Visual computing

Image Segmentation

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thanks to W. Buntine, K. Graunman, V. Hlavac, J.-C. Baillie, A. Boucher for inspiration.

Outline

- Introduction
- Contour-based approaches
- Region-based approaches
- Conclusion

Textbooks

- Digital Image Processing – R.C. Gonzales, R. E. Woods – ed Prentice Hall
- Computer Vision, a Modern Approach – D. Forsyth, J. Ponce – ed Prentice Hall

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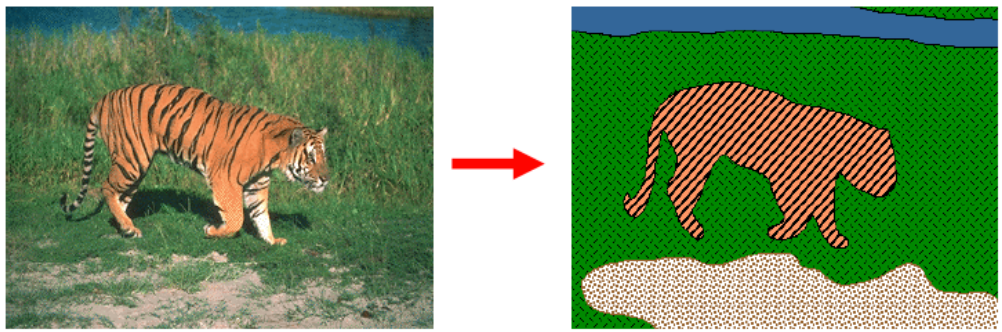
Image segmentation

Goal

- Identify the objects of interest in an image
- Differentiate those objects from the background
- Associate to each pixel a code that indicates the object it belongs to

How ?

- An object is a region in an image that is *semantically* coherent
- in pratice: connex, of coherent color, defined by sharp boundaries, with an *a priori* shape, etc.



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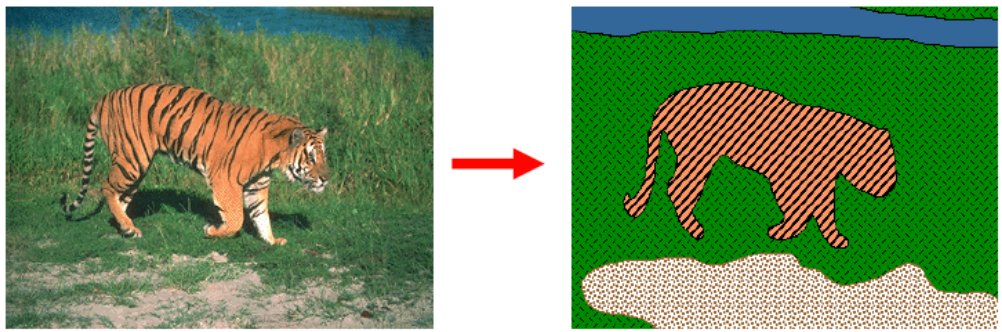


Image segmentation

Why? In image analysis, we are usually interested in the *objects* of the image

- to understand the image content
- to have a specific treatment on the object (e.g. tracking, object recognition)

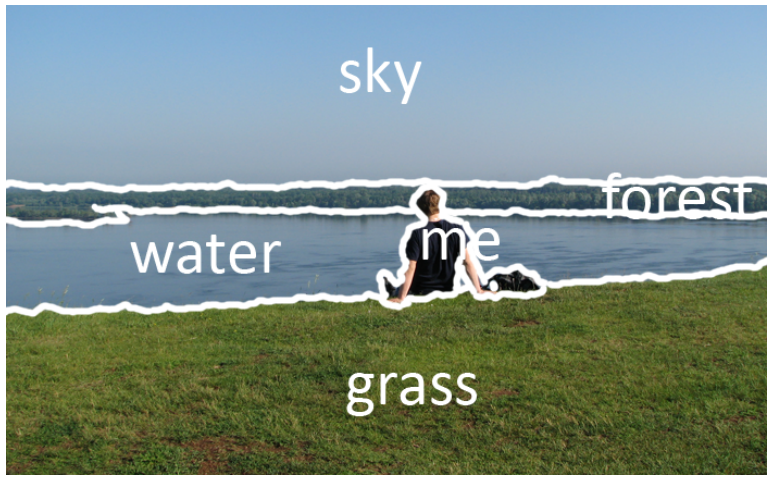
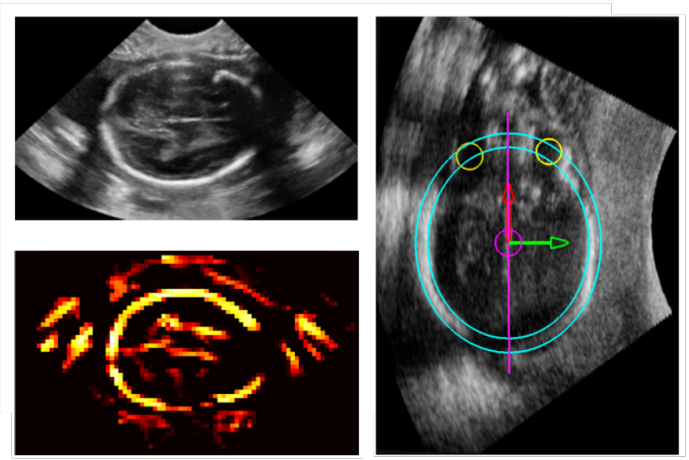
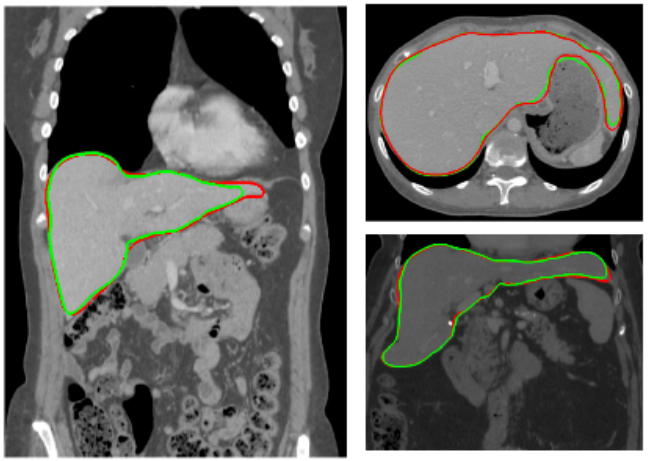


Image segmentation for medical imaging

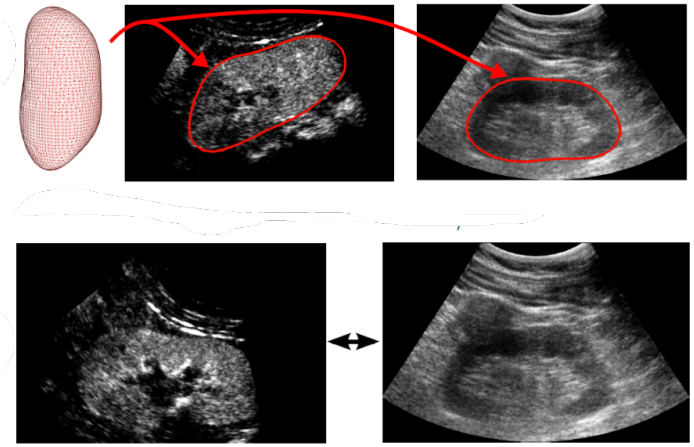
baby segmentation



liver segmentation



kidney segmentation



brain tumor segmentation

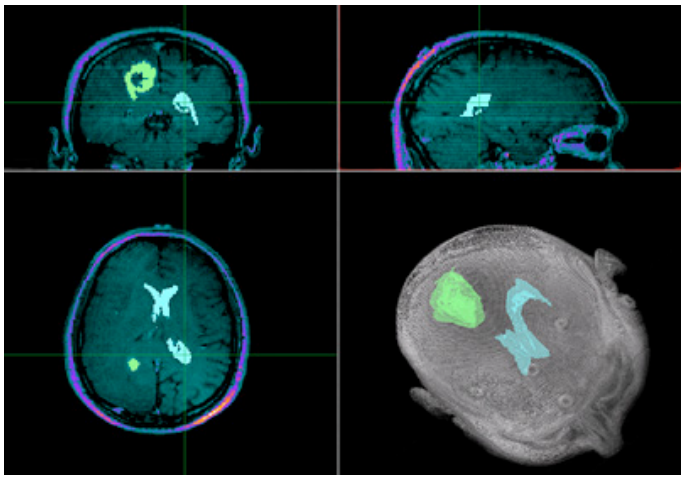


Image segmentation for surveillance

ORIGINAL FRAME

FOREGROUND MASK

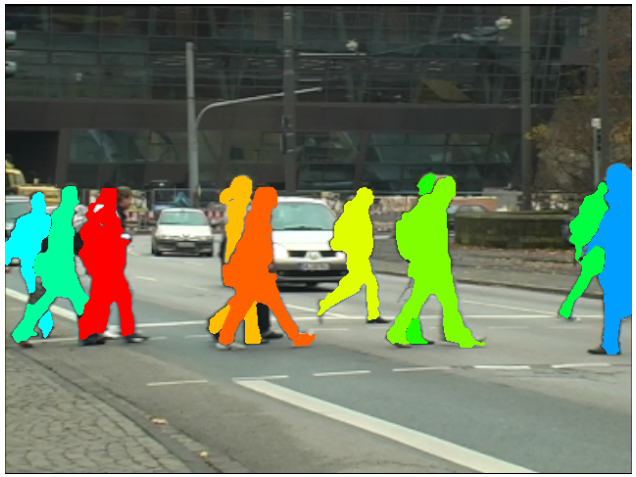


Image segmentation for entertainment

Image segmentation ... at the origin of special effects !

