Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

**MIN-Fakultät**
**Fachbereich Informatik**
Arbeitsbereich SAV/BV (KOGS)

# Image Processing 1 (IP1)
# Bildverarbeitung 1

## Lecture 10 – Image Segmentation 1

Winter Semester 2015/16

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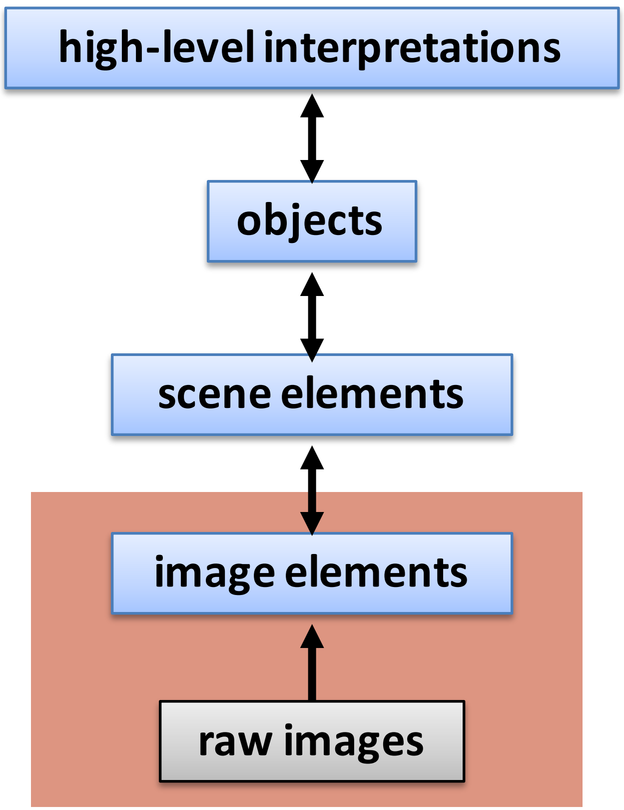
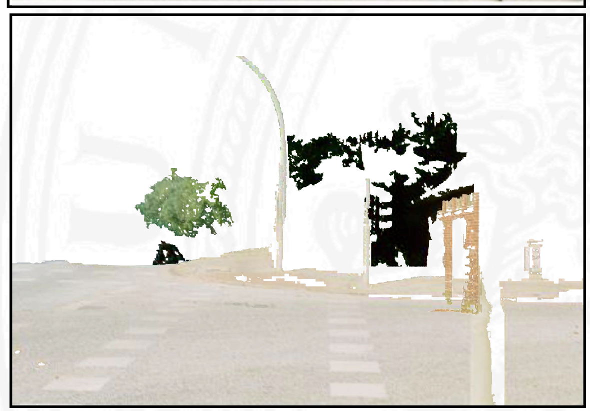
Slightly revised by: Dr. Benjamin Seppke & Prof. Siegfried Stiehl

