Segmentation of Image Sequences by Mathematical Morphology

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Outline

- ↓ Introduction
- ↓ Connected Filters
- ↓ Watershed
- ↓ Beucher-Meyer Segmentation Paradigm
- ↓ Aperture Operators
- ↓ Automatic Design of Morphological Operators
- ↓ Methodology and Applications

Introduction

- Digital video edition is an important task nowadays.
- Some usual areas of applications are:
  - Advertisement
  - Special effects on movies
  - Re-mastering of old movies
  - Rotoscoping

Introduction

- Computational tools are being used to help this task.
- Some applications are not easy, for instance:

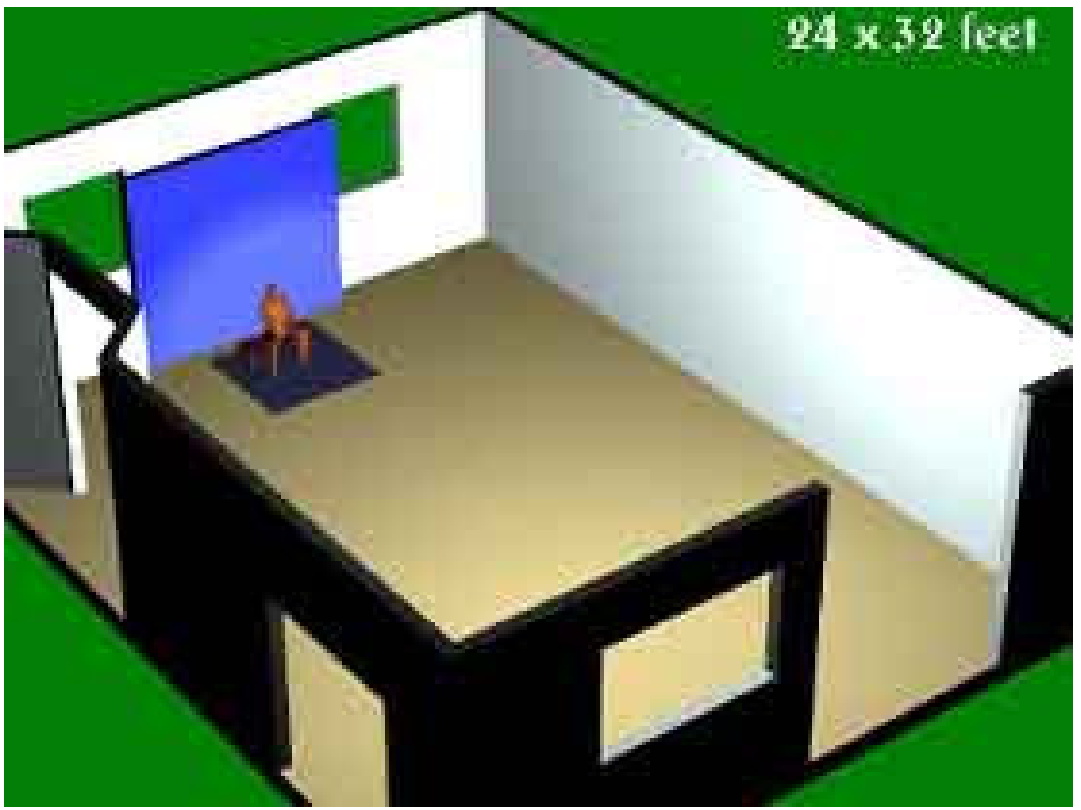
  composing (i.e. segmentation and mixing of video sequences.)
- A known technique is called *Chroma Keying.*

Introduction

- Some special cares have to be taken, though:
  - The scene has to be photographed in front of a bright, colored background.
  - Objects to be substituted have to be covered by a colored (green, blue, etc) cloth.
  - The image processing technique applied in the chroma keying is classical pattern recognition, using pixel color intensities as attributes.

Chroma Keying

↖ Photo Studio applications



Chroma Keying

- Video sequence applications

Forrest Gump and John Lennon being interviewed "together"

Rotoscoping

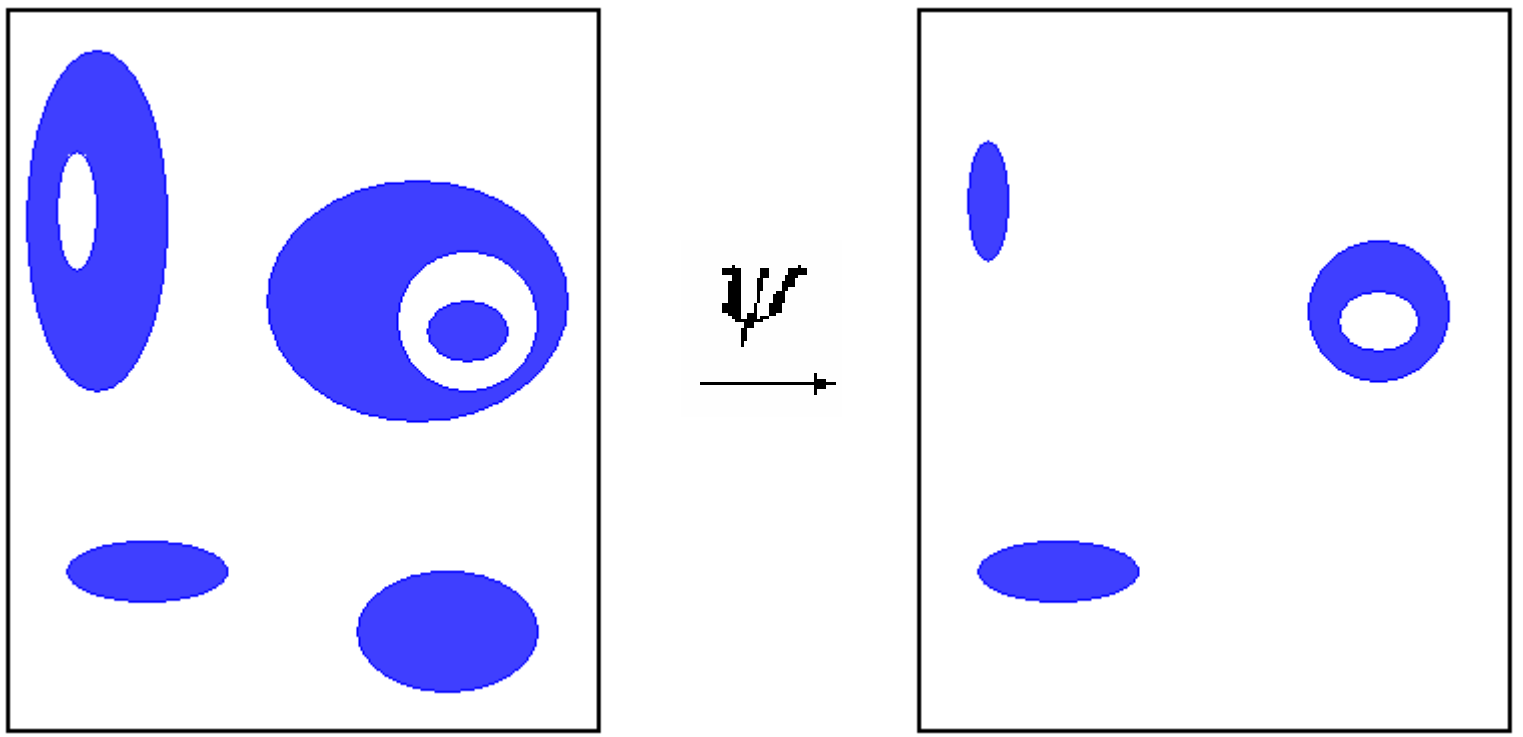
- Tracking live actions to create animation or an animated matte is usually called **Rotoscoping**
- It is applied mainly for short sequences
- The tracking is usually done manually with the help of a pointing device

Connected Filters

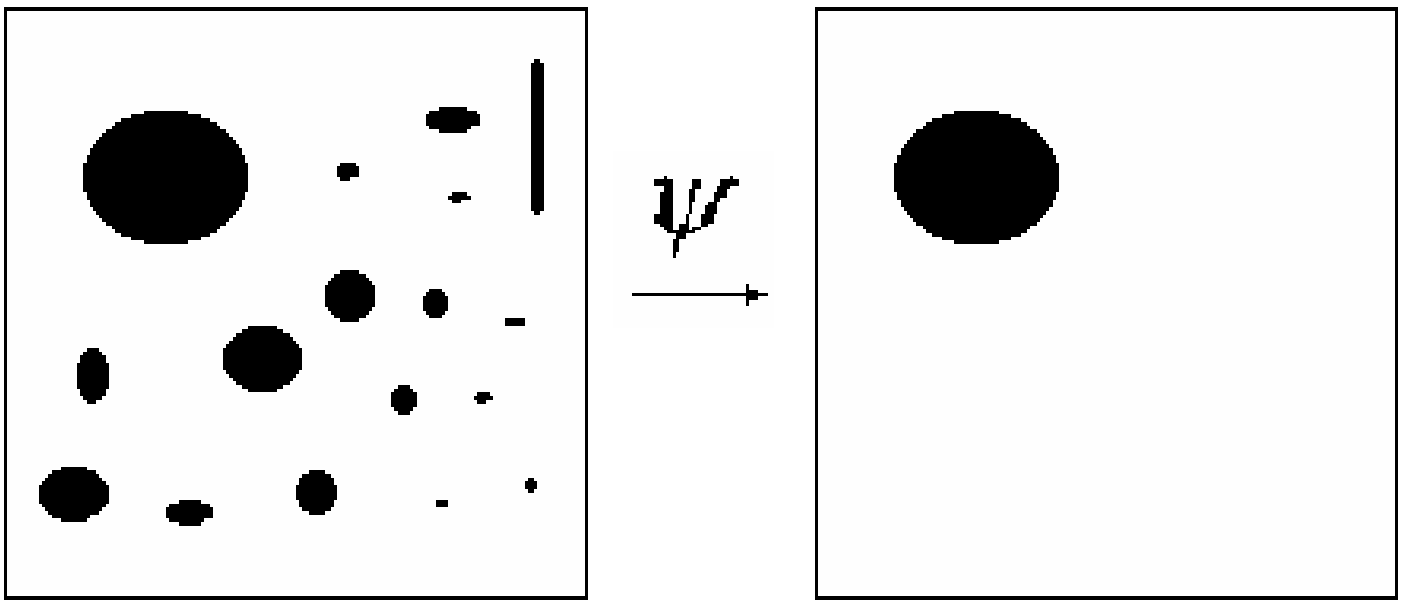
- **Connected filters are operators that act on the level of the flat zones of an image, not on the level of the pixels.**
- **They can not introduce new discontinuities, only suppress existing ones.**
- **They are well suited for image segmentation because they preserve the important desired borders.**