Chroma keying : technique used for combining two frames or images by replacing a color or a color range in one frame with that from the another frame (wikipedia).

Greenscreen footage is placed on a layer above the background

All green is removed from the greenscreen footage

The background is visible in all parts of the image that were originally green

- video : history of greenscreen composing
- video : Alice in Wonderland

Image segmentation ... at the origin of special effects !

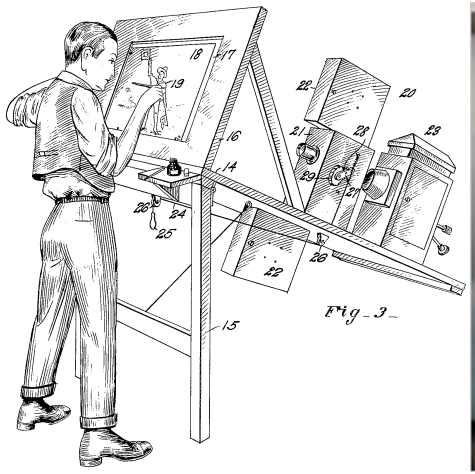
Chroma keying

Image segmentation ... at the origin of special effects !

Rotoscoping is an animation technique used by animators to trace over motion picture footage, frame by frame, when realistic action is required.

In the visual effects industry, the term Rotoscoping refers to the technique of manually creating a matte for an element on a live-action plate so it may be composited over another background. (wikipedia)

- video : explanation
- video : example



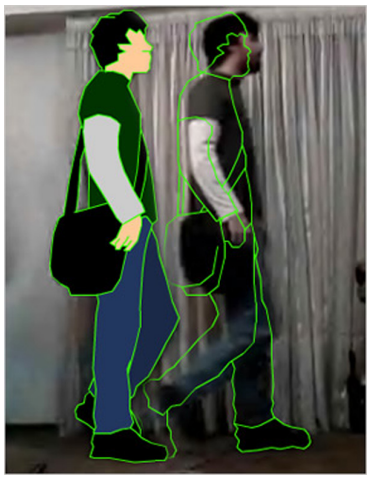


Image segmentation

but image segmentation is a difficult problem ....

Image segmentation - methods

Regions / Contours Duality

- A region is defined by its contour
- A contour is a boundary between two regions

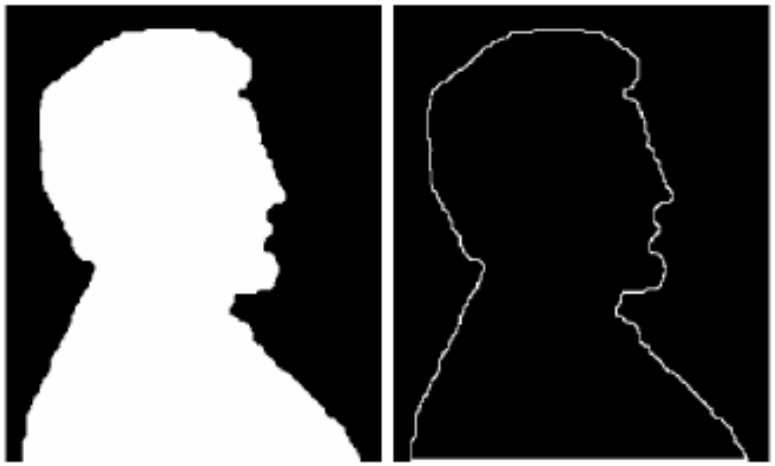


Image segmentation - methods

Regions / Contours Duality

- Region-based approaches

  Search for regions in the image that are coherent with respect to a given criterion (colour, texture, motion, grey level, etc.)
  idea: collect together pixels that "belong together"

- Contour based approaches

  Search for discontinuities in the image



Image segmentation

Segmentation methods may be classified in

- Contour-based approaches
- Region-based approaches

- Global approaches
- Local approaches

goal of the session:

an overview of possible approaches ... not exhaustive

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contour-based approaches

- Edge detector is applied to find boundary candidates.
- Thresholding of the edge magnitude gives the boundary candidates.
- Some iterative technique is used to find boundaries.

technical details given in next lecture session

contour-based approaches

- it is difficult to obtain closed boundaries, i.e., regions
- the whole image need not be segmented.

- active contours
  [A. Blake, M. Isard, Active Contours, ed. springer 1998]
- level sets
  [Malladi, R., Sethian, J.A., and Vemuri, B., Shape Modeling with Front Propagation: A Level Set Approach , PAMI 1995.]

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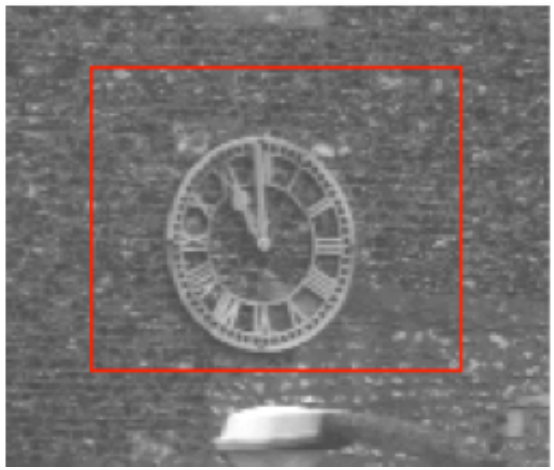
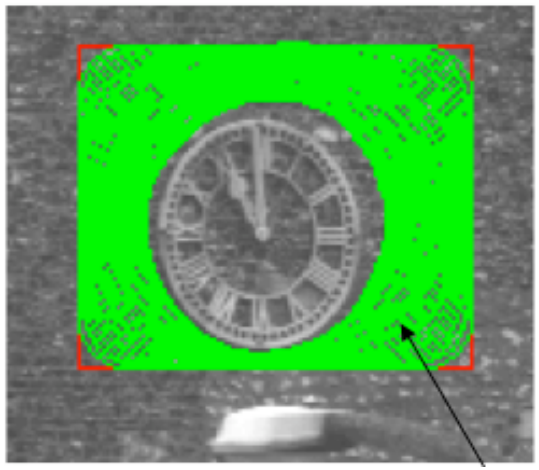
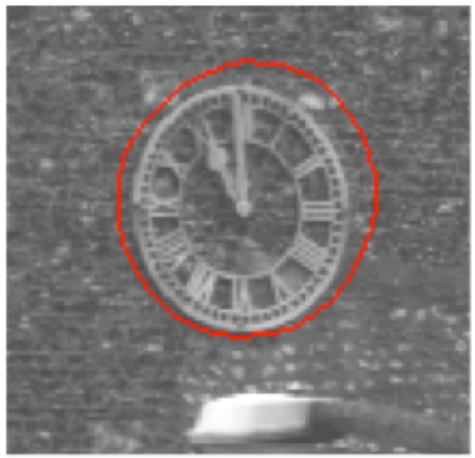
contour-based approaches

active contours – snakes

- idea: use a *deformable* curves that are *attracted* by shapes in the image
- exemple: the snake shrinks to fit the clock

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region-based approaches

- The idea of region-based approaches is to partition the image into regions that correspond to objects or parts of an object
- The result will be a image where each pixel is assigned to a region's label