# Segmentation

**Segmenting the image into image elements which may correspond to meaningful scene elements**

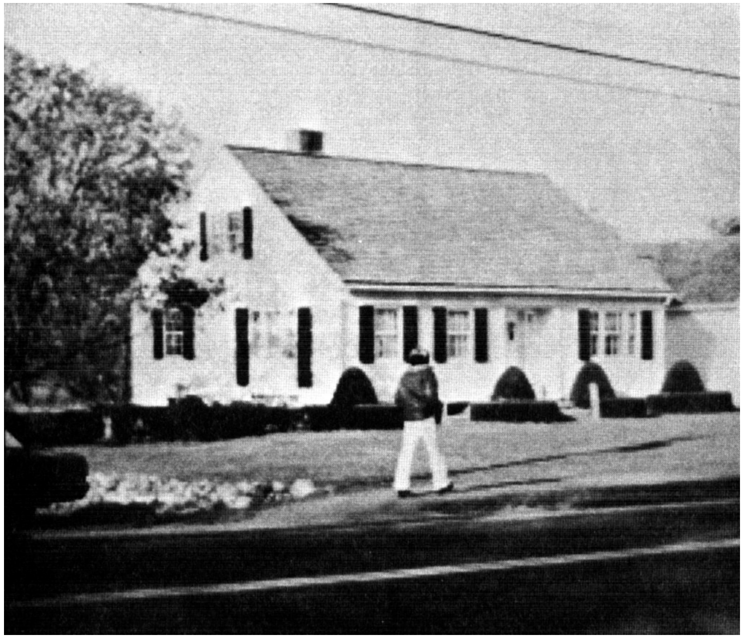



**Example:**
Partitioning an image into regions which may correspond to objects

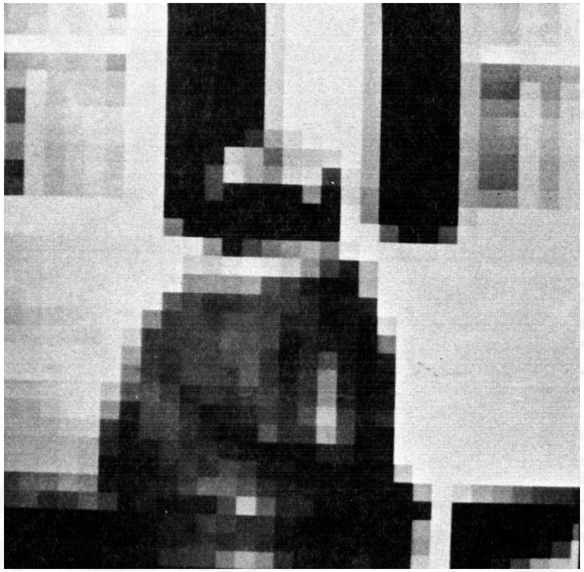


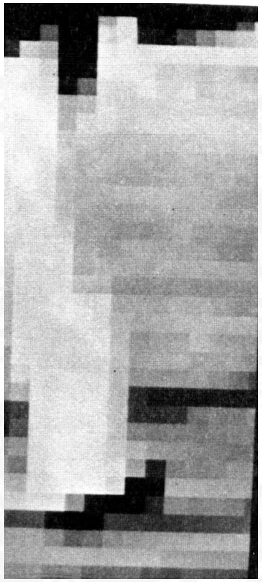
Typical results of first segmentation steps

# Problems with Segmentation



landhouse scene





upper part and leg of person

Greyvalues of foreground may be indistinguishable from greyvalues of background.

**In general, context knowledge is necessary for successful segmentation!**

# Primary Goal of Segmentation

***"Segmenting an image into image elements which may correspond to meaningful scene elements"***

**What sort of image elements may correspond to meaningful scene elements?**

Answer depends on type and complexity of images: Less constrained scenes must be segmented more conservatively.

**Segmentation into ...**

| | | |
|---|---|---|
| **... entire objects** | e.g. for | printed character recognition<br>industrial object recognition<br>medical cell analysis |
| **... edge lines** | e.g. for | aerial image analysis<br>indoor scenes |
| **... edge elements, vertices, groupings** | e.g. for | natural scenes |

# Secondary Goals of Segmentation

## Multiple resolutions for subsequent processes

- coarse resolution description for e.g.
  - analysis of image layout (horizon, foreground, background)
  - control of attention
  - planning a detailed analysis
- fine resolution description e.g. for
  - details
  - stereo analysis
  - motion analysis

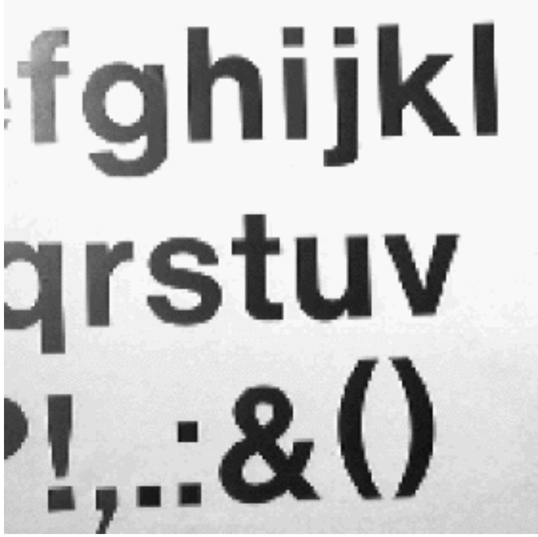
## Data reduction

- Because of their large data volume, raw images are inconvenient as basic data structures for image analysis, e.g.:

| | |
|---|---|
| TV colour image | 3 x 512 x 576 ≈ 7 MB |
| 10 sec TV colour images | 10 x 25 x 7 ≈ 1750 MB |

