Image Analysis

Segmentation

K. Buza, Lars Schmidt-Thieme

Information Systems and Machine Learning Lab (ISMLL)
Institute of Economics and Information Systems
& Institute of Computer Science
University of Hildesheim
http://www.ismll.uni-hildesheim.de

Segmentation

- Which are the background pixels? Which are object pixels?
- Which pixels belong to different objects?

Segmentation

- Find finite set of disjont regions $R_1, R_2 \ldots$ covering the image R:

$$R = \bigcup_{i=1}^{n} R_i \qquad \forall i, j : i \neq j \Rightarrow R_i \bigcap R_j = \phi$$

Segmentation

Thresholding

Edge-based Segmentation

Region-based Segmentation

Motion for Segmentation

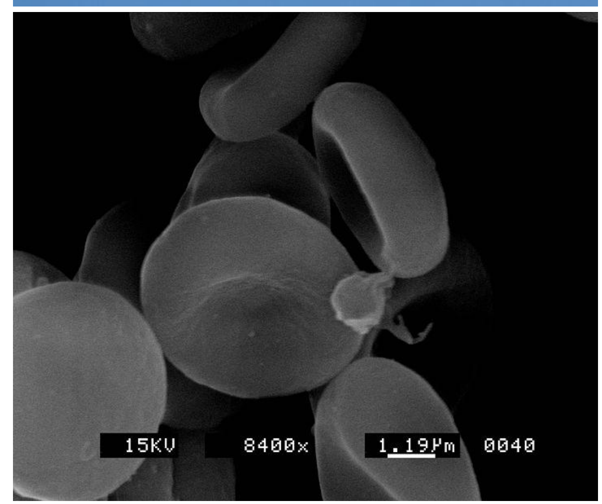
Graph Cut

Thresholding

- Input: gray-scale intensity image $f(x,y)$ and threshold T or domain D
  Output: binary image $g(x,y)$

$$g(x,y) = \begin{cases} 1, & f(x,y) \geq T \\ 0, & f(x,y) < T \end{cases}$$

$$g(x,y) = \begin{cases} 1, & f(x,y) \in D \\ 0, & else \end{cases}$$



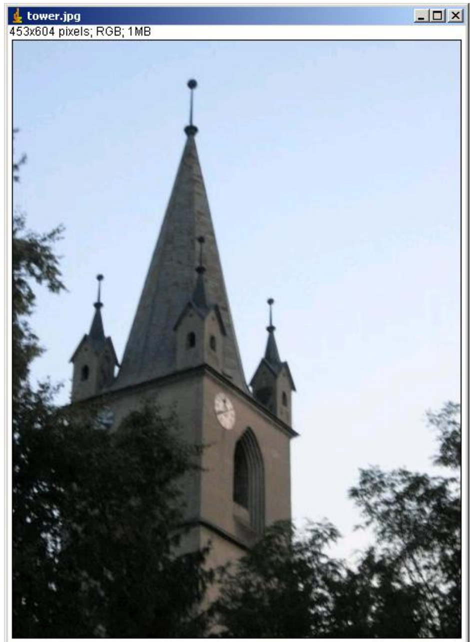
Human blood cells (Wikipedia)

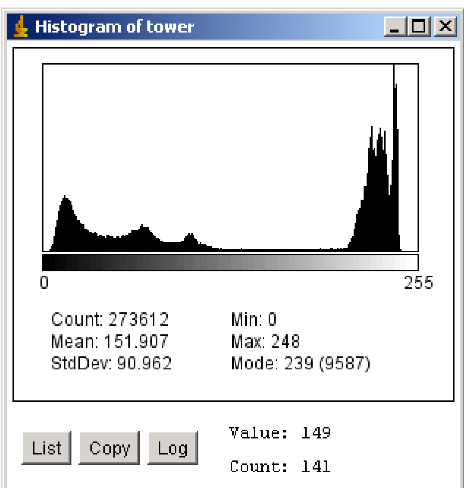
Thresholding

- Where are the stars in the image?

http://en.wikipedia.org/wiki/File:Pleiades_large.jpg

Thresholding





- Global thresholding
- Adaptive (local) thresholding
  - Threshold selection for each region
  - Moving average
- Threshold selection for image/region
  - Based on spectrum (intensity histogram)
  - Multi-spectral method (color images)
  - Multi-dimensional spectra methods
- Avoid Noise
  - ignore small regions in the threshold image

Iterative Threshold Selection

```
B = set containing the pixels in the corners;
O = set containing all other pixels;
T = undefined, T_next = undefined;
while (T == undefined) or (T_next == undefined) or (T_next != T) {
    T = T_next;
    sum_B=0;
    for all pixel p in B { sum_B = sum_B + intensity(p); }
    avg_B =sum_B/size(B);
    sum_O=0;
    for all pixel p in O { sum_O = sum_O + intensity(p); }
    avg_O =sum_O/size(O);
    T_next=(avg_B+avg_O)/2;
    B = empty set, O = empty set;
    for all pixel p in the image
        if (intensity(p) > T_next) O.put(p) else B.put(p);
}
// finally T contains the selected threshold
```