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  - histogram thresholding
  - region growing
  - region splitting
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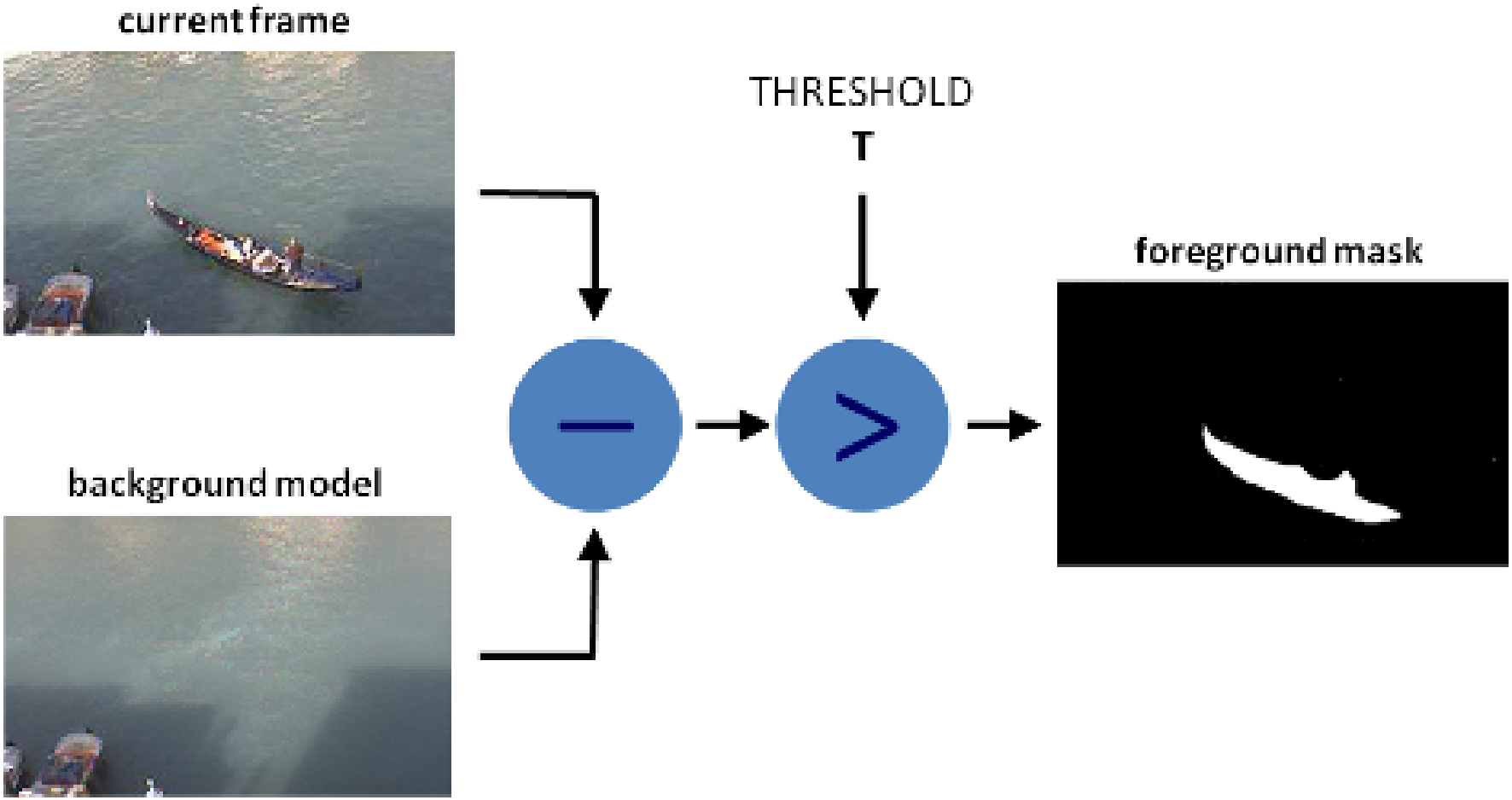
region-based approaches

Segmentation ... when the background is known



region-based approaches

Segmentation ... when the background is known

basic method: one threshold, 2 labels

- If *value(pixel) - value(background pixel)* $\geq$ *threshold*, then *value(pixel)* $= 1$
- If *value(pixel) - value(background pixel)* $<$ *threshold*, then *value(pixel)* $= 0$

\+ very simple, easy to implement and fast

\+ possibility to average over a window to reduce noise

\- images must be of same size, co-registered, same lighting, etc.

\- may clean up small objects

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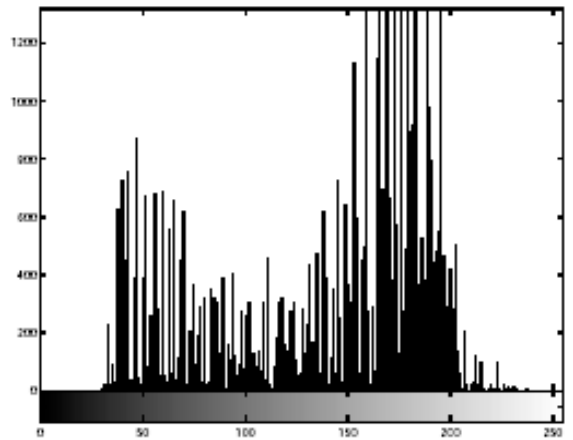
region-based approaches - histogram thresholding

Segmentation using thresholding

- very simple and popular algorithm
- based on image histograms
- idea: find threshold(s) that will separate the histogram into parts, thus the image into regions



region-based approaches - histogram thresholding

Binarisation

- basic method: one threshold, 2 labels
  - If *value(pixel)* $\geq$ *threshold*, then *value(pixel)* = *1*
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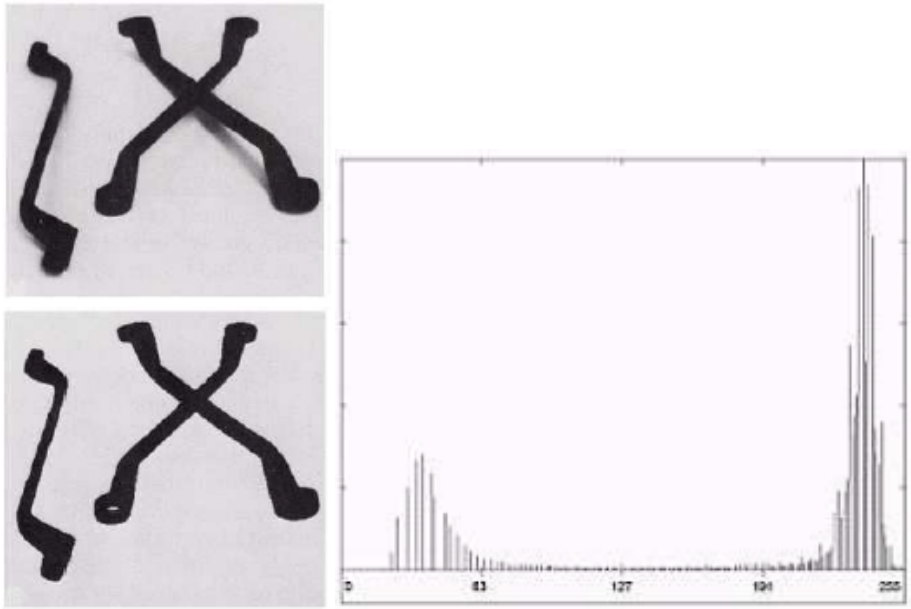
- result: a binary image



... but how can we choose the threshold ?

region-based approaches - histogram thresholding

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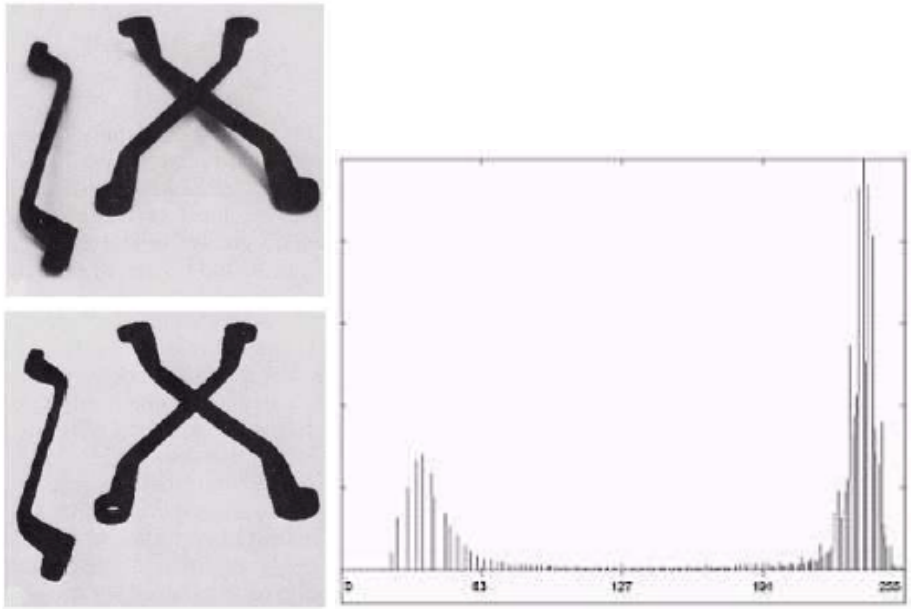

