Mechatronic Engineering program

Computer Vision
Image Segmentation

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Schedule

- Lecture 1: An Introduction
- **Lecture 2: Image Segmentation**
  - Image Segmentation
  - Thresholding
  - Morphological Operations
  - Color, Texture Segmentation
  - Object features – an introduction
- Lecture 3: Image Features
- Lecture 4: Video Processing

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Image Segmentation – An Idea

Idea – partition the image into objects and background
Analyze only objects, ignoring background
What are the objects depends on applications


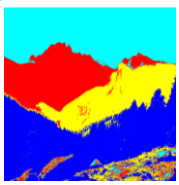

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Image Thresholding (Binarization)

Change a grayscale image into **binary image** using threshold value
Based on the image histogram

White pixel – logical 1 – object pixel
Black pixel – logical 0 – background pixel

White pixels for I > threshold
Black pixels otherwise

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Thresholding + Logical opertions

Goal – find the middle square

I > threshold 1

I < threshold 2

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Thresholding + Logical opertions

I > threshold 1

AND

I < threshold 2

I > threshold 1 **AND** I < threshold 2

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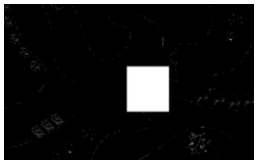
Dealing with noise

We have seen that after thresholding noise may remain on the image
How to deal with it? Recall image filtering
Recall **morphological filters**

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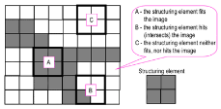
Morphological Fiters



Applied after thersholding to remove noise
Four basic morphological operations

- **Erosion**
- **Dilation**
- **Opening**
- **Closing**

Realized by shifting a mask, called structuring element and performing some logical opeation between pixels of a mask and pixels of binary image under the mask

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Erosion

Output pixel becomes black if at least one image pixel under white pixel of the mask is black

Removes single white pixels, small white pixel groups (smaller than mask), decreases objects' area, disconnects objects connected by bridges


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Dilation

Output pixel becomes white if at least one image pixel under white pixel of the mask is white

Removes single black pixels (holes), increases objects' area, connects objects that are close to each other

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Opening

Two consecutive operations: **erosion and dilation**

Removes single white pixels, small groups of white pixels (smaller than mask), but preserves the area and shape of objects

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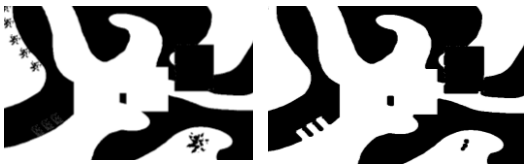
Closing

Two consecutive operations: **dilation and erosion**

Removes single black pixels (holes), but preserves the area and shape of objects



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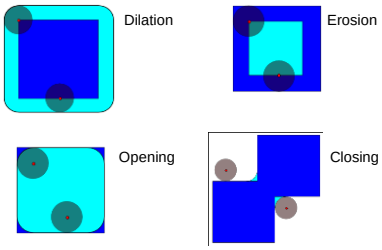
Four morphological operations a comparison



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Morphological gradient

Image morphology (e.g. closing and opening) applied to detect edges

Can be done by different combinations of basic morphological operations

e.g. Exlusive OR of Dilation and Closing results

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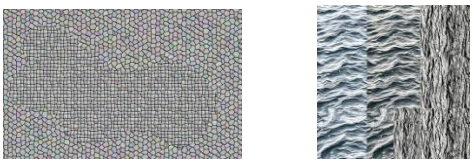
Texture segmentation

If objects have texture, a simple thresholding will lead to wrong segmentation results or segmentation may be even impossible



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Texture segmentation

Before applying thresholding, you may apply texture filters to simpily the image

They are based on local nonlinear filtering of each image pixel

Examples: Standard deviation filter
Entropy filter
Range filter
Gabor filters
Intensity Level Co-Occurence Matrix
Local Binary Patterns
…

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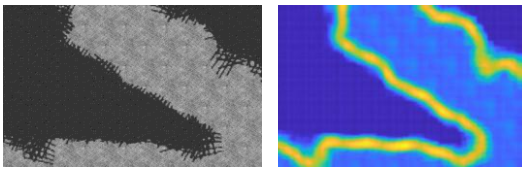
Standard Deviation Filter

