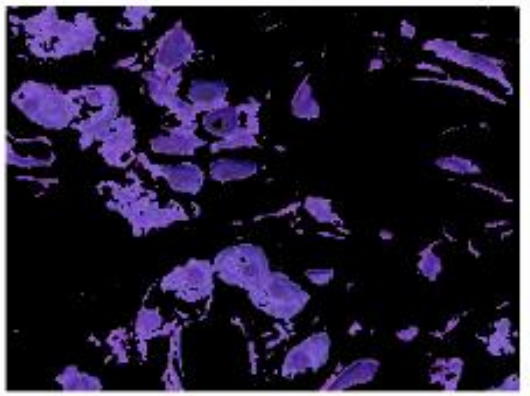
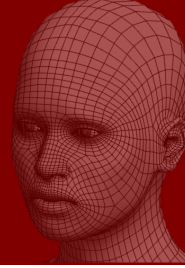


Image courtesy of Alan Partin, Johns Hopkins University

blue nuclei





Hybride segmentation

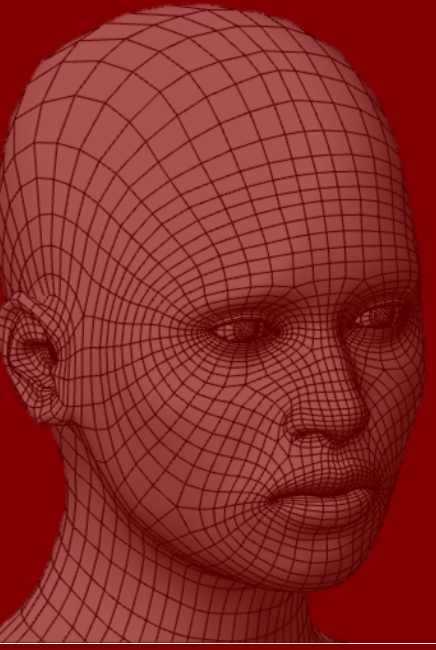
Hybride segmentation: combine different categories/families of image segmentation like comibing edge and region-based techniques, ..

[1] Haris, K., Efstratiadis, S. N., Maglaveras, N., & Katsaggelos, A. K. (1998). Hybrid image segmentation using watersheds and fast region merging. *IEEE Transactions on image processing*, *7*(12), 1684-1699.

[2] Othmani, A., Piboule, A., & Voon, L. F. L. Y. (2013, June). Hybrid segmentation of depth images using a watershed and region merging based method for tree species recognition. In *IVMSP Workshop, 2013 IEEE 11th* (pp. 1-4). IEEE.

[3] Yokoya, N., & Levine, M. D. (1989). Range image segmentation based on differential geometry: A hybrid approach. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *11*(6), 643-649.

[4] Borenstein, E., & Ullman, S. (2008). Combined top-down/bottom-up segmentation. *IEEE Transactions on pattern analysis and machine intelligence*, *30*(12), 2109-2125.



Thank you for your attention

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