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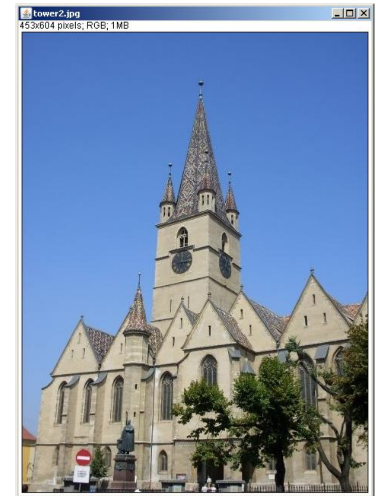
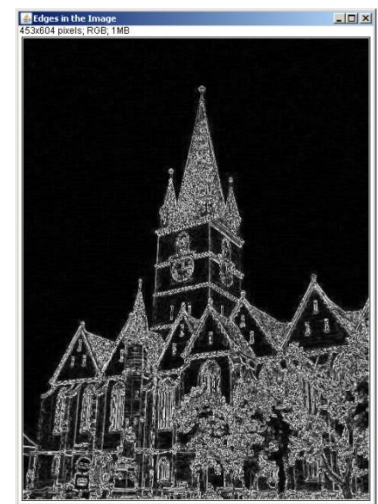
Edge-based segmentation

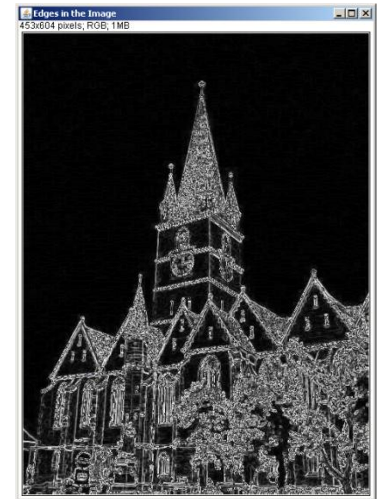
- First step
  - Edge detection
- Second step – „correction“
  Edge Linking and Boundary Detection
  - Local processing
  - Regional Processing
- Resulting edges separate regions of the image





Local processing

i_g = gradientImage(image);
for all pixels **p** in **i_g** {
  L = local neighborhood of **p** // set of pixels „near“ p
  for all pixels **p_n** in L {
    if (absoluteValue(magnitude(p_n)-magnitude(p)))
      && (absoluteValue(direction(p_n)-direction(p))) {
        connect(**p**,**p_n**);
      }
  }
}



Regional Processing

- Poligonal approximation of region boundaries

```
Sequence P = orderEdgePixelsCyclic();
(A, B) = specifyStartingPoints();
T = specifyThreshold();
OPEN = new Stack(), CLOSED = new Stack();
OPEN.put(B); OPEN.put(A); CLOSED.put(B);
While (not empty(OPEN))
    LINE = calculateLine(OPEN.topElement(),CLOSED.topElement());
    for each X in P {
        PixelsAndDistances = new Set();
        if (X between OPEN.topElement() and CLOSED.topElement() in P)
            d = calculateDistance(X,LINE);  PixelsAndDistances.put( (X,d) );
        (Y, dist_Y) = selectPixelWithMaximalDistance(PixelsAndDistances);
        if (dist_Y > T ) { OPEN.put(Y); }
        else { Z = OPEN.getAndRemoveTopElement();  CLOSED.put(Z); }
    }
}
```

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Region-based Segmentation

- Often applied on the gradient of the image (i.e. not directly)
- Region Splitting and Merging
  - Given region predicate Q(R)
  - Recursively split image into 4 regions, as long as Q(R)=false
  - Merge adjacent regions P and R, if Q(P)=true and Q(R)=true
- Watersheds
  - Topographic interpretation of the image
  - “Flood”
  - Dam Construction (build dam, if dilations would merge two regions)
  - Avoid oversegmentation
    - Internal Markers (areas of interest, e.g. local minima areas)
    - External Markers (separate the image into regions)

Segmentation

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<u>Motion for Segmentation</u>

Graph Cut

Motion for Segmentation

Motion for segmentation

- Suppose we are given two “similar” pictures: one with the target object, an other one without → segmentation trivial
- But
  - Who gives us such similar images?
  - Noise between “similar” images
- Videos
  - Series of images
  - Accumulate differences: Absolute, Positive, Negative Difference Images
    - Increment pixels if $|R(x,y) - f(x,y)| > T$

$$(R(x,y) - f(x,y)) > T$$

$$(R(x,y) - f(x,y)) < -T$$

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Motion for Segmentation

Graph Cut

Graph Cut

- Input: image I with some labeled pixels
  - O → Object, B → Background
- Task: label the other pixels
- $B(p,q)$
  - Small if p and q belong to different regions (e.g. p should be labeled as O and q should be labeled as B)
  - Large if p and q belong to the same regions (e.g. both should have label as O)
- $R(p,B)$ cost of labelling p as background
- $R(p,O)$ cost of labelling p as object

Graph Cut

- Construction of the flow problem
  - Image pixels → graph nodes
  - If the pixels p and q are adjacent → edge between the corresponding nodes with weight $B(p,q)$
  - Two "special" nodes: s and t
  - Weights of edges (s,p)
    - $R(p,B)$ for unlabeled pixels
    - K for pixels labeled as object
      (K denotes such a big capacity that the edge can not be saturated)
    - 0 for pixels labeled as background
  - Weights of edges (p,t)
    - $R(p,O)$ for unlabeled pixels
    - 0 for pixels labeled as object
    - K for pixels labeled as background

Graph Cut

- How to choose R and B ?

$$R(p,O) = -\ln P(I_p \mid O)$$

$$R(p,B) = -\ln P(I_p \mid B)$$

$$B(p,q) = \frac{1}{\| p,q \|} e^{-\frac{(I_p - I_q)^2}{2\sigma^2}}$$

where

I_p denotes the intensity of pixel p

σ denotes the expected intensity variation within the object/background

$||p,q||$ denotes the distance between p and q

- After solving the flow problem, the image segmentation is determined based on the edges in min. cut