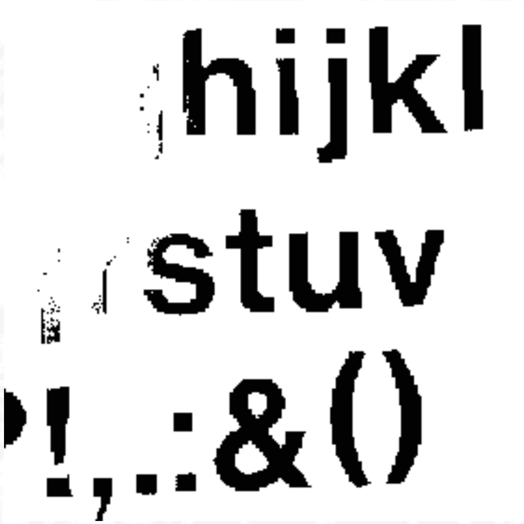
# Thresholding

**Thresholding has been introduced as a discretization technique. The same techniques can be applied for segmentation.**




greyvalue image

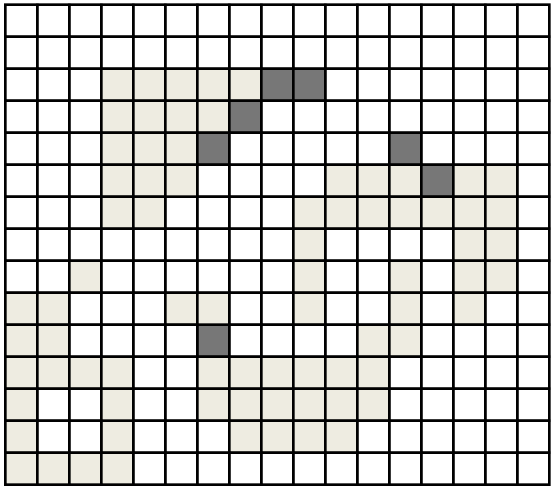

threshold too low




threshold too high

# Representing Regions

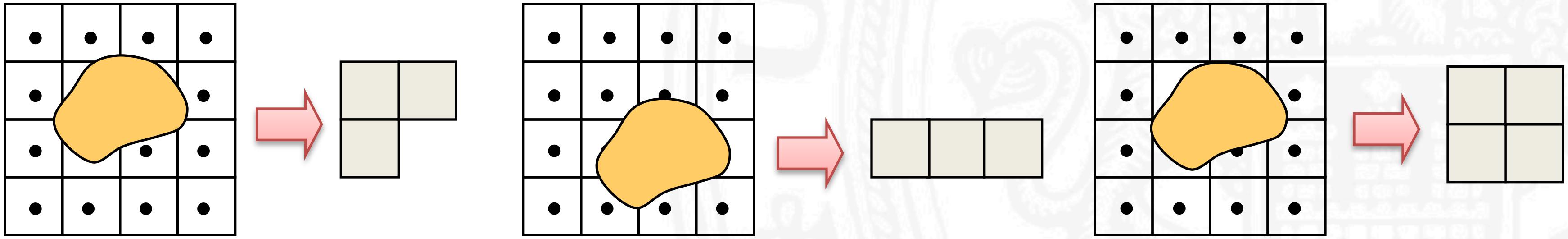
**A region is a maximal 4- (or 8-) connected set of pixels.**



Methods for digital region representation:

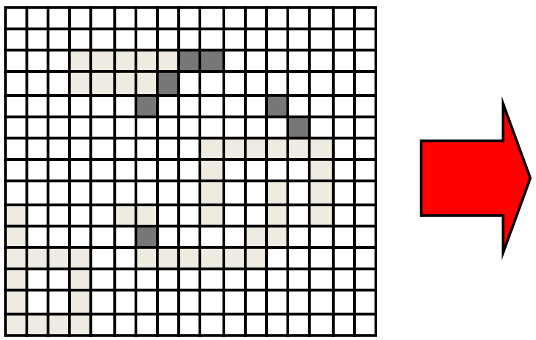
- grid occupancy
  - labelling
  - run-length coding
  - quadtree coding
  - cell sets
- boundary description
  - chain code
  - straight-line segments, polygons
  - higher-order polynomials

Note that discretizations of an analog region are not shift or rotation invariant:



# Component Labelling

## Determining connected regions in B/W images



Component 1
(2 3 9)(3 3 7)(4 6 6)

Component 2
(4 12 12)

Component 3
(5 13 13)(6 9 14)(7 9 9 14 14)(8 9 9 14 14)(9 9 9 14 14)

Component 4
(9 0 0)(10 0 0)(11 0 3)(12 0 0 3 3)(13 0 0 3 3)(14 0 0 3 3)

Component 5
(9 5 6 12 12)(10 6 6 11 12)(11 6 11)

**In this example: component descriptions using run-length coding**

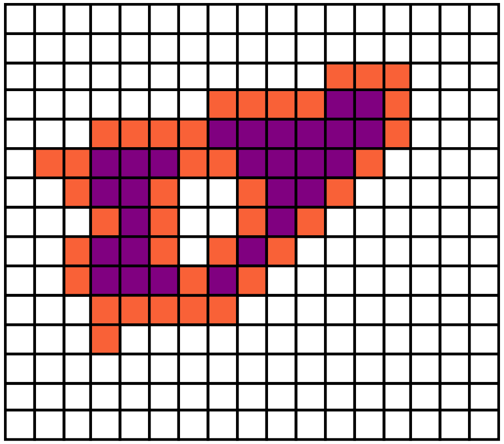
**Component labelling of B/W images with 4-neighbourhood**