Connected Filters

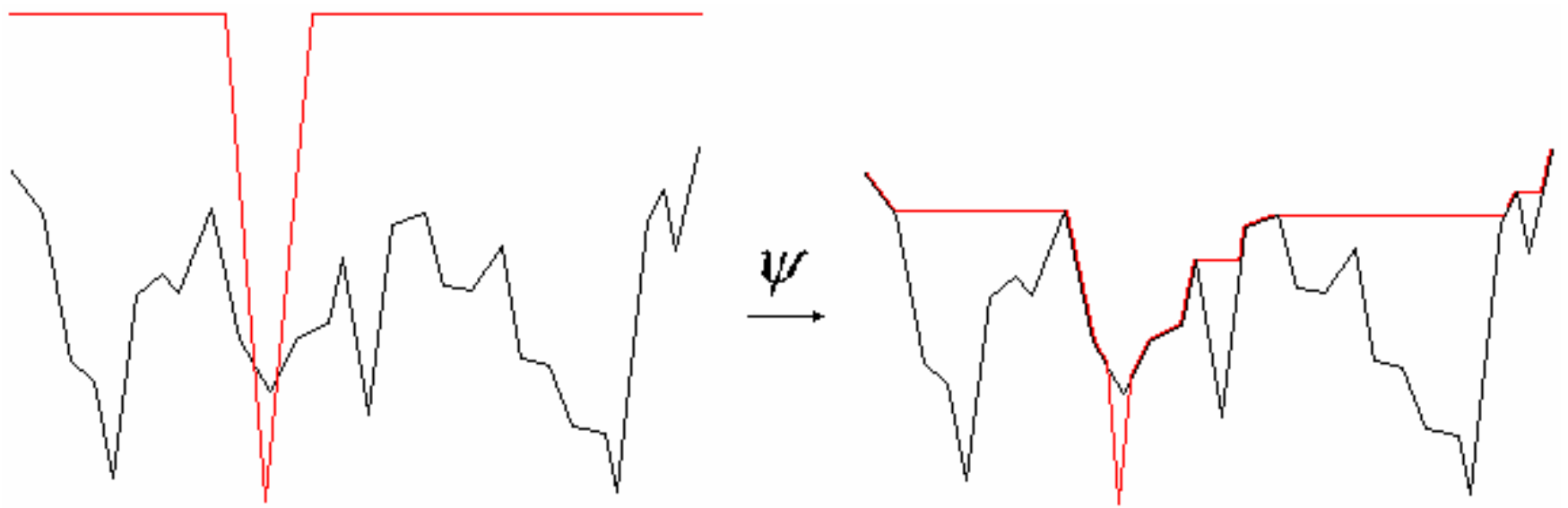
Planning



Areaopen Filter



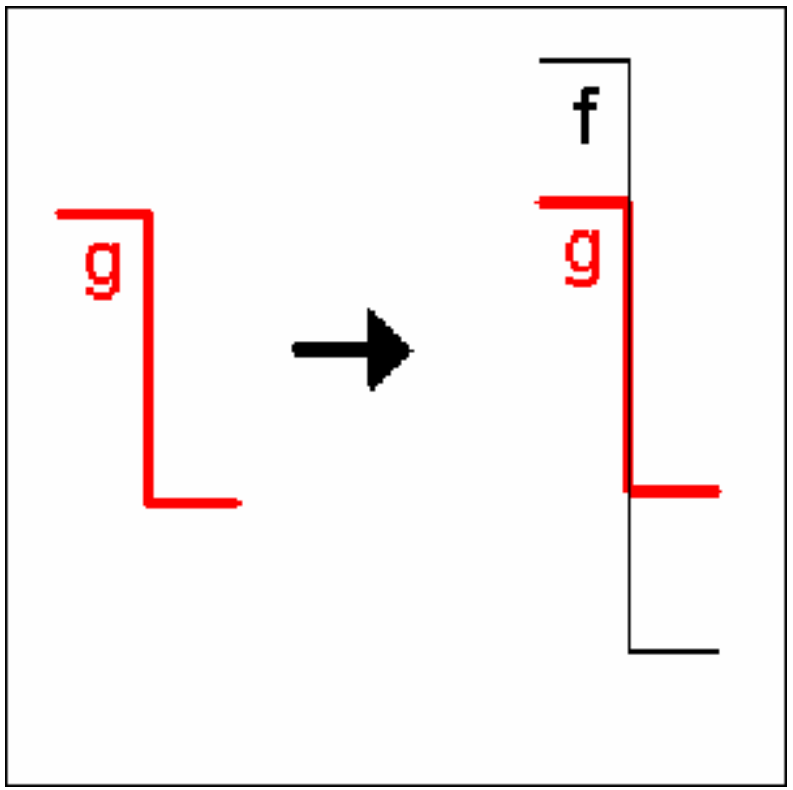
Homotopy Filter



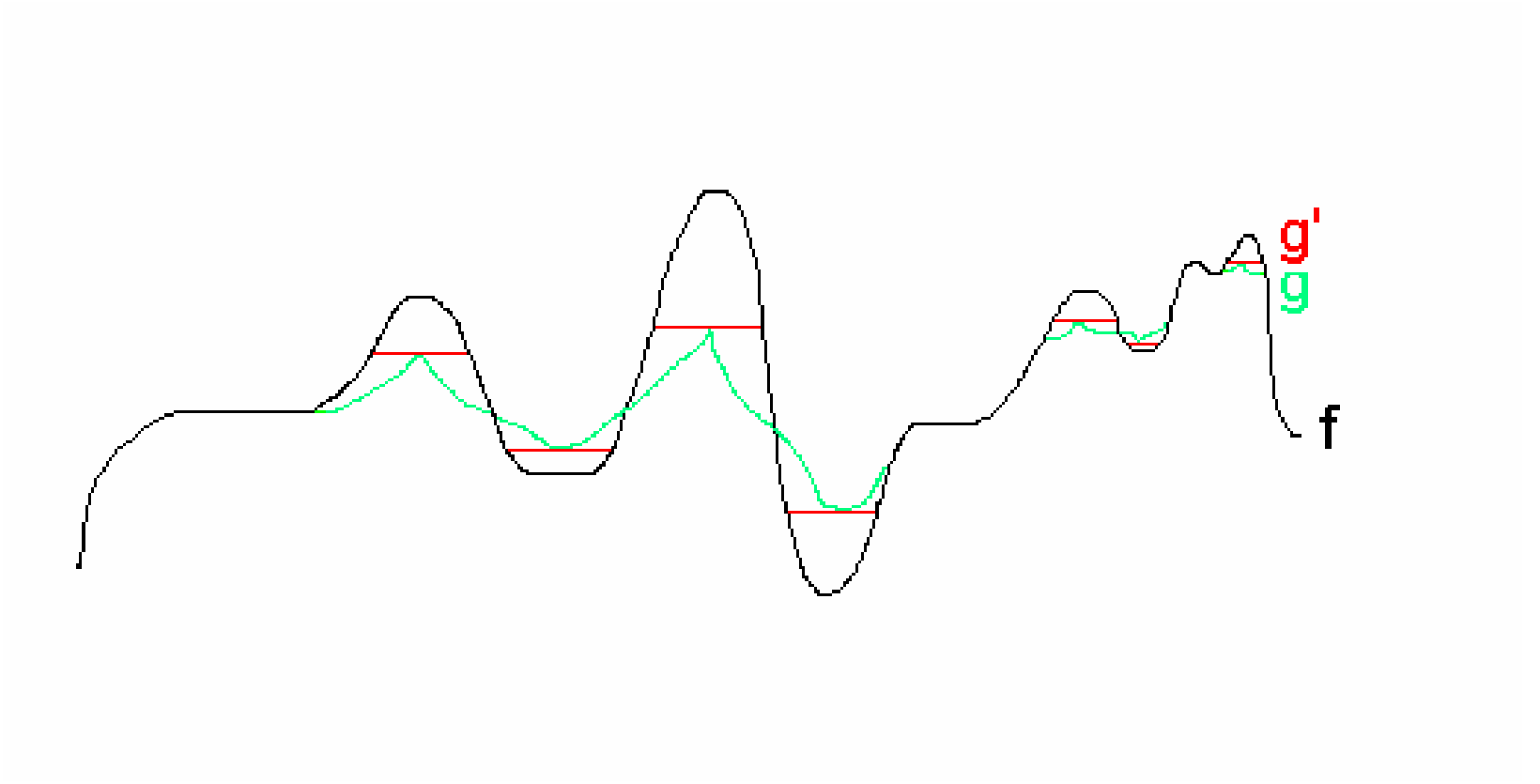
Levelings

- **Levelings** is a good methodology to simplify the image before segmentation
- It creates and enlarges homogeneous (quasi-flat) zones
- It can simplify the image before automatic design of operators