... but how can we choose the threshold ?

region-based approaches: histogram thresholding

Binarisation - Choice of threshold

- mean value
- median value

- adaptive threshold: find a threshold for the image in an automatic manner
  1. choose an initial value T
  2. we thus obtain 2 groups of pixels
  3. calculate the mean value of the grey values for these two groups μ_1 et μ_2
  4. calculate a new T such as $T = 1/2(\mu_1 + \mu_2)$
  5. repeat until T is constant

region-based approaches: histogram thresholding

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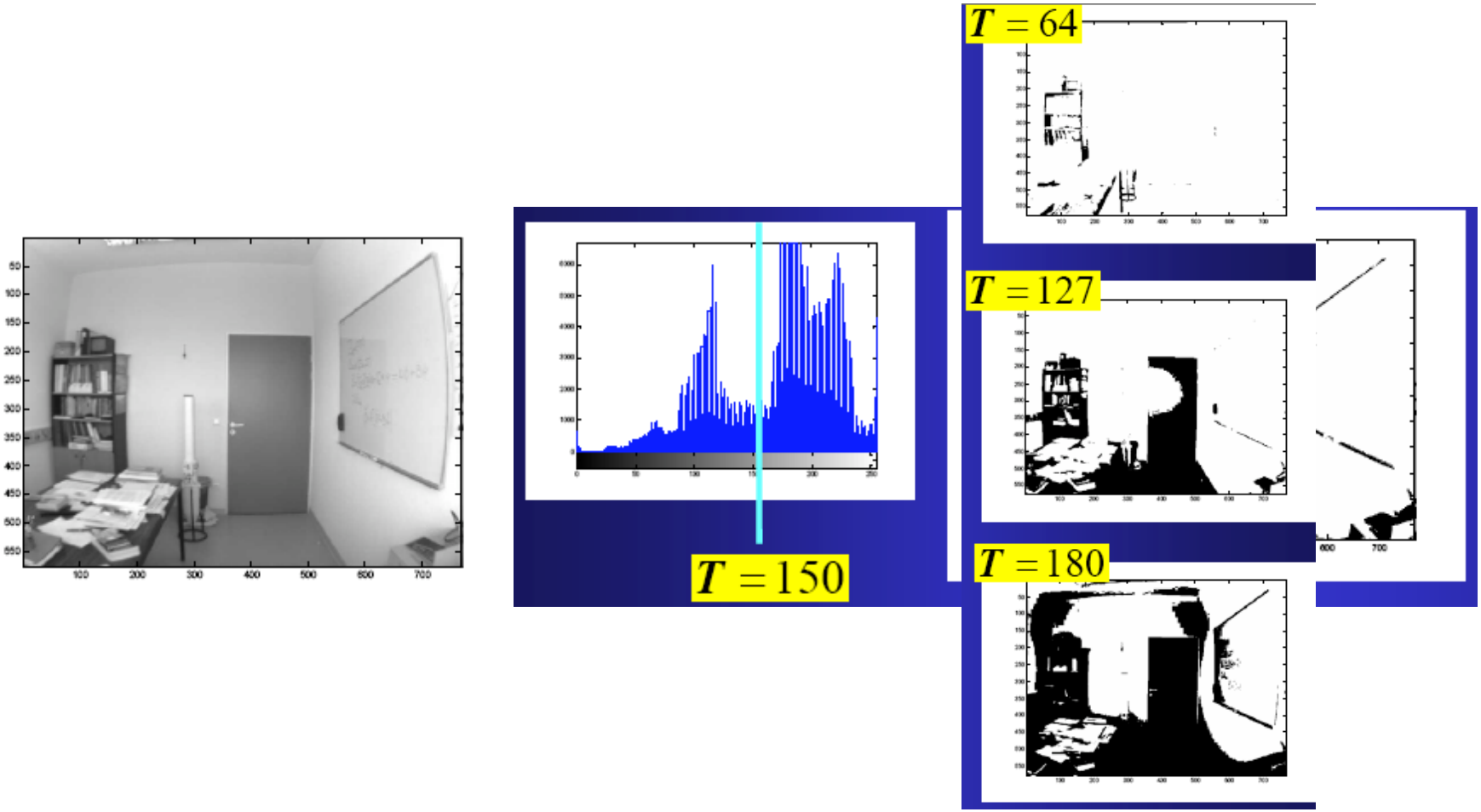
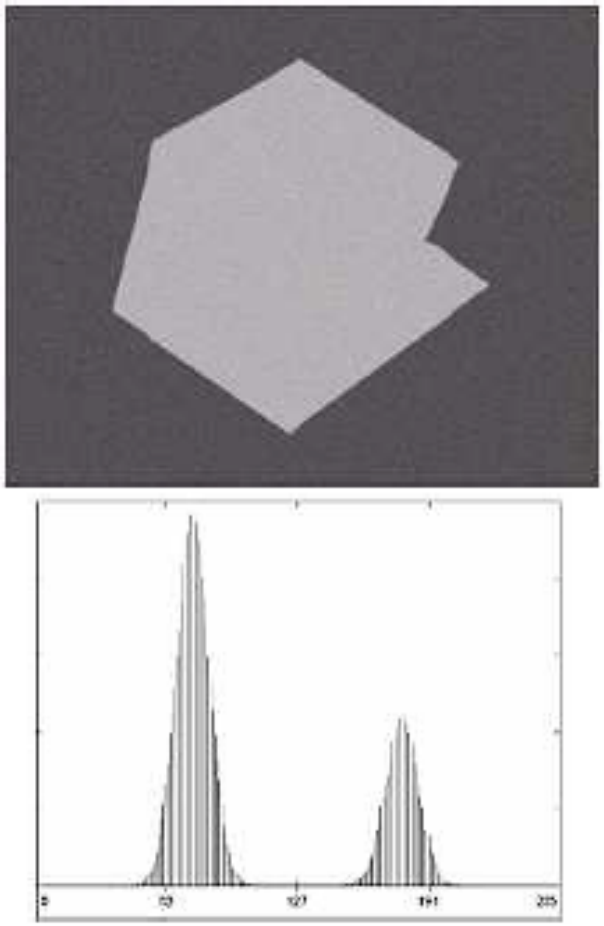
region-based approaches: histogram thresholding