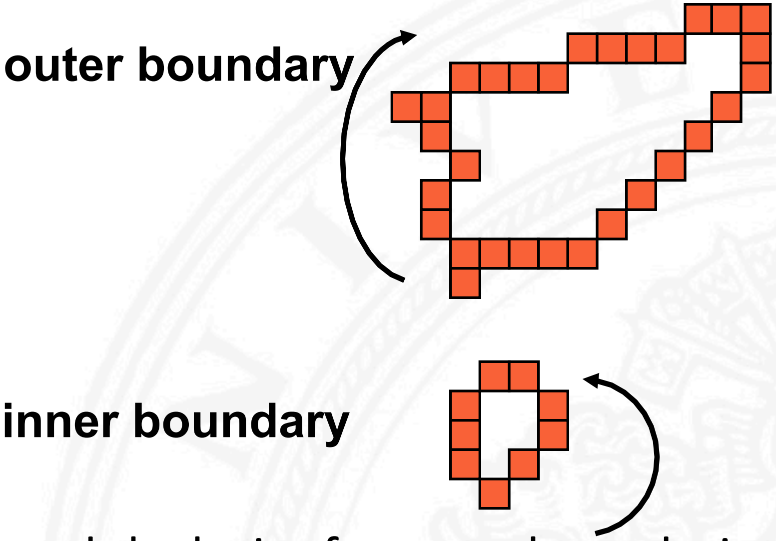
Scan image left to right, top to bottom:
- if pixel is white then continue
- if pixel is black then
  - if left neighbour is white and upper neighbour is white then assign new label
  - if left neighbour is black and upper neighbour is white then assign left label
  - if left neighbour is white and upper neighbour is black then assign upper label
  - if left neighbour is black and upper neighbour is black then
    assign left label, merge left label and upper label

# Boundaries

For a 4- (8-) connected region R the boundary is defined as the set of pixels of R which are 8- (4-) connected to the complement $R^c$ of R.

**Example for 8-connectivity:**





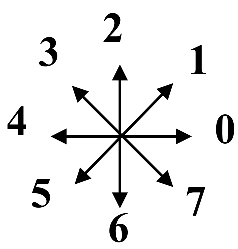

Boundary pixels are usually ordered clockwise for outer boundaries and counter-clockwise for inner boundaries.

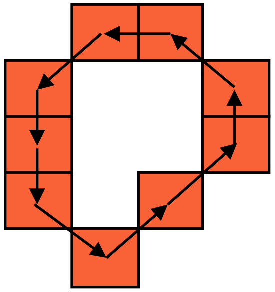
- Disadvantage of this boundary definition:
- R and $R^c$ have different boundaries - but nothing is in between.

# Chain Code

**Chain code represents boundaries by "chaining" direction arrows between successive boundary elements.**

**Chain code for <u>8-connectivity</u>:**



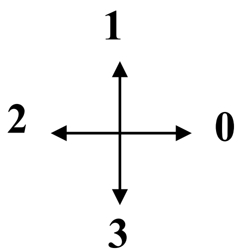
Arbitrary choice of starting point, chain code can be represented e.g. by

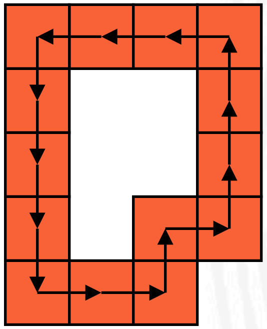
{456671123}

Normalization by circular shift until the smallest integer is obtained:

{112345667}

**Chain code for <u>4-connectivity</u>:**



Arbitrary starting point:

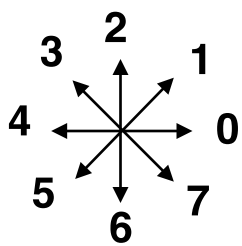
{22233330010111}

Normalized:

{00101112223333}

# Chain Code Derivatives

Chain code is highly susceptible to discretization noise. Hence derived properties are usually also noisy.



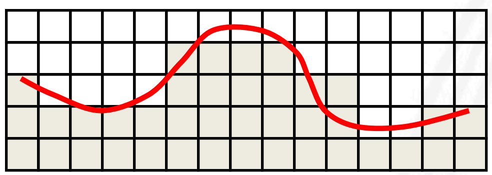

**Slope:**

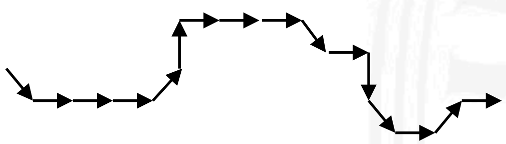
| chain code | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|---|
| tan θ | 0 | 1 | ±∞ | -1 | 0 | 1 | ±∞ | -1 | |
| θ | | 0 | 45 | 90 | 135 | ±180 | | -135 | -90 |

-45

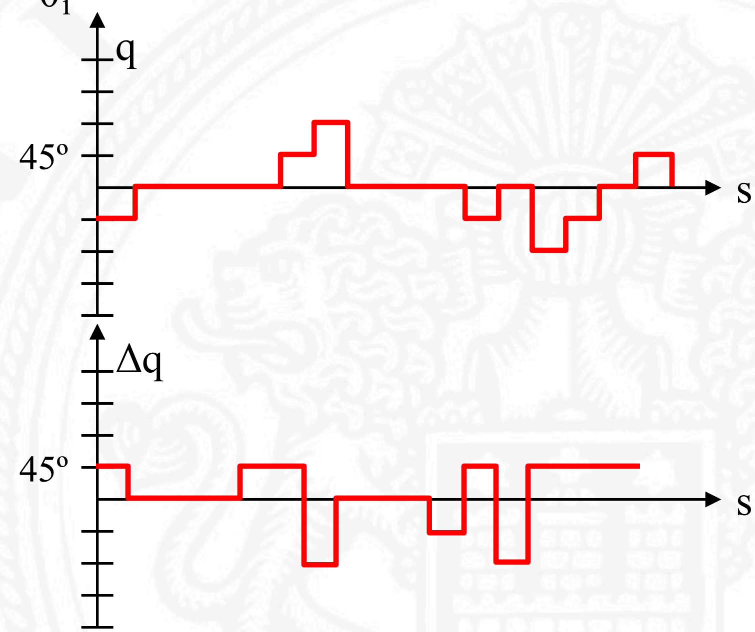
**Curvature:** $\Delta\theta = \theta_{i+1} - \theta_i$