Levelings



Levelings



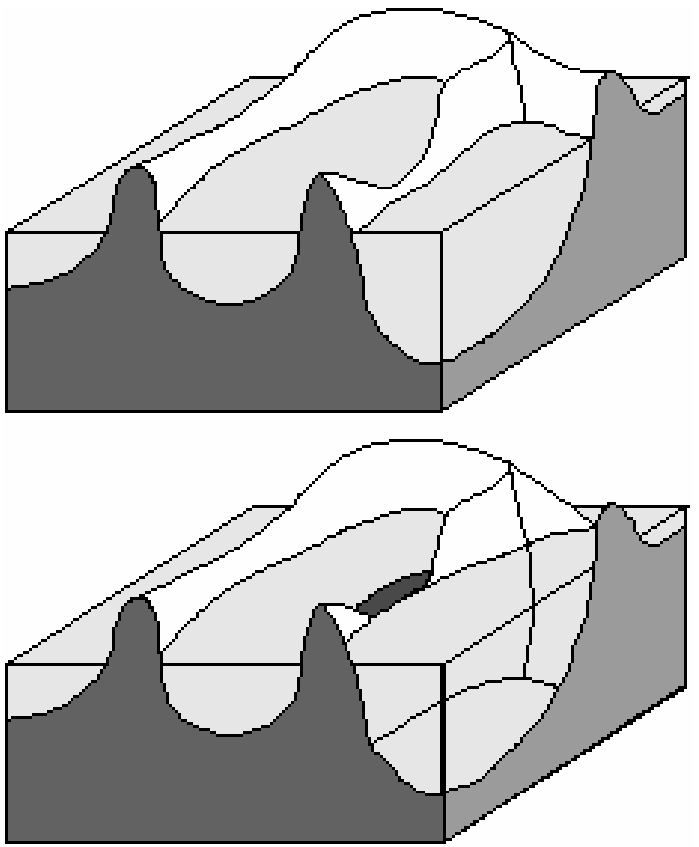
Levelings

Original

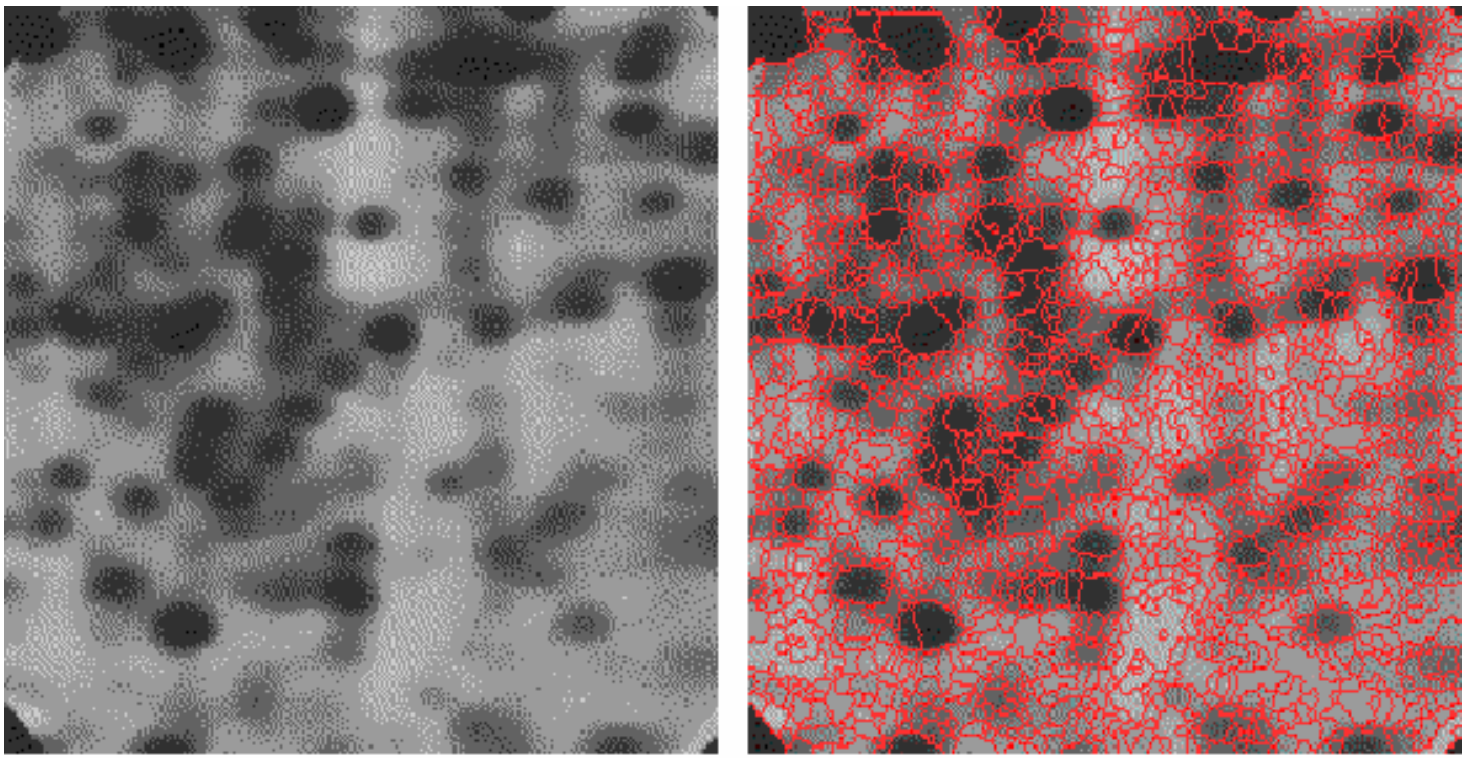
Marker

Result

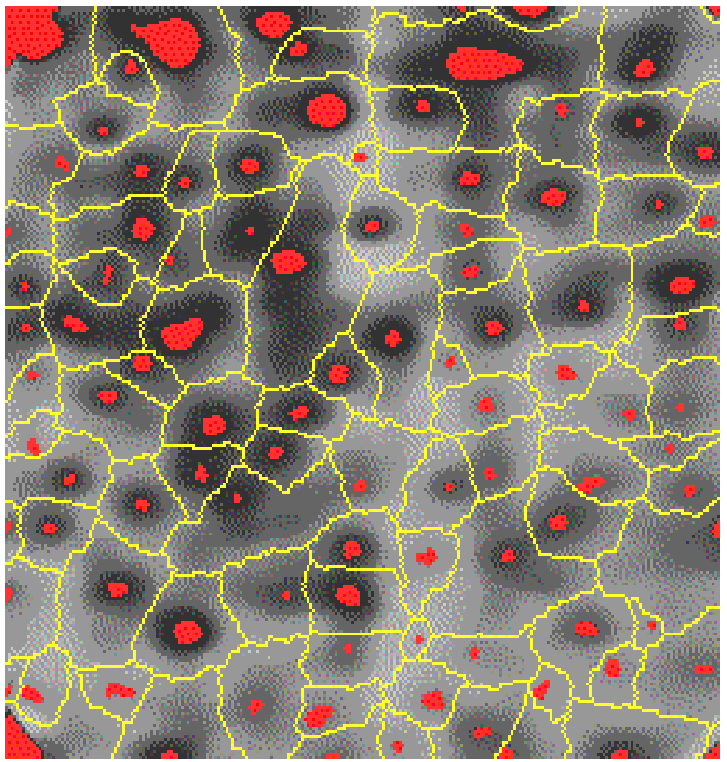
Watershed

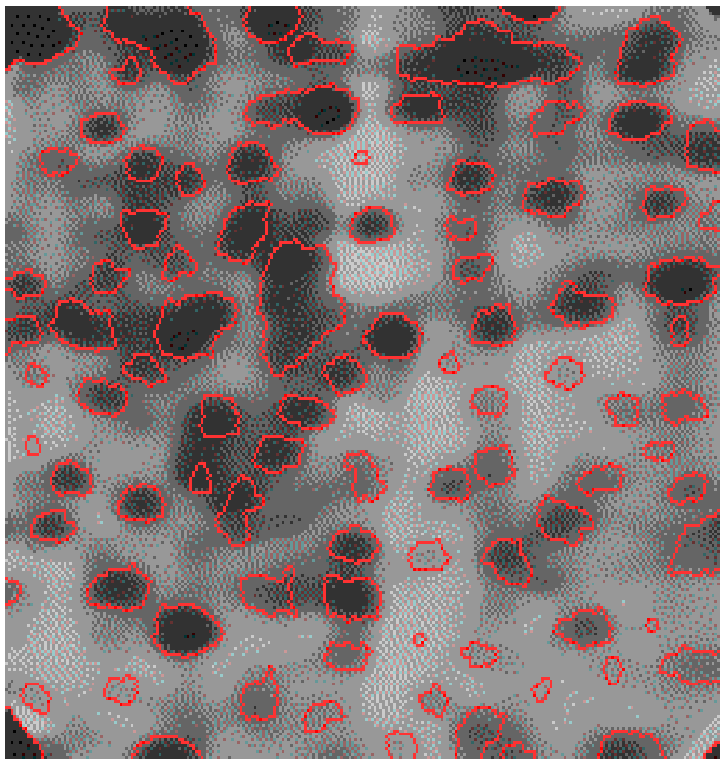


Oversegmentation



Markers

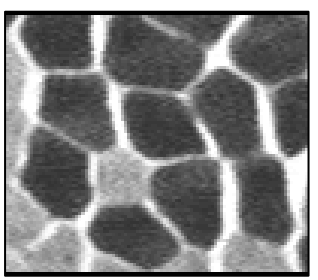




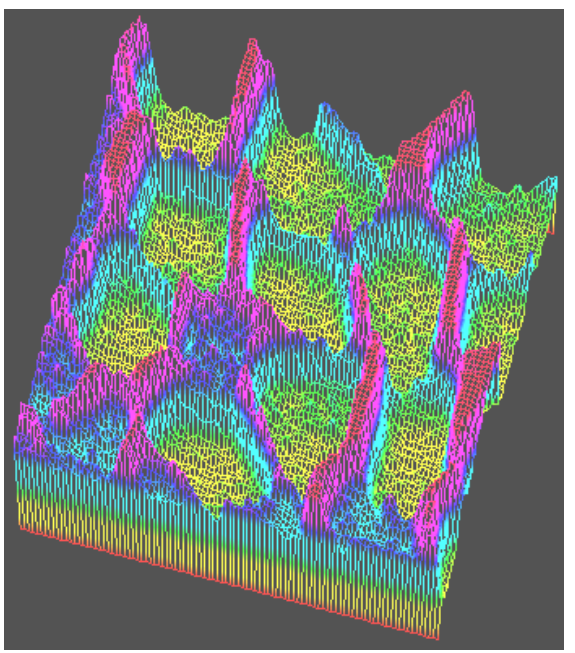
Beucher-Meyer Paradigm

- A powerful segmentation method to find the **borders** of specified objects in an image.