For each pixel, it computes a local **standard deviation** of pixel intensity in its neighborhood



Std Filter Mask Size 39x39

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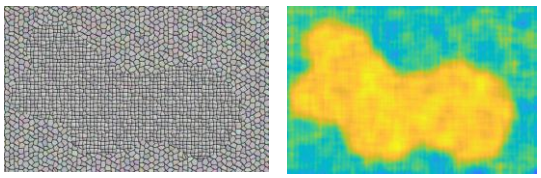
Entropy Filter

$$-\sum p * \log(p)$$

For each pixel, it computes an entropy of pixel intensity in its neighborhood



Entropy Filter Mask Size 39x39

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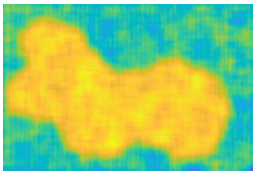
Entropy Filter

$$-\sum p * \log(p)$$

And now the thresholding is easy

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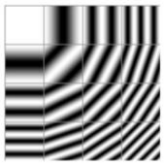
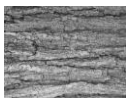
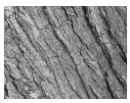
Gabor Filters

Recall the frequency content of the image

Bank of filters, each tuned to a specific spatial frequency of intensity change in a particular direction

We can detect areas with different textures under different orientations



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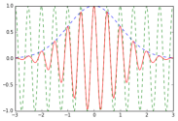
Gabor Filters

They are complex filters given by the following formulae

$$g(x, y; \lambda, \theta, \psi, \sigma, \gamma) = \exp\left(-\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2}\right) \exp\left(i\left(2\pi\frac{x'}{\lambda} + \psi\right)\right)$$

$$x' = x\cos\theta + y\sin\theta \quad y' = -x\sin\theta + y\cos\theta.$$

Real and imaginary parts are sine waves modulated by a Gaussian



An example of 1D Gabor filter

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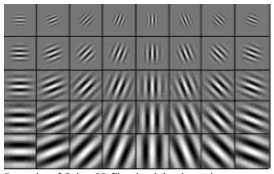
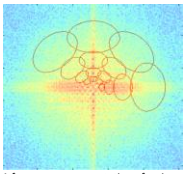
Gabor Filters

In 2D, an angle – the extra parameter that decides orientation



Examples of Gabor 2D filter bank (real parts)



A frequency representation of an image covered by Gabor 2D filter bank

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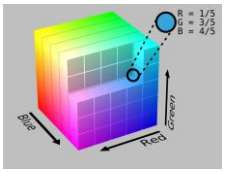
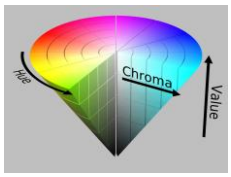
Color Image Review

RGB Color Space



Default in Matlab
Non-intuitive
Channels correlated

HSV Color Space



Intuitive
Decoupled color and intensity information

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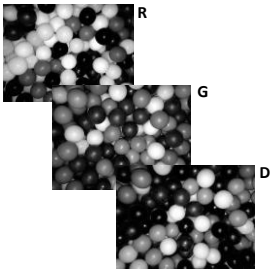
Color Image Segmentation

Thresholding performer using three color channels

Depends on the color model used to represent color pixels



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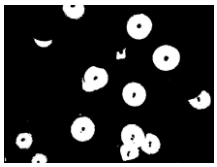
Color Image Segmentation

Possibilities:

- separate thresholding of three color channels
- thresholding in 3D color space – based on distance to model color



An example:

Light blue balls segmentation

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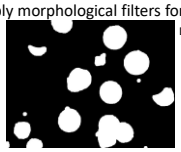
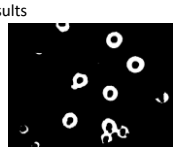
Postprocessing

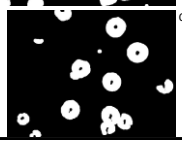
Apply morphological filters for better results