**Example:**





{70001200070670 10}



# k-Slope and k-Curvature

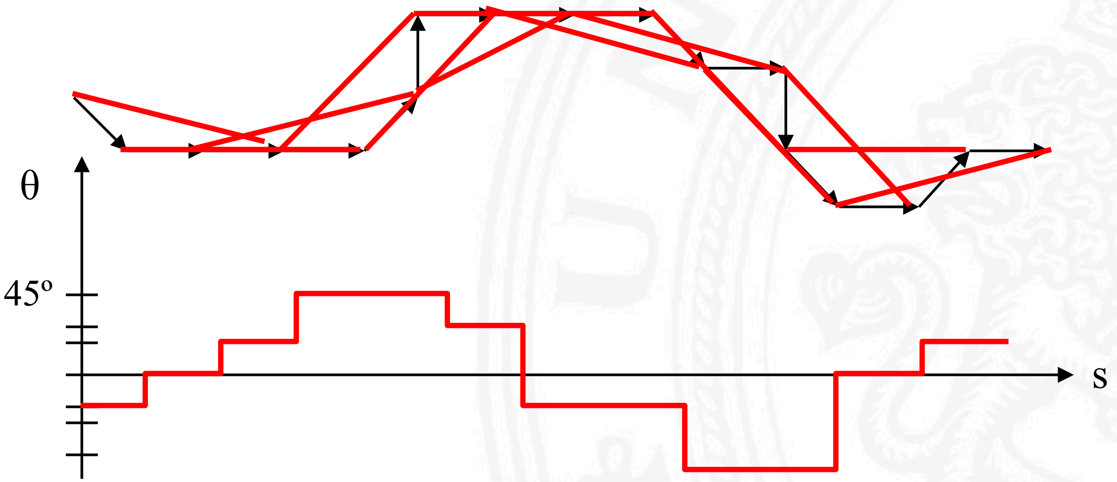
**Smoothed chain code slope and curvature:**

| | |
|---|---|
| $L$ | chain code |
| $\{p_1 \ldots p_N\}$ | starting points of chain code elements |

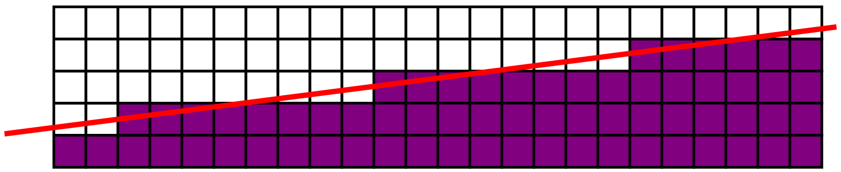
- right k-slope of $L$ at $i$, $k \geq 1$, is slope from $p_i$ to $p_{i+k}$
- left k-slope of $L$ at $i$, $k \geq 1$, is slope from $p_i$ to $p_{i+k}$
- k-curvature at $i$ is difference between right and left k-slope