2D

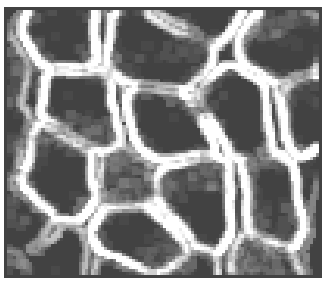


3D

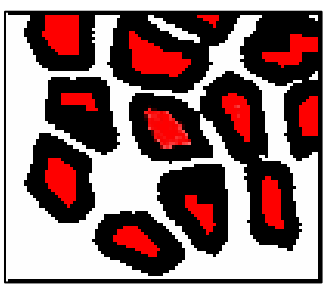


Beucher-Meyer Paradigm

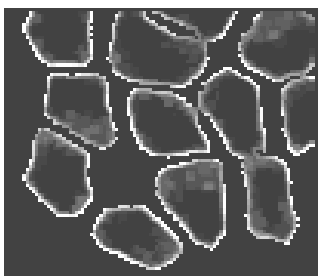
Gradient



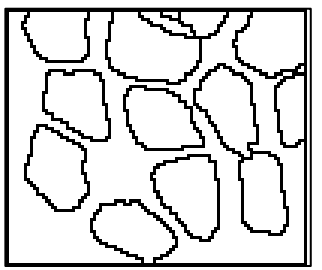
Marker



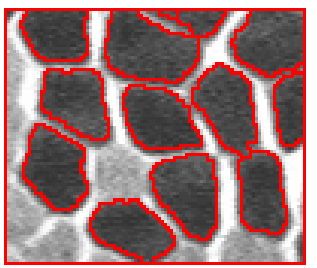
Filtered Gradient



Watershed lines



Composed Image



Design of Image Operators

- A fundamental problem in Mathematical Morphology is the design of function operators
- An approach for operators design is statistical optimization in a space of operators
- In the optimization, it is fixed a family of useful operators that have a standard representation
- The complexity of the optimization depends on the size of the family of operators considered

Design of Image Operators

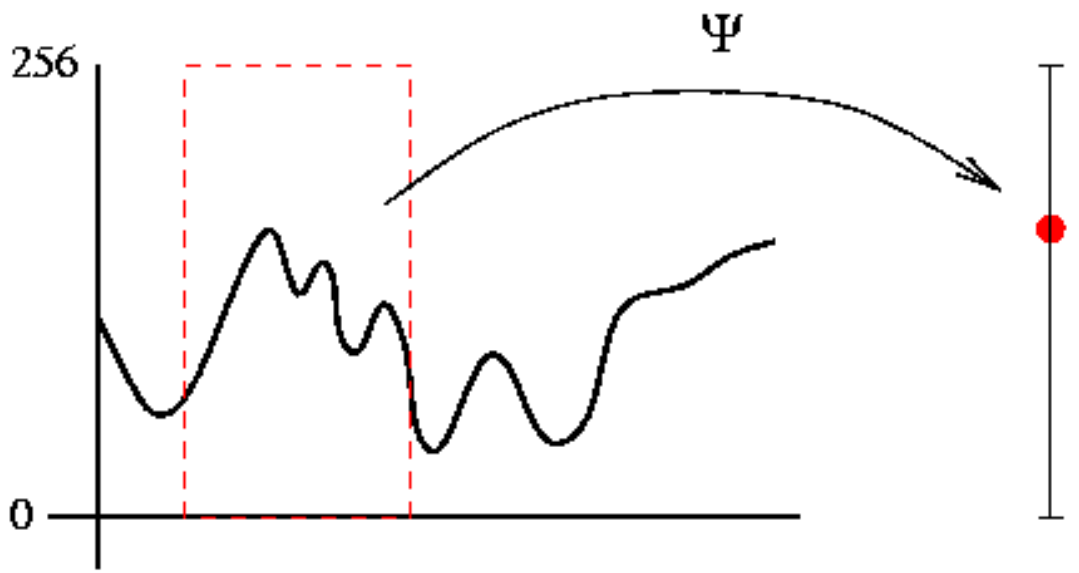
- In the **binary** case, the family of W-operators is usually considered
- The family of **binary** W-operators has $2^{2^{|W|}}$
- In the **gray-scale** case, the family of W-operators is also usually considered
- The family of **gray-scale** W-operators has $l^{m^{|W|}}$
- In **ordinary** applications ***l=m=256***

Design of Aperture Operators

- The family of **Aperture operators** depends on a spatial window ***W*** and a gray-scale window ***K***
- The **family** of aperture filters has $k^{k^{|W|}}$
- The **complexity** of the optimization problem is controlled by ***k*** and $|W|$
- The values of ***k*** and $|W|$ depends on the problem: $k=3, 5, 7, \ldots$ and $|W| = 9, 25, 49, \ldots$

Characteristic Functions

$$\psi : L^W \rightarrow M$$



Design of Aperture Operators

K-characteristic functions

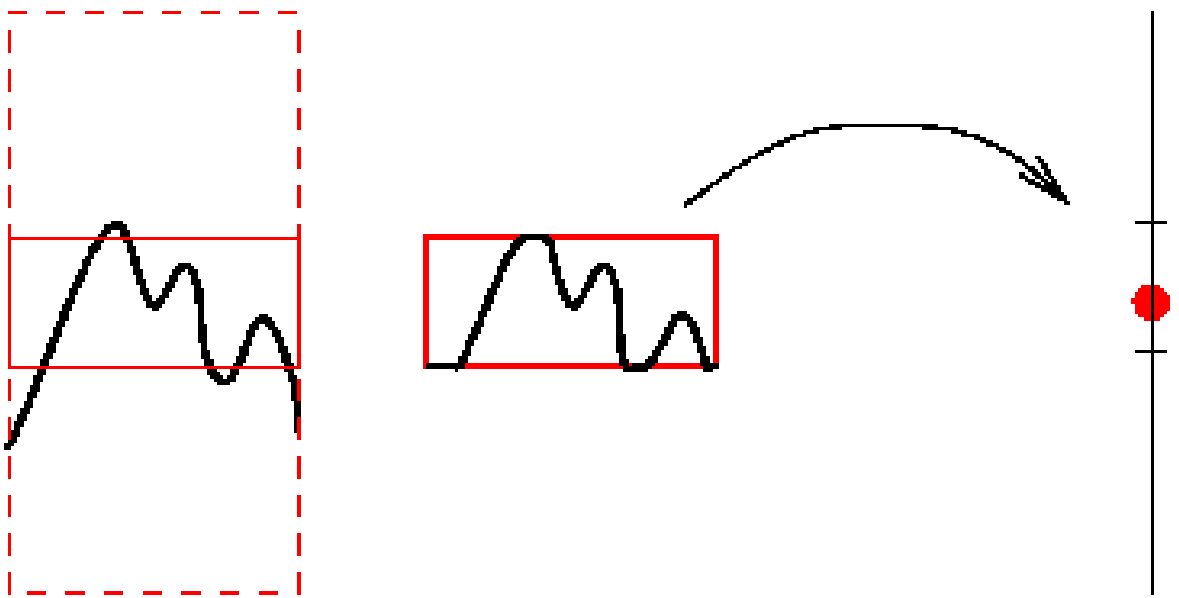
- **Gray-scale translation:** $(u + y)(z) = u(z) + y$

- **Gray-scale window:** $\left\{-\frac{k-1}{2},\ldots,-1,0,1,\ldots,\frac{k-1}{2}\right\}$

Design of Aperture Filters

Windowing in the space and range

$$(u / K_y)(z) = \bigcap \left\{ \bigcup \left\{ -\frac{k-1}{2}, u(z) - y \right\}, \frac{k-1}{2} \right\}$$



Design of Aperture Operators

- **gray-scale t. i.:** $\psi(u + y) = \psi(u) + y$
- **locally defined in K:** $\psi(u) = u(o) + \beta_{u(o)}\left(u / K_{u(o)}\right)$
- **representation:** $\psi(u) = u(o) + \beta_{\psi}\left(u / K_{u(o)}\right)$

β_ψ

2	-2	1	2	2	2
1	-2	1	2	2	2
0	-2	1	2	2	2
-1	-2	1	1	1	1
-2	-2	-2	-2	-2	-2
	-2	-1	0	1	2

ψ = $u(o)$ + β_ψ

14	12	13	14	15	16
13	12	13	14	15	15
12	12	13	14	14	12
11	12	13	13	11	12
10	12	12	10	11	12
	10	11	12	13	14