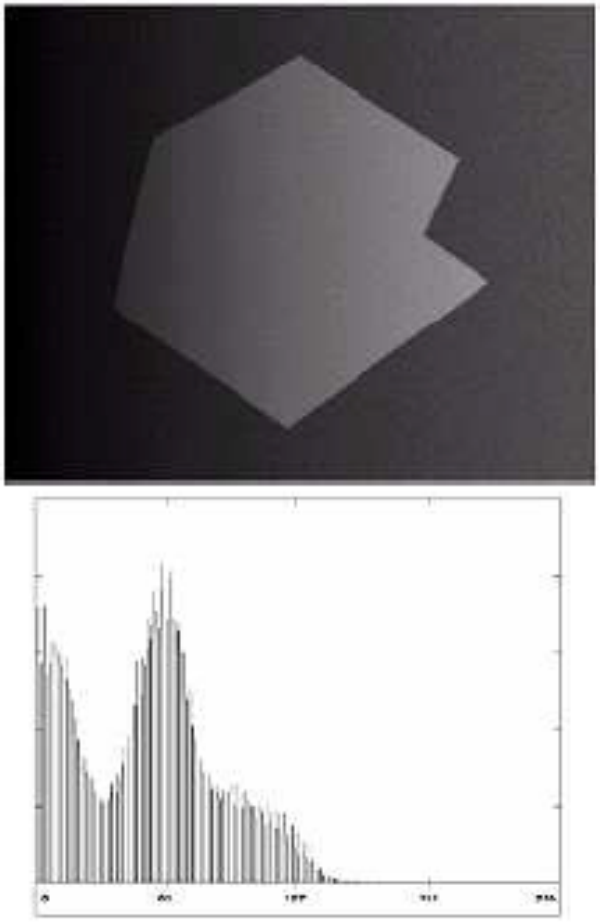
Binarisation - global adative threshold



region-based approaches: histogram thresholding

Binarisation - issues

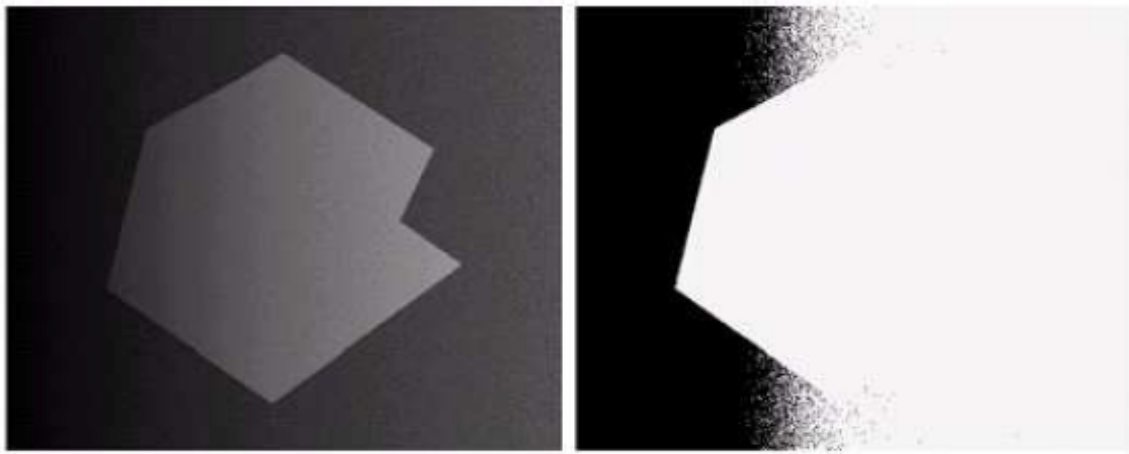




region-based approaches: histogram thresholding

Binarisation - issues

- problem: the global thresholding can not treat this case
- solution: adaptive local threshold on sub-images



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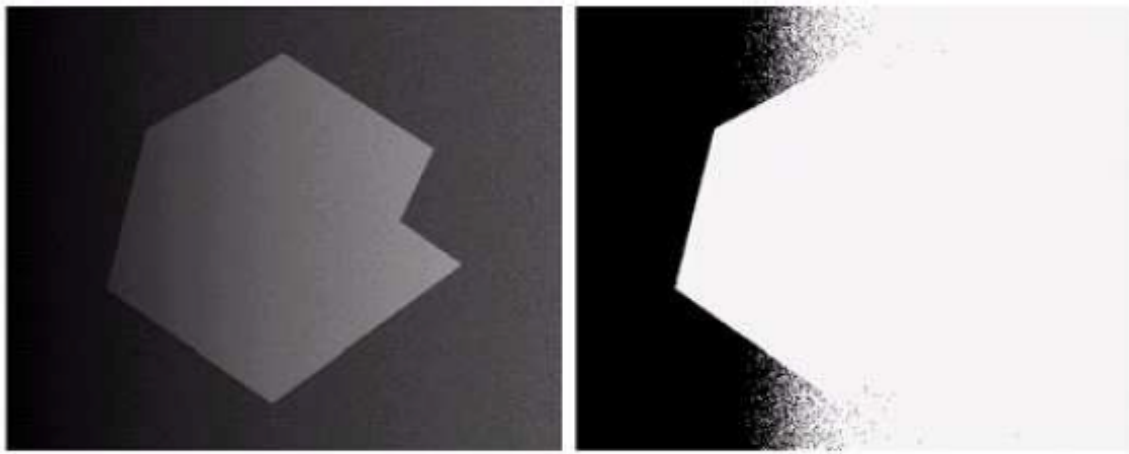
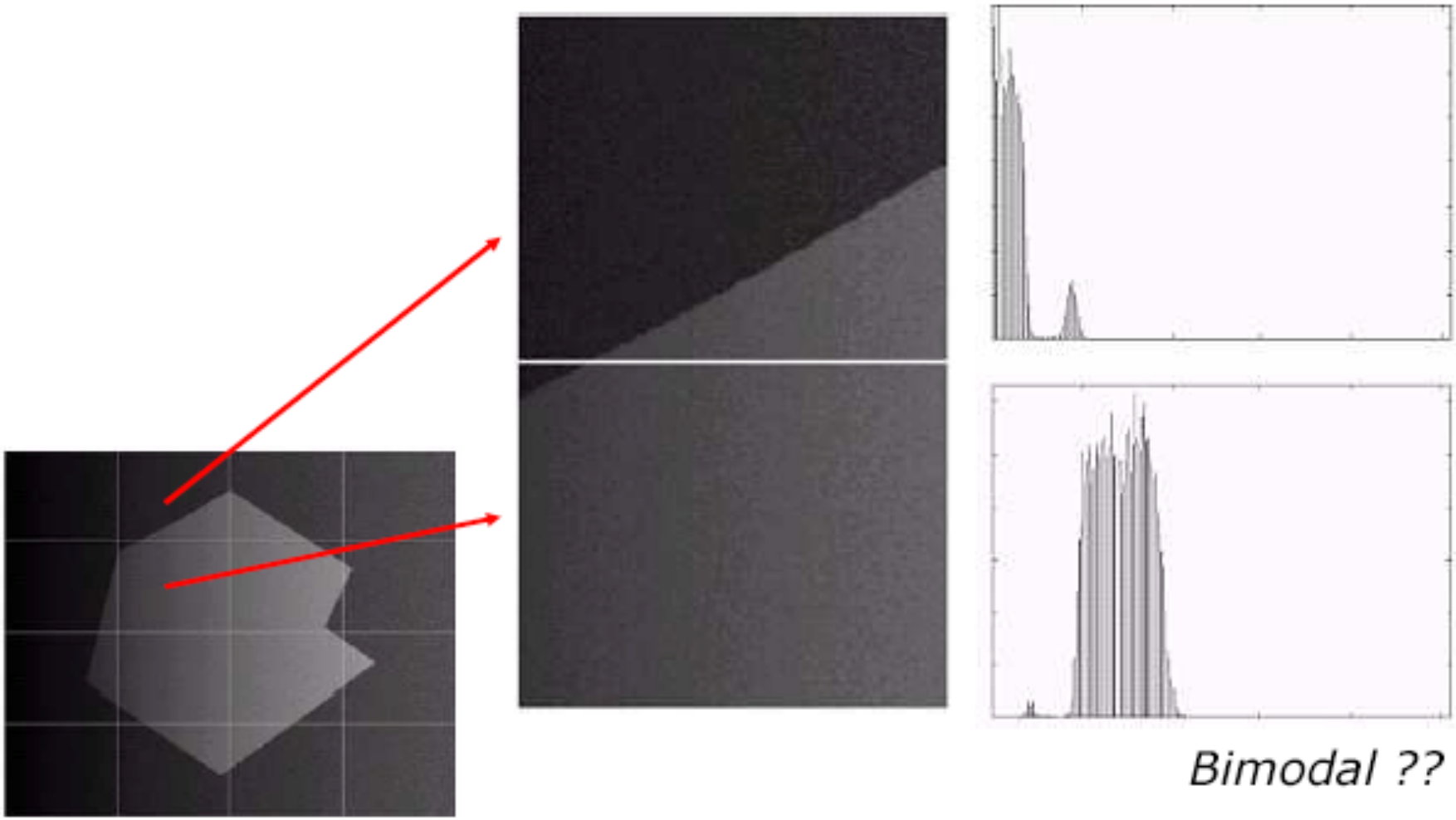


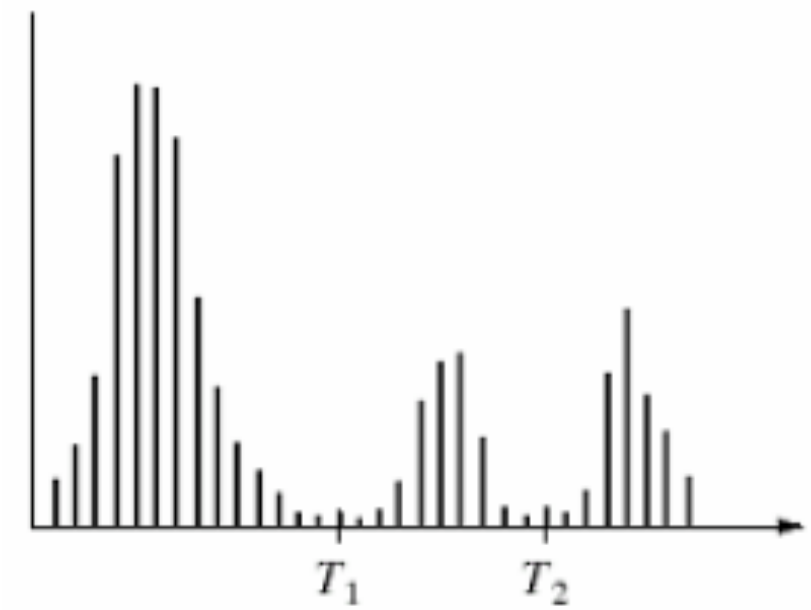
region-based approaches: histogram thresholding