**Example:**

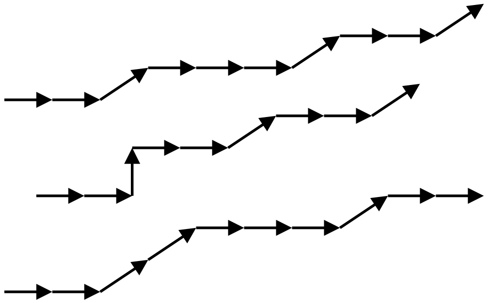
$k = 3$



# Digital Straight Lines



**What are the properties of a chain code which represents a straight line boundary?**



**may represent a straight line**

**may not represent a straight line**

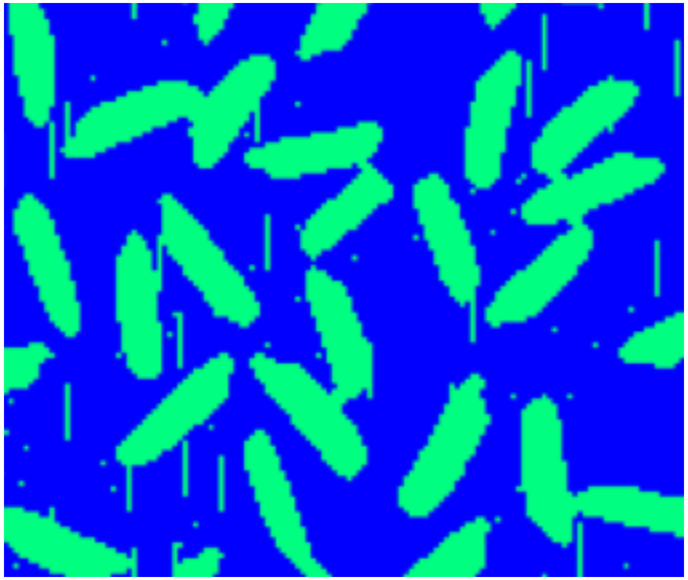
**may not represent a straight line**

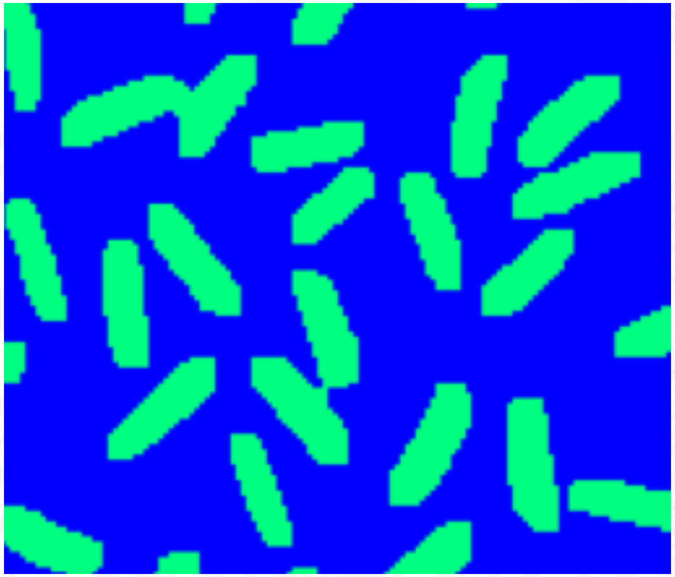
**Necessary and sufficient straight line properties of chain code:**

1. **Only 2 element types**
2. **Numerical difference of element types (mod 8) at most 1**
3. **One of the element types occurs only in runs of length 1 and is distributed "as regularly as possible".**

"as regularly as possible": Assume 2 types a and b, b single. Runs of a must have lengths $l_0$ and $l_0$+1. Consider $l_0$-runs and $l_0$+1-runs as 2 chain code types and apply straight line criteria recursively.

# Removal of Small Disturbances



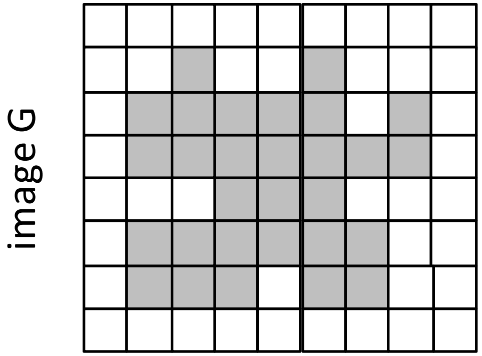


- **Salt-and-pepper noise creates false objects or holes**
- **Objects are merged because of touch or noise**

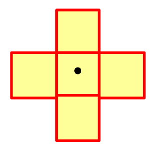
# Morphological Operations

- „morphology“ ≈ laws of structure, relevant for many disciplines
- Qualitative characterizations of morpholocigal operations on images:
  - Erosion removes boundary strip from regions
  - Dilation expands regions by boundary strip
  - Opening erosion followed by dilation, removes small protrusions from a region
  - Closing dilation followed by erosion, removes small intrusions from a region
- Morphological operations in Image Processing are defined by logical operations on binary images:
  - black = 0 = F
  - white = 1 = T

# Erosion and Dilation



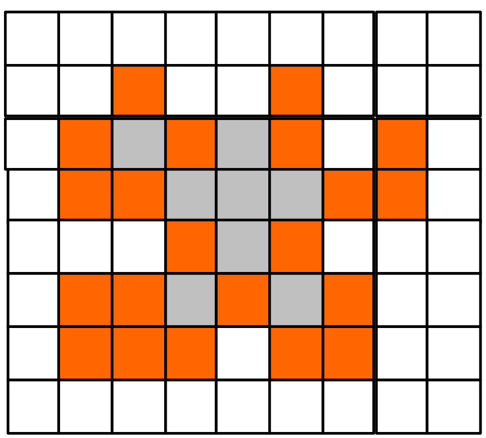

example of structuring element H



Local neighborhood operation with $g' = f(G_H, H)$ where $G_H$ are pixels of G covered by H.

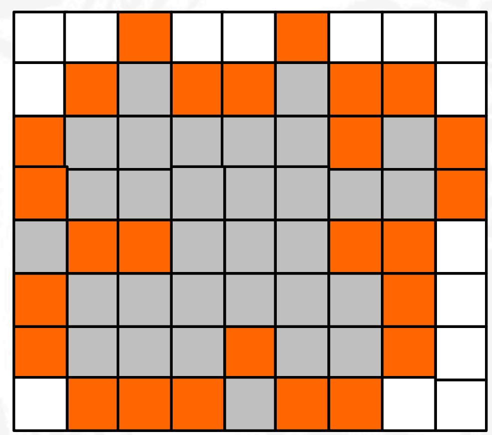
**Erosion: $g' = AND(G_H, H)$**

Reference location is 1 if all pixels covered by H are 1.