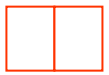
=

14	10	11	12	13	14
13	10	11	12	13	14
12	10	11	12	13	14
11	10	11	12	13	14
10	10	11	12	13	14
	10	11	12	13	14

+

14	2	2	2	2	2
13	2	2	2	2	1
12	2	2	2	1	-2
11	2	2	1	-2	-2
10	2	1	-2	-2	-2
	10	11	12	13	14

Aperture Operators

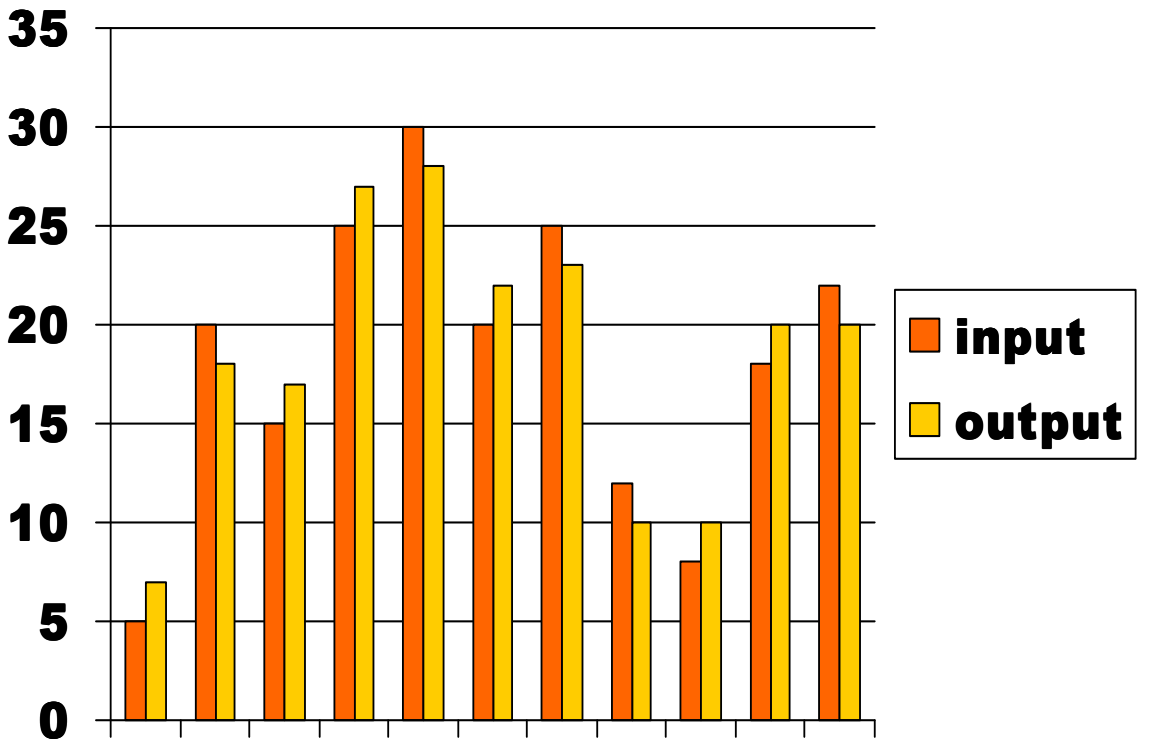
W 

$$K = \{-2,-1,0,1,2\}$$

β_ψ

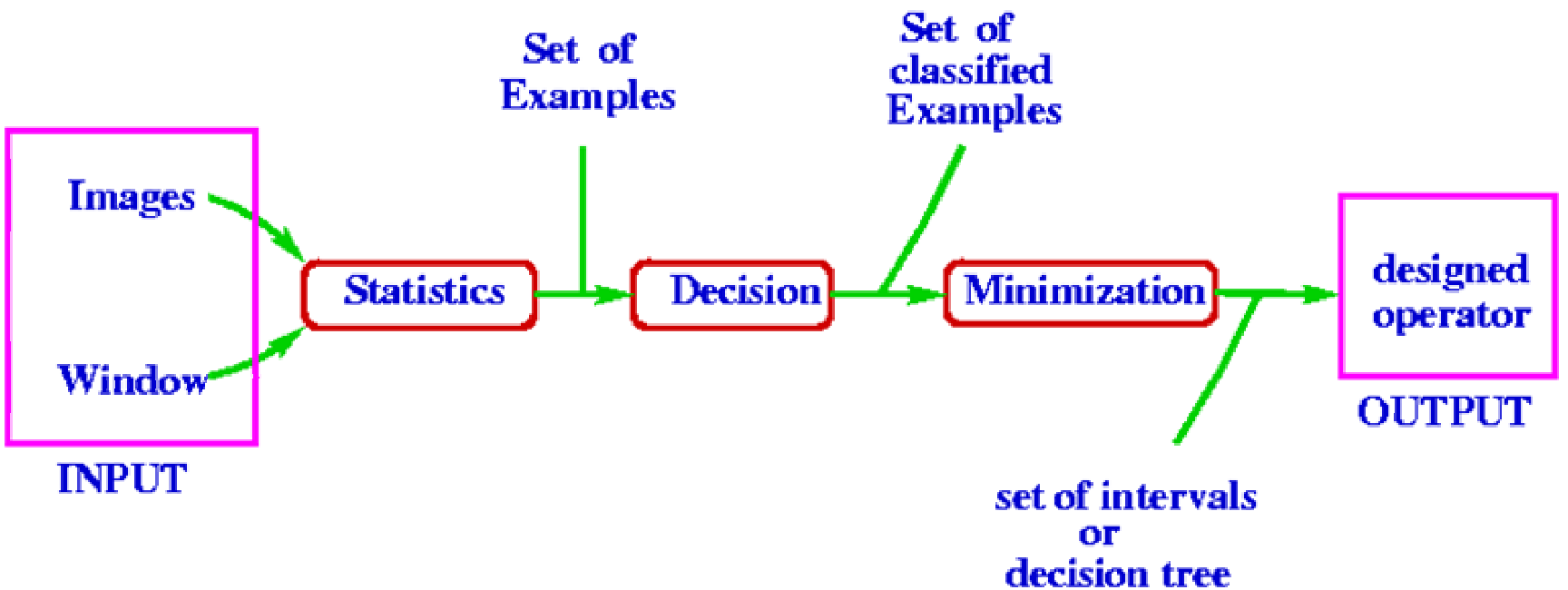
2	-2	1	2	2	2
1	-2	1	2	2	2
0	-2	1	2	2	2
-1	-2	1	1	1	1
-2	-2	-2	-2	-2	-2
	-2	-1	0	1	2