Binarisation - adaptive local threshold



region-based approaches: histogram thresholding

Multiple thresholding



region-based approaches: histogram thresholding

+ simple and real-time
+ works well on complex histograms (with several peaks)

- number of regions needed
- no spatial coherence taken into account

- region growing
- region splitting

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region-based approaches - Region growing

Region growing

- from a seed, we add to the region the points on the frontier that satisfy some criterion of homogeneity

region-based approaches - Region growing

algorithm for a single region

- initialise the seed point in the region to be segmented, either by a human or automatically by avoiding area of high contrast
- Let R be the region to extract

  initially, the region R only contains its seed point p
- Let F be a list that contains the boundary points of R

  initially, the list F contains the 8-neighborhood of the seed point p
- while F is not emtpy
  - for each pixel $p*$ in F
    - if $p*$ is similar to p
      - $p*$ is added to R
      - neighboor pixels of $p*$ (not in R) are added to F
    - else
      - set $p*$ as non R

region-based approaches - Region growing

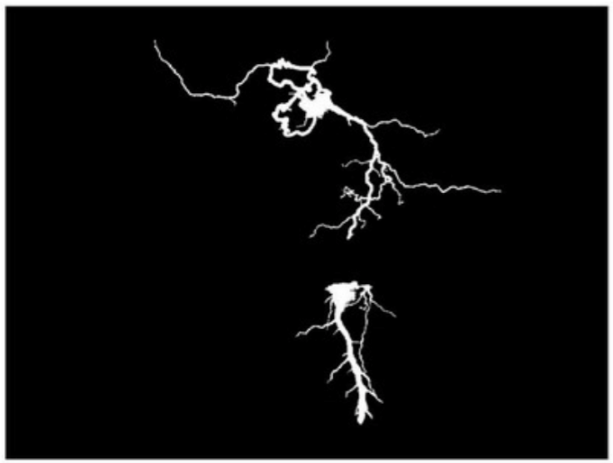
The seed points are chosen as the points having the highest gray-scale value which is 255

original image

threshold = 255 returns multiple seeds

threshold: 225~255

threshold: 190~225



threshold: 155~255

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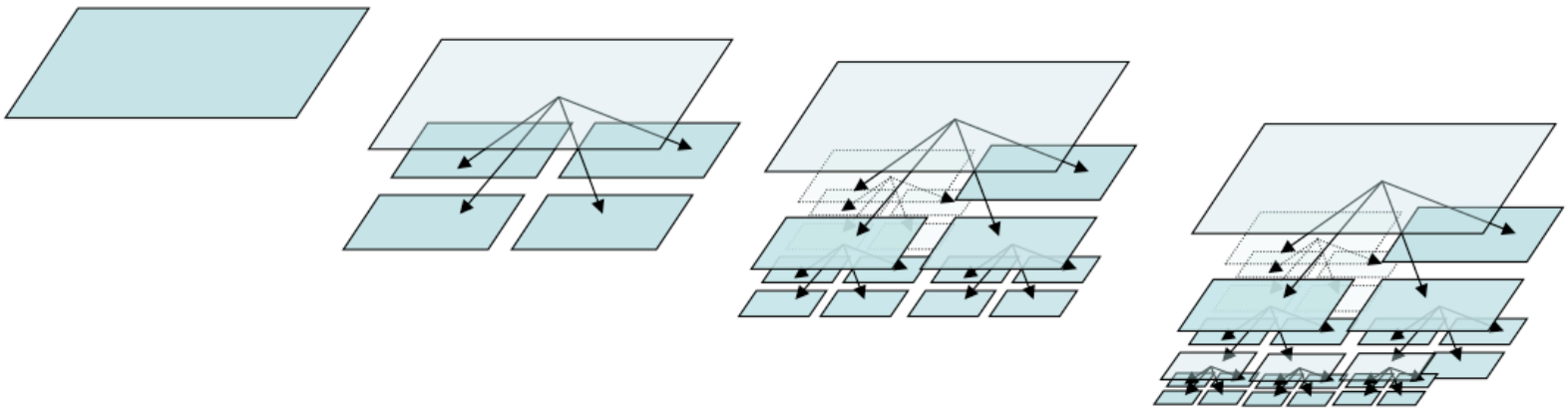
region-based approach - Region splitting

Region splitting

- the image is described as a tree, whose root is the entire image
- recursively, each leaf is subdived in 4 if it is not homogeneous enough
- homogeneity = criterion on the variance



region-based approach - Region splitting

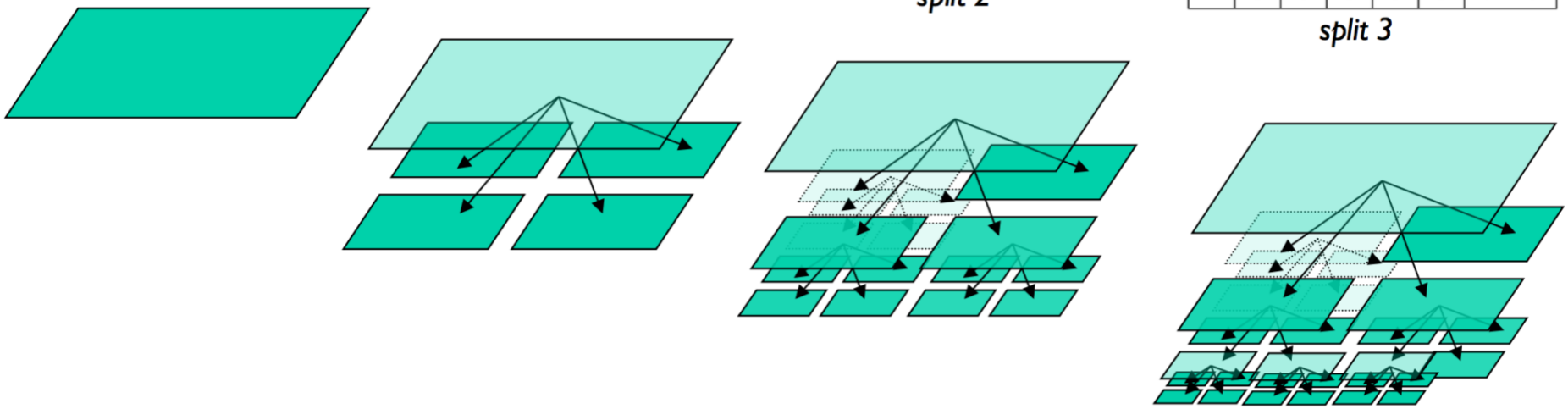
0	1	0	0	7	7	7	7
1	0	2	2	7	7	7	7
0	2	2	2	7	7	7	7
4	4	2	2	7	7	7	7
0	0	1	1	3	3	7	7
1	1	2	2	3	7	7	7
2	4	3	0	5	7	7	7
2	3	3	5	5	0	7	7