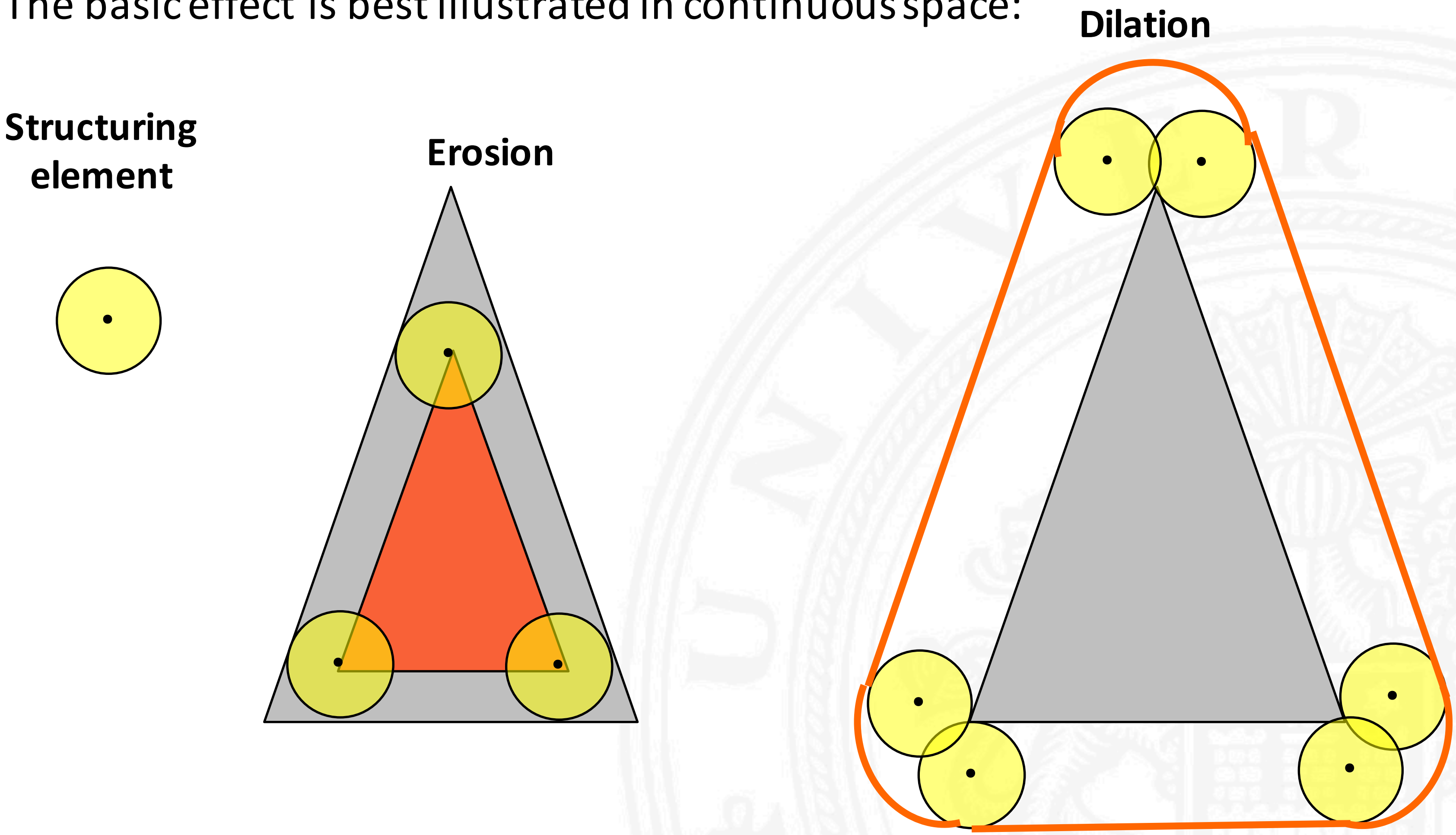
**Dilation: $g' = OR(G_H, H)$**

Reference location is 1 if at least one pixel covered by H is 1.