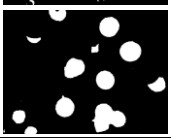
Dilation



Erosion



Opening



Closing

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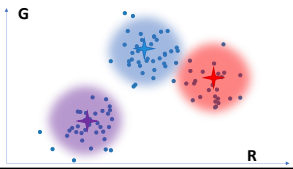
K-Means clustering for image segmentation

Idea: Each pixel has assigned a 3 element feature vector – its R, G and B color values

Each pixel corresponds to one point in 3D feature space

Segmentation – assigning pixels to **clusters** in this 3D feature space

Compute position of clusters – **centroids**



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K-Means clustering for image segmentation

K-Mean algorithm – a review

1) Initialize cluster centers' positions randomly
2) Assign each point to the closest cluster
3) Recompute cluster centers – means of assigned points
4) Repat until convergence is reached

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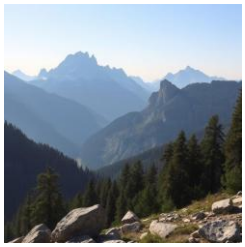
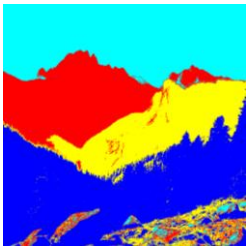
K-Means clustering for image segmentation





K-Means RGB Segmentation, 4 clusters

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K-Means clustering for image segmentation

Enlarge dimension of feature space by adding another image quantities for each pixel

– Its coordinates (favoring close pixels)
- Edge information (HP filtered images)
- Texture informations (texture filters, Gabor filters results)
- …

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K-Means clustering for image segmentation

Example: Use information given by Gabor filter bank

Data: pixel data from images filtered by the entire filter bank
- 24 grayscale 8-bit images,
- Each pixel gives a feature point in 24 dimensional space,
- We may add RGB color information (27 dimensional space)

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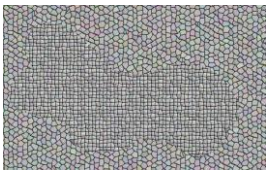
K-Means clustering for image segmentation




K-Means Gabor-based Segmentation, 2 clusters

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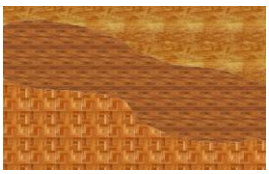
K-Means clustering for image segmentation




K-Means Gabor-based Segmentation, 3 clusters

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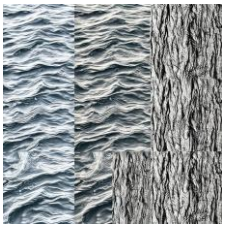
K-Means clustering for image segmentation



K-Means Gabor-based Segmentation, 2 clusters

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Geometric features – an introduction

After segmentation we have binary image with white objecys
What's next? Compute object's geometrical features

Area = ?
Centroid = ?
Euler Number = ?
Eccentricity = ?
Orientation = ?
…

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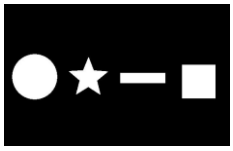
Geometric features – an introduction

First you have to find how many there are on the image
Perform **labelling** – assign a natural number to each **disjoint object** in the image



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Geometric features – an introduction

Next step, analyze each object separately – compute its geometric features
In Matlab – **regionprops** function

Let's first see ‚basic' features offered by the function:

Area – number of pixels of the object
Centroid – its centroid
Bounding Box – rectangle circumscribed on the object

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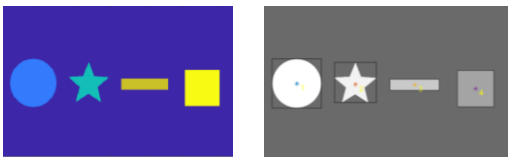
Geometric features – an introduction

An example – objects with their centroids and bouding boxes



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Review Material

What is image segmentation?
What is thresholding?
How does Erosion/Dilation/Opening/Closing work on binary image?
What is morpgological gradient?
List texture filters that you know
What do the scale and angle parameters represent in Gabor filter?
How is K-Means clustering applied for color image segmentation?
What are gemetrical object features?
What is labelling?
How binary and labelled images differ?

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Thank you for attention

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