original image

split 1

split 2

split 3



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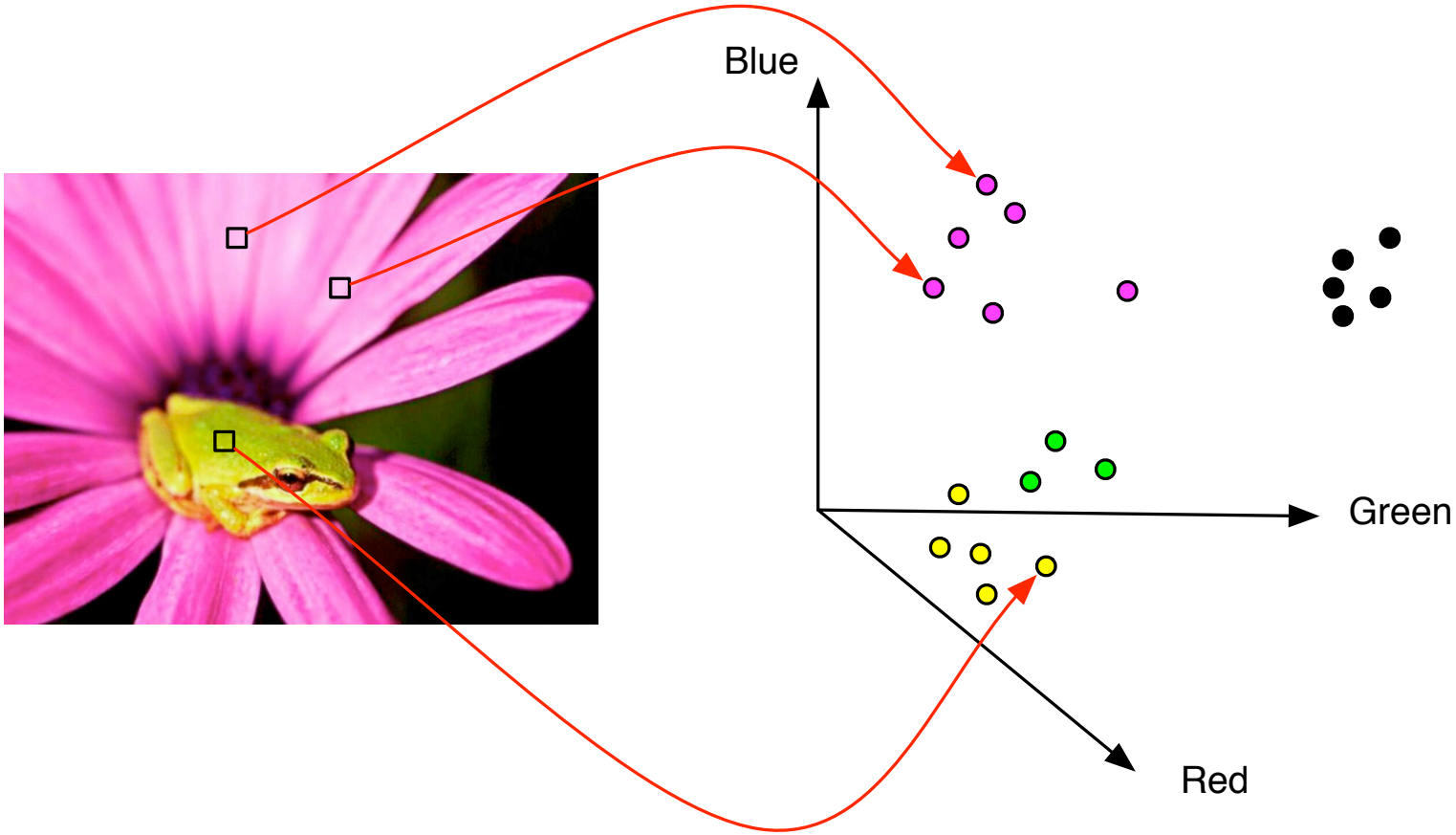
Region-based approaches : segmentation by clustering

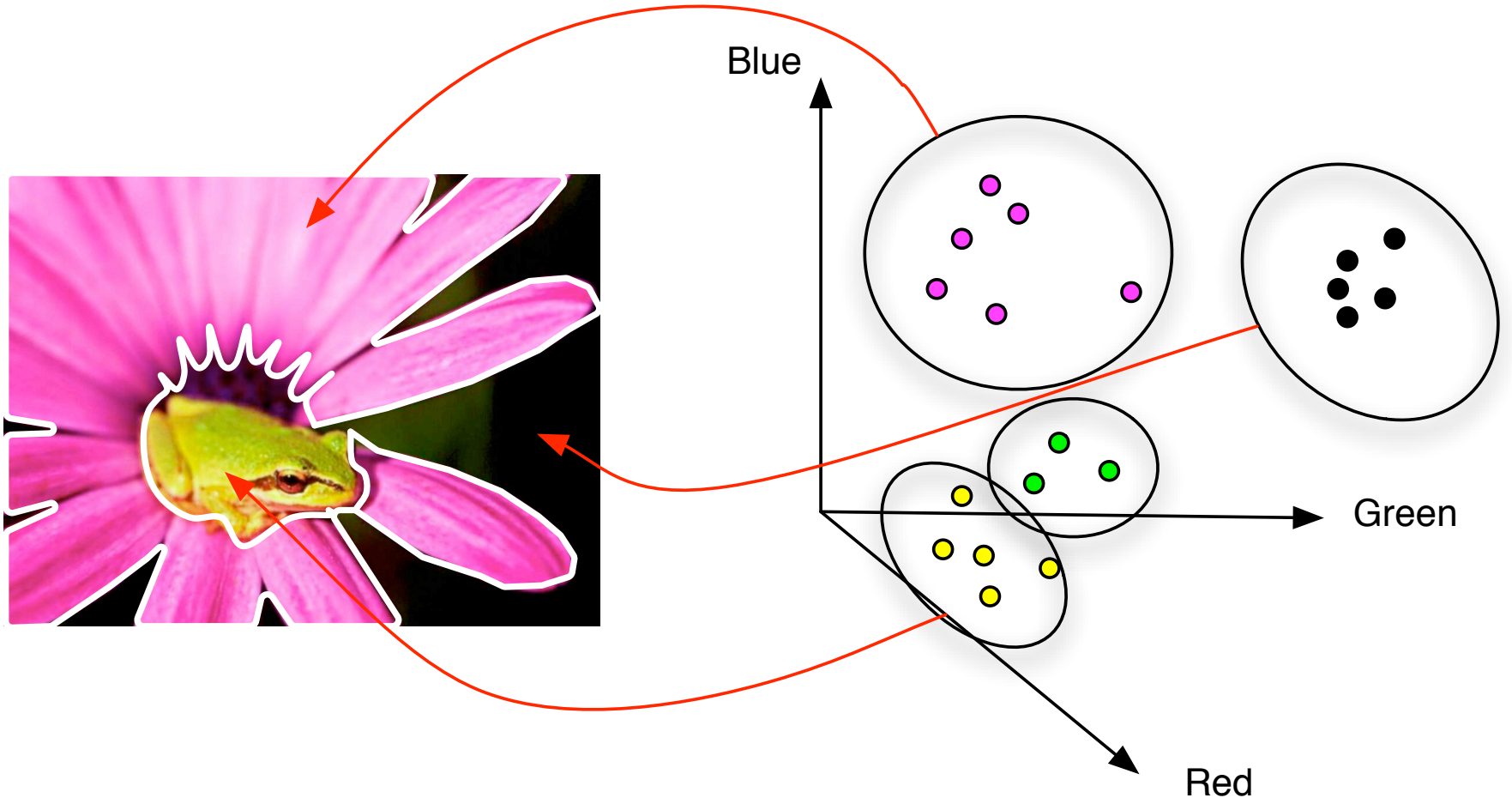
- A region will be represented in terms of **clusters** of pixels that belong together
- the specific criterion to be used depends on the application
- pixels may belong together because they have the same color, same texture, they are nearby, and so on.