# Erosion and Dilation Examples

The basic effect is best illustrated in continuous space:



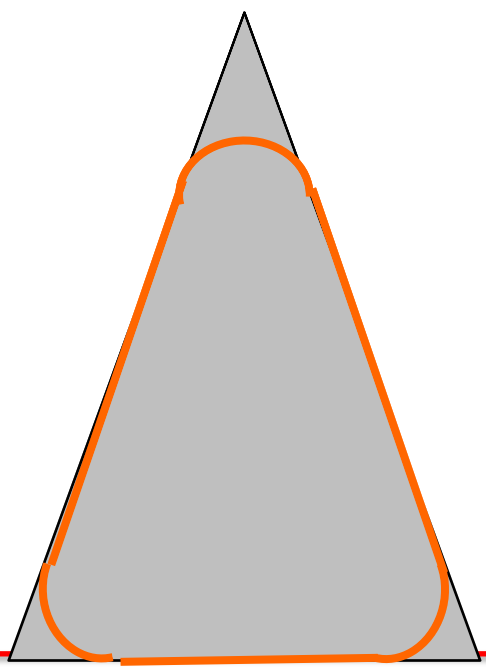
# Opening and Closing

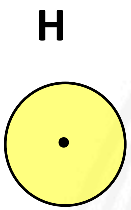
**Opening** is erosion of G by H, resulting in G', followed by dilation of G' by H.

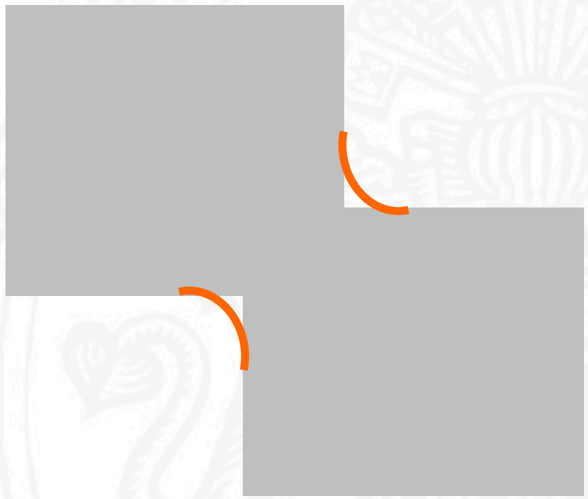
Opening removes small protruding structures.

**Closing** is dilation of G by H, resulting in G', followed by erosion of G' by H.

Closing adds small protruding structures.

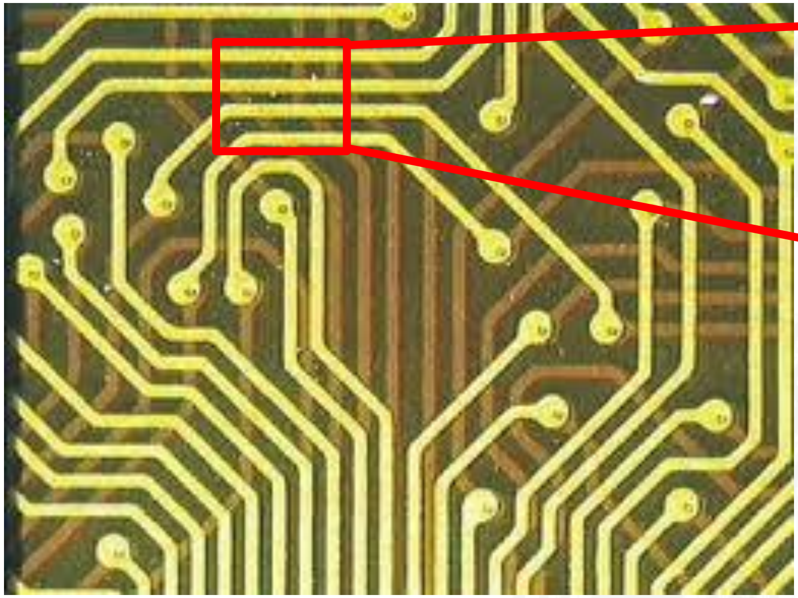




# Example for Morphological Operations

- Quality control of printed circuits:
- Find small unwanted protrusions



- What morphological operations can locate protrusions?

# Erosion and Dilation for Greyvalue Images

**Erosion:** $g' = \min(G_H, H)$

New value g' at reference location is minimum of all greyvalues of G covered by H.

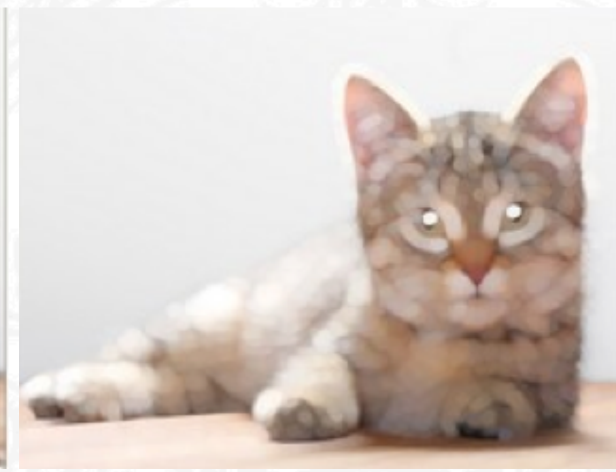
**Dilation:** $g' = \max(G_H, H)$

New value g' at reference location is maximum of all greyvalues of G covered by H.

**original**

**eroded**

**dilated**



Note that morphological operations are often defined similar to convolution:
Move mirror image of H across G (no difference if H is symmetrical).