Ψ



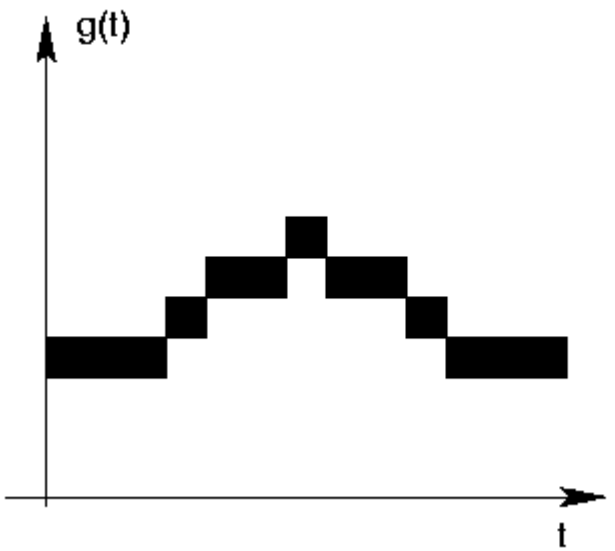
Design of Aperture Operators

Learning System

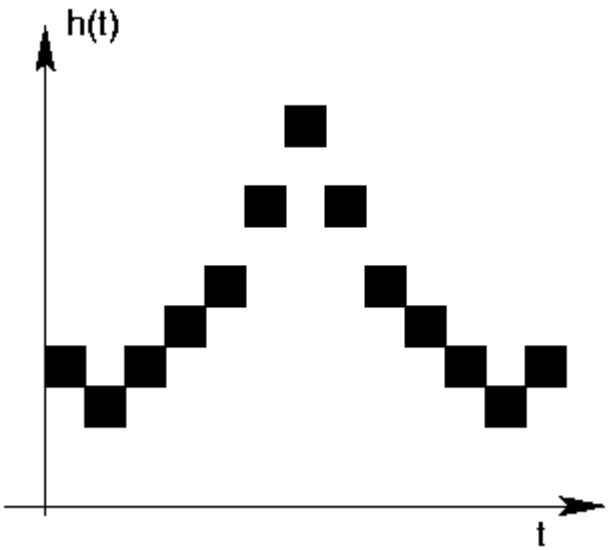


Design of Aperture Operators

Observed



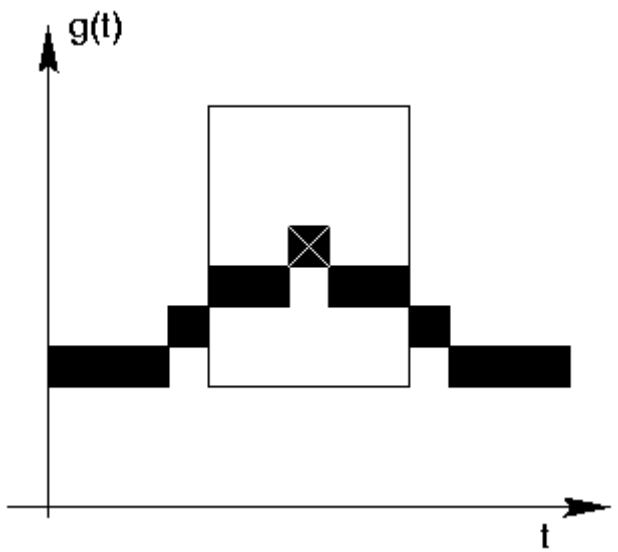
Ideal

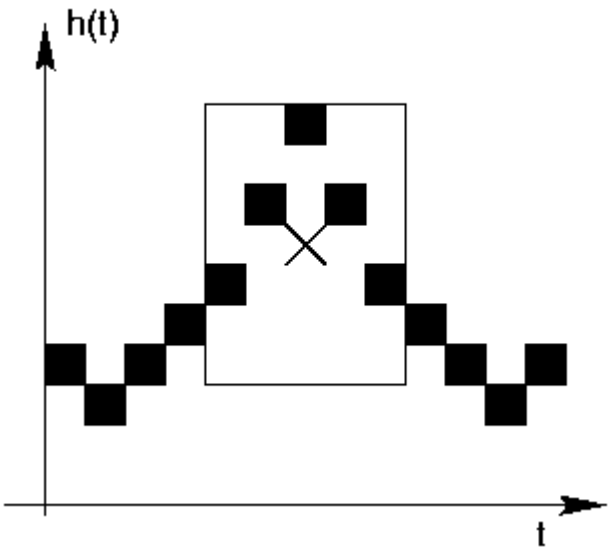


Design of Aperture Operators

Windowing observed

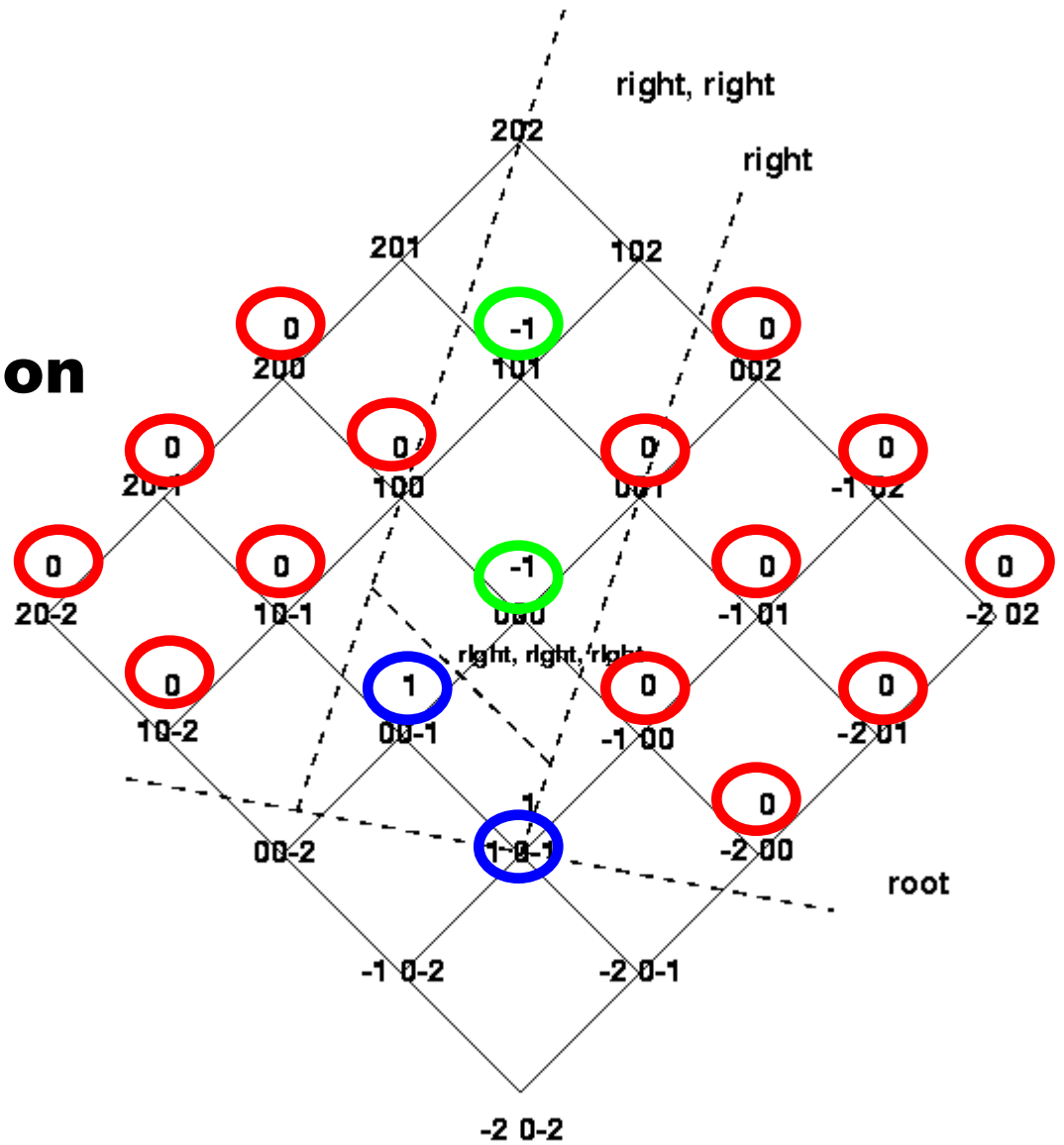
The center of the window seen at the same position in the Ideal





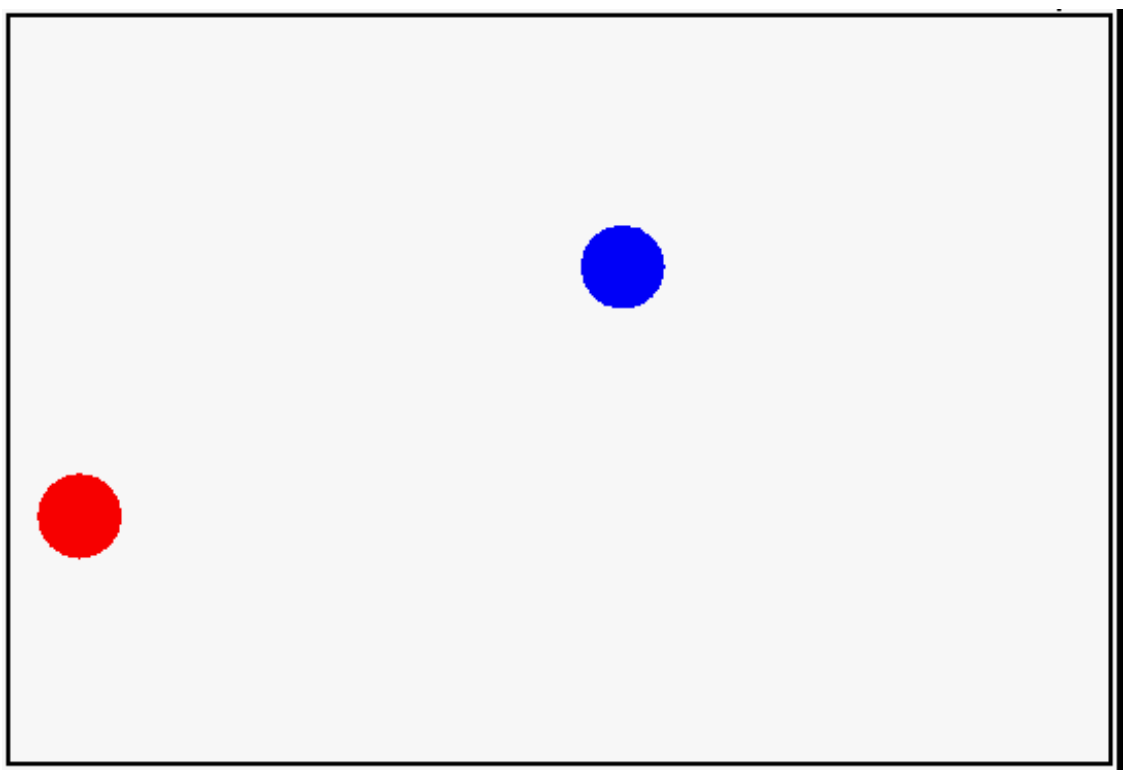
One representation of Aperture Operators

Lattice representation of the kernel of the operator



The proposed technique

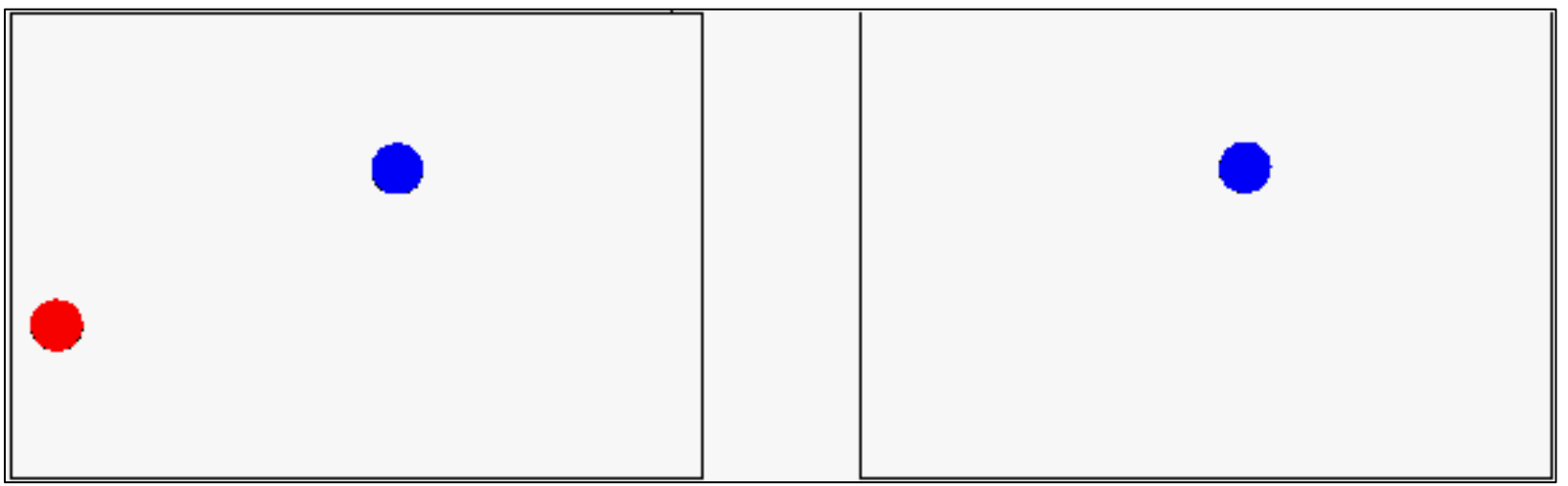
Automatic design of morphological operators for Motion Segmentation