Segmentation by clustering

Segmentation by clustering

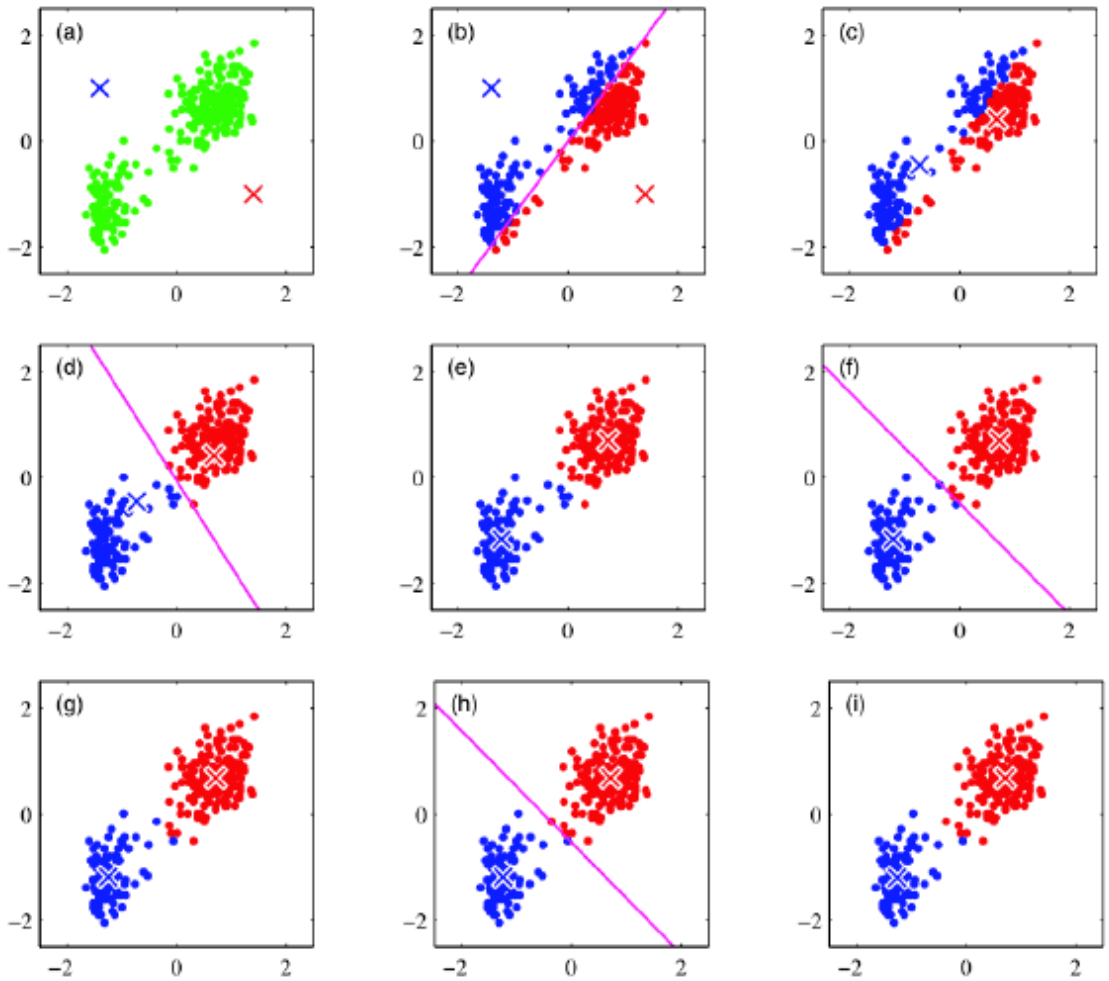


Segmentation by clustering



Segmentation by clustering - Kmeans

Kmeans: general clustering algorithm



Segmentation by clustering - Kmeans

Notations

- N data points $\mathbf{x}_1, \ldots \mathbf{x}_N$
- K clusters, presumably $K << N$
- each cluster has a corresponding center μ_k
- each data point $\mathbf{x}_n$ has a corresponding label indicating which cluster it is in: $k_n \in \{1, 2, \ldots K\}$.

Segmentation by clustering - Kmeans

Idea

- given K, we want to assign each data point to one cluster, so that the error among the clusters is minimized.
- the error is defined as the distance of a cluster points to its center

$$\sum_{k \in \text{clusters}} \sum_{n \in \text{kth cluster}} (\mathbf{x}_n - \mu_k)^T (\mathbf{x}_n - \mu_k)$$

Kmeans: Iterative algorithm

1. fix the cluster centers; allocate points to closest cluster
2. fix allocation, compute cluster centers

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Segmentation by clustering - Kmeans

Kmeans: Iterative algorithm

1. **initialisation:**
   - choose K
   - randomly guess K cluster center locations
2. **allocation:** each data point finds out which center it is closest to, and is assigned to the corresponding cluster
3. **center calculation:** the position of each center is updated by the mean of the data points assigned to that cluster. In other words, the center is moved towards the center of its assigned points.
4. repeat 2-3 until terminated (centers do not move any more)

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Segmentation by clustering - Kmeans results

influence of the choice of K

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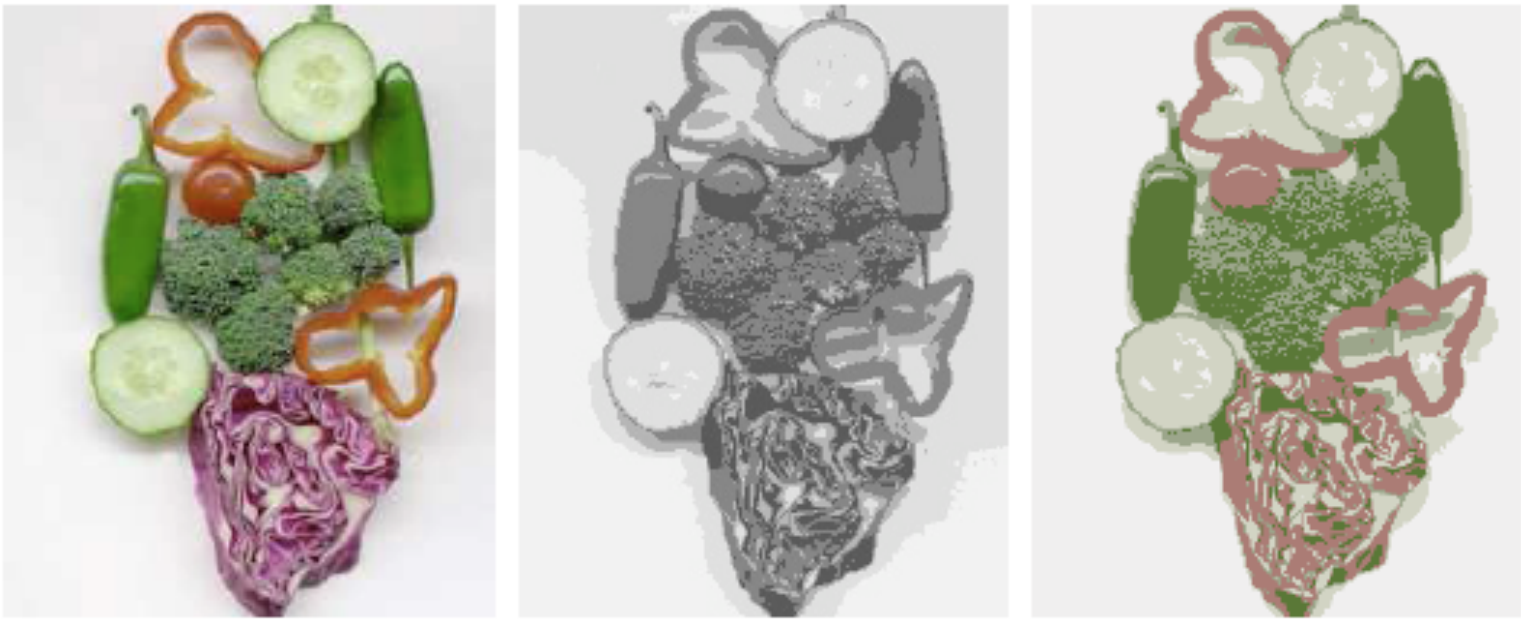
Kmeans clustering using intensity alone and color alone



Segmentation by clustering - Kmeans

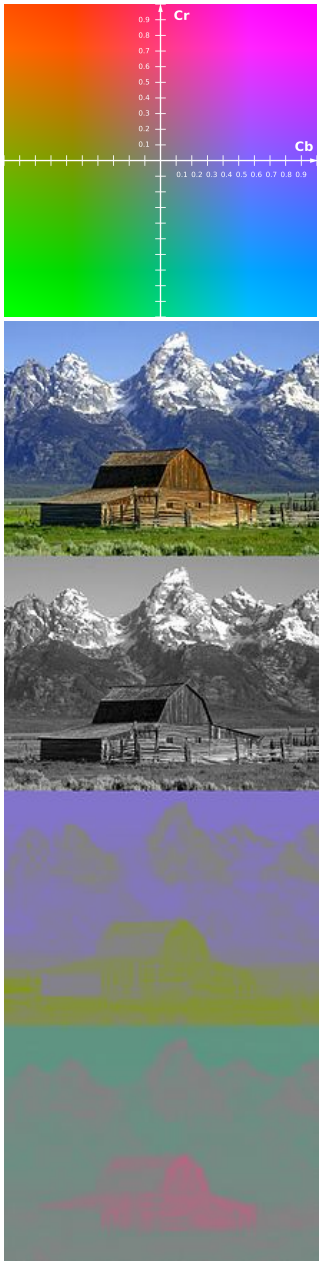
+ simple
+ converges to local minimum of within-cluster squared error
+ fast to compute

- choise of K ?
- sensitive to initial centers
- detects spherical clusters
- careful combining feature types

Outline

- introduction
- Contour-based approaches
- Region-based approaches
  - segmentation when the background is known
  - histogram thresholding
  - region growing
  - region splitting
  - segmentation by clustering : k-means
  - back to chroma keying
- Conclusion

region-based approaches



when the background is green :
back to chroma keying

- Convert the image into YCbCr and look at the CbCr plane (luminescence is ignored).
- then each pixel's color defines a point on the plane as well as the key color.
- for each pixel, calculate the distance between its color and the key color
- if the distance is below a threshold, then the pixel belongs to the background

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Conclusions

- Of course, this overview of existing methods was not exhaustive
- Active field of research
- New methods combine segmentation with ... classification, stereo, 3d reconstruction, etc.

Conclusion and advices

- open issue: how to evaluation the segmentation results ? ... subjectif opinion
- One of the main difficulty: to define the goal of our segmentation process.
- What are we looking for in an image ? global elements or details ?
- Necessary to know how will be used the segmentation results to define the degree of precision

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