The proposed technique

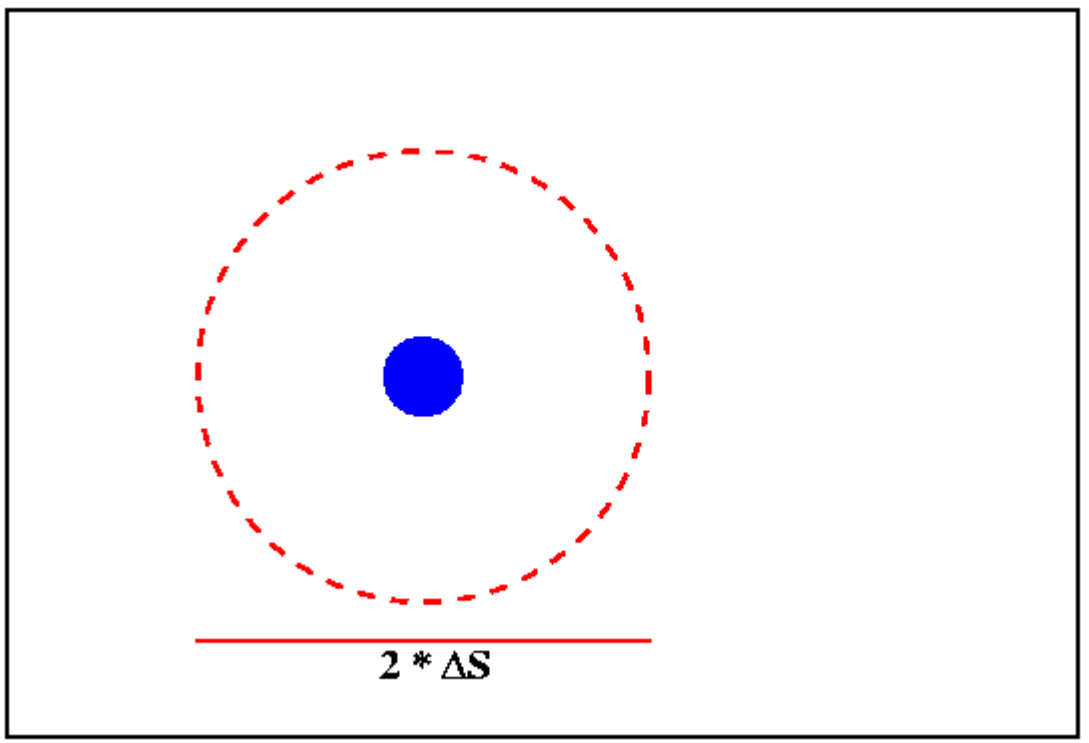
Some frames are segmented and used to train an operator

Observed → Ideal



Applying the proposed technique

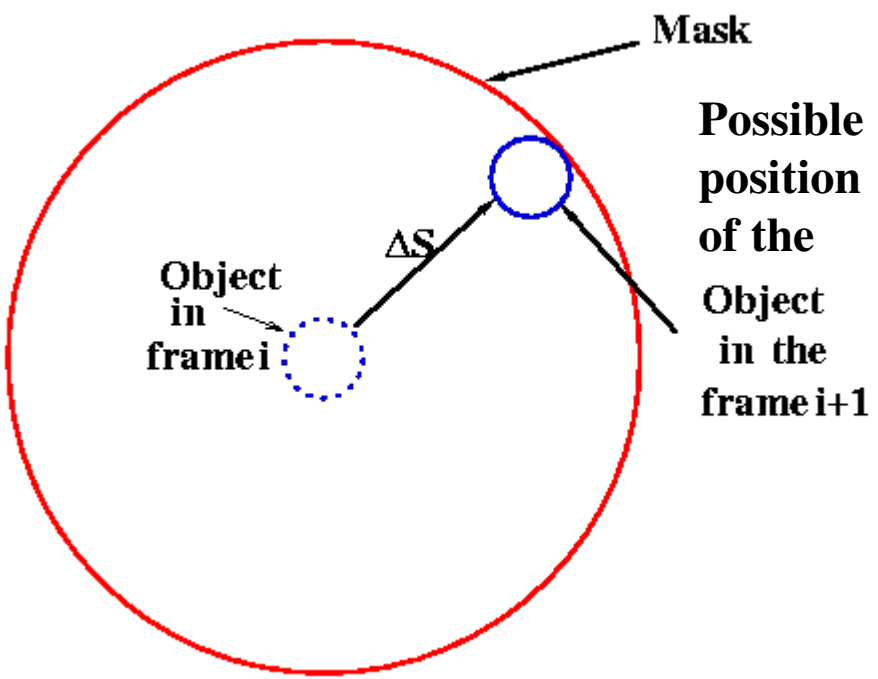
The first frame of the sequence is segmented manually



The speed of the object is also a parameter

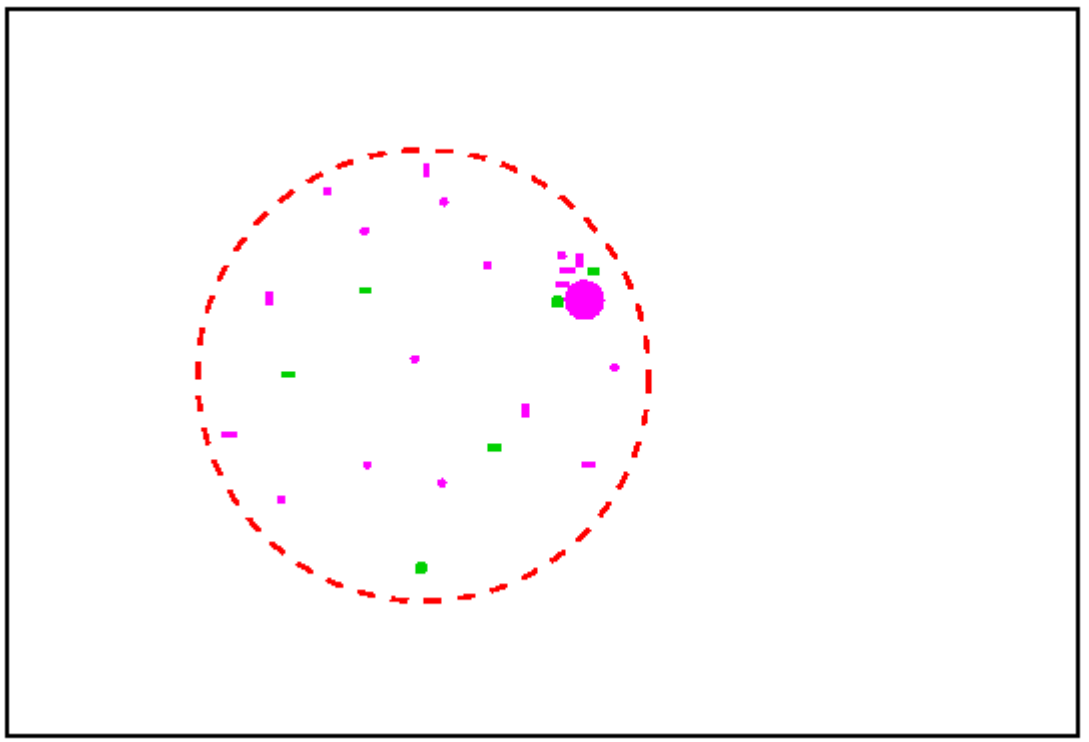
Applying the proposed technique

The position of the object in the first frame plus its speed determine the application mask for the next frame



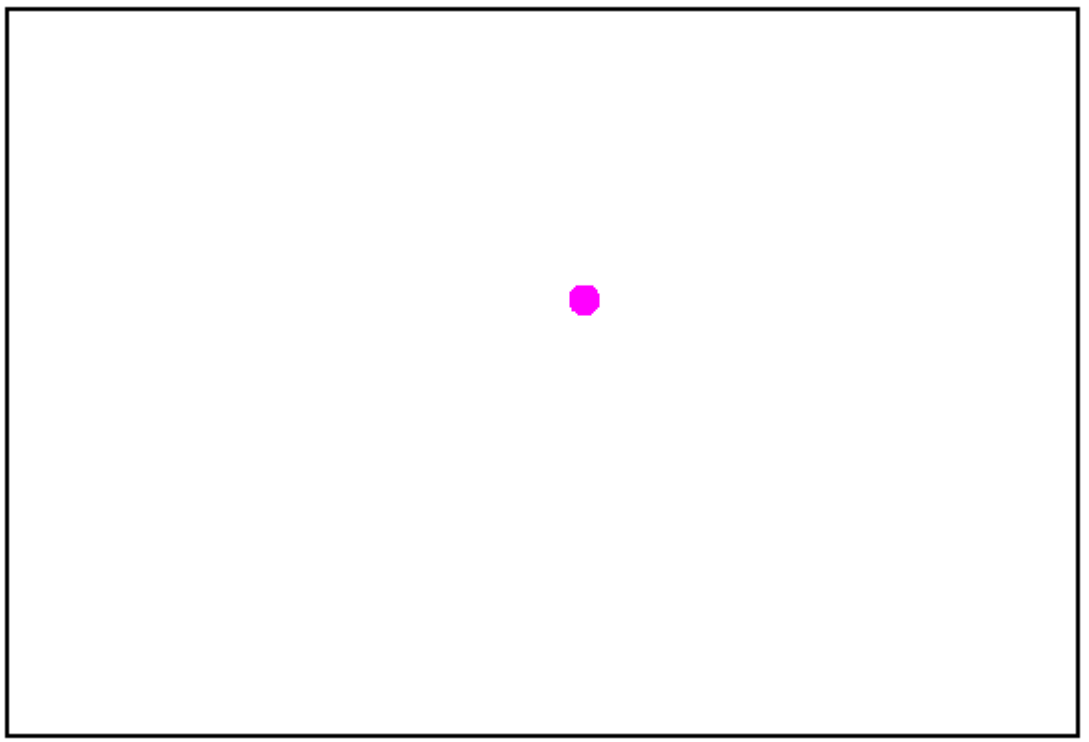
Applying the proposed technique

The operator is applied inside the application mask



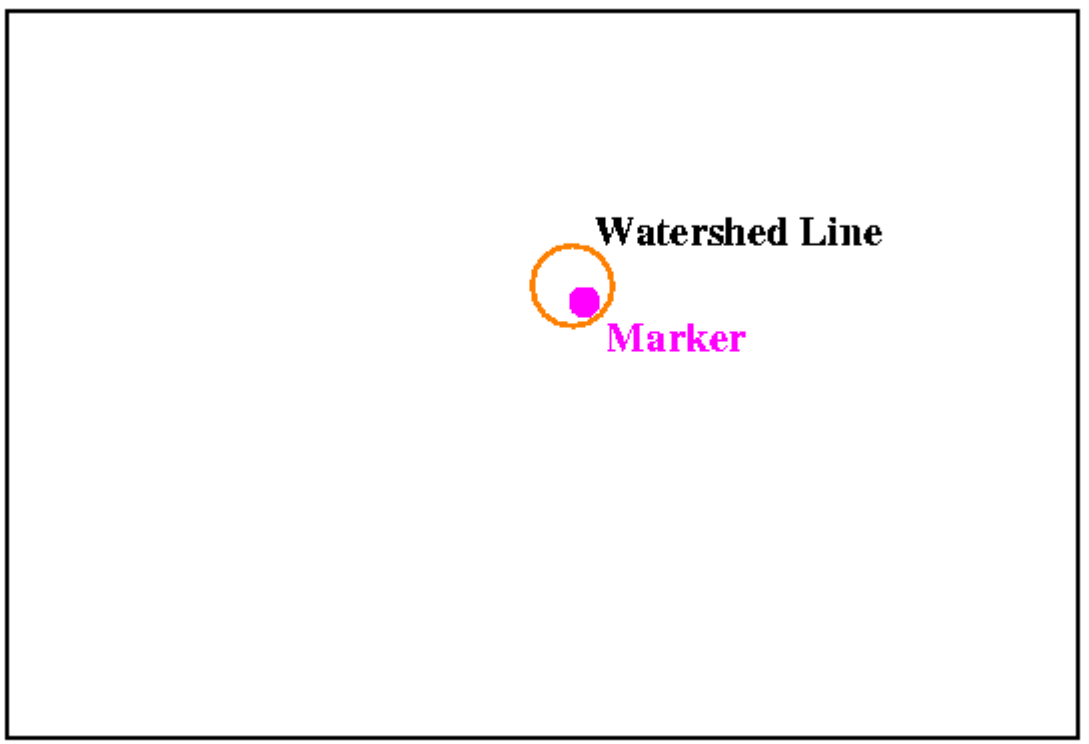
Applying the proposed technique

The result is filtered (area opening)



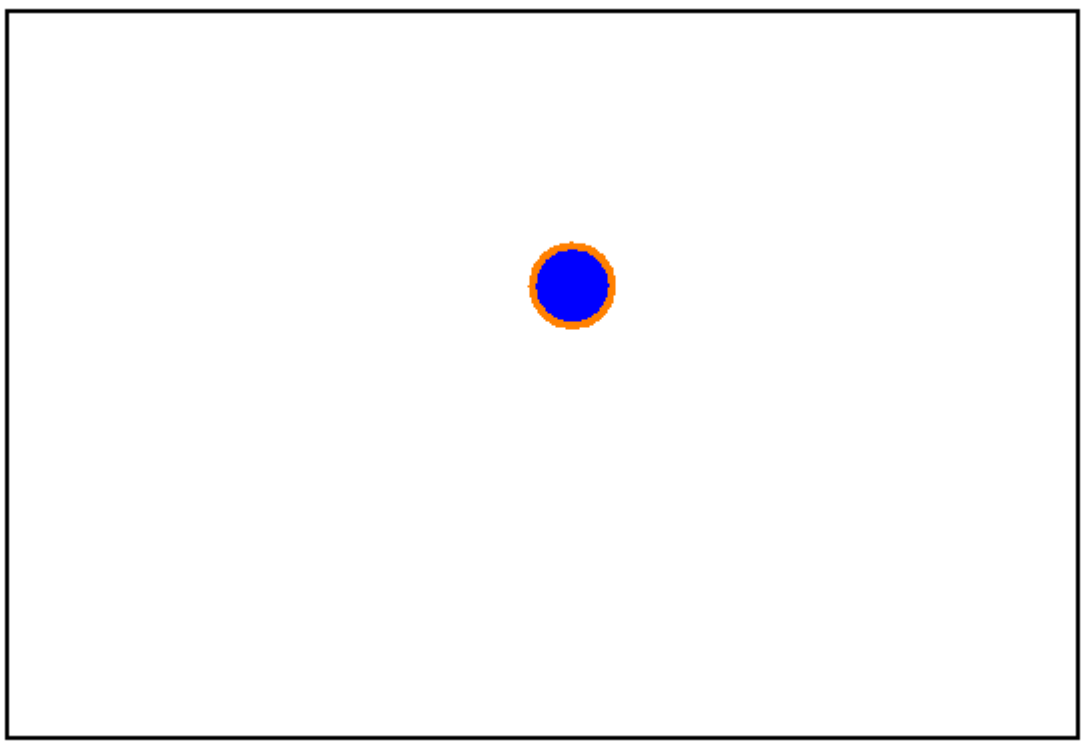
The proposed technique

Beucher-Meyer paradigm is applied



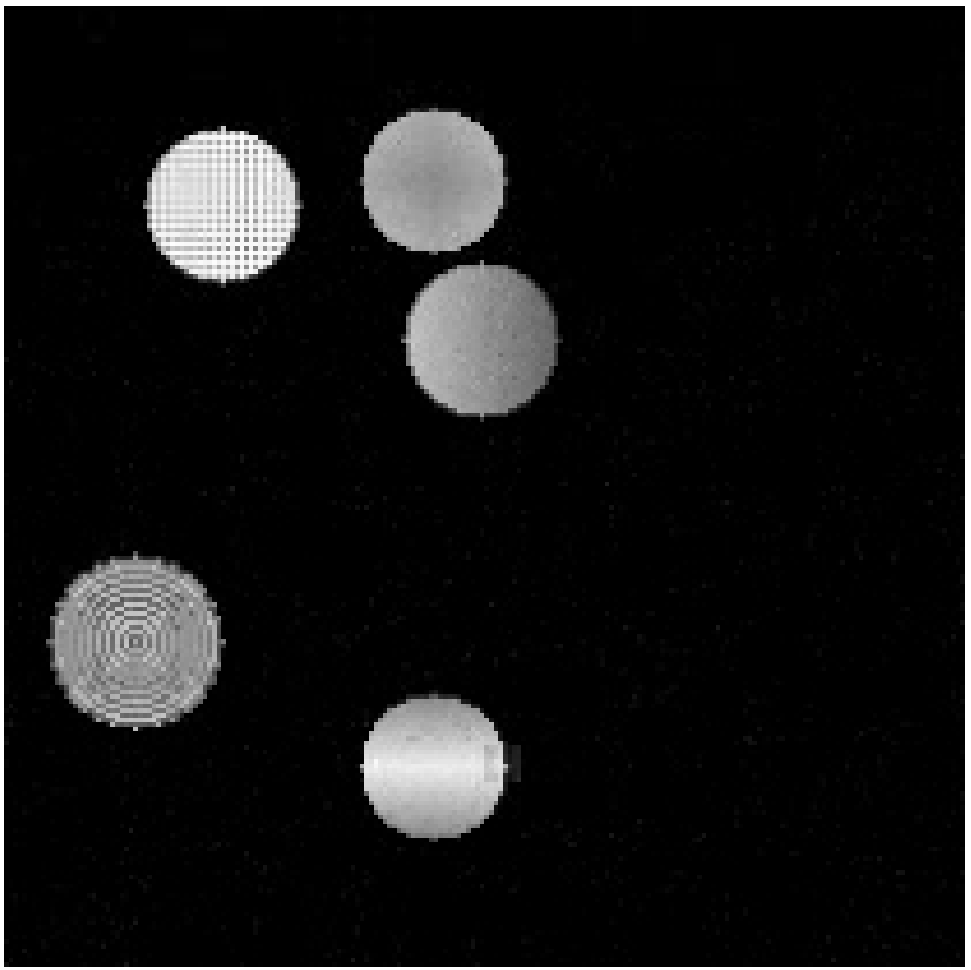
The proposed technique

The segmented object can be substituted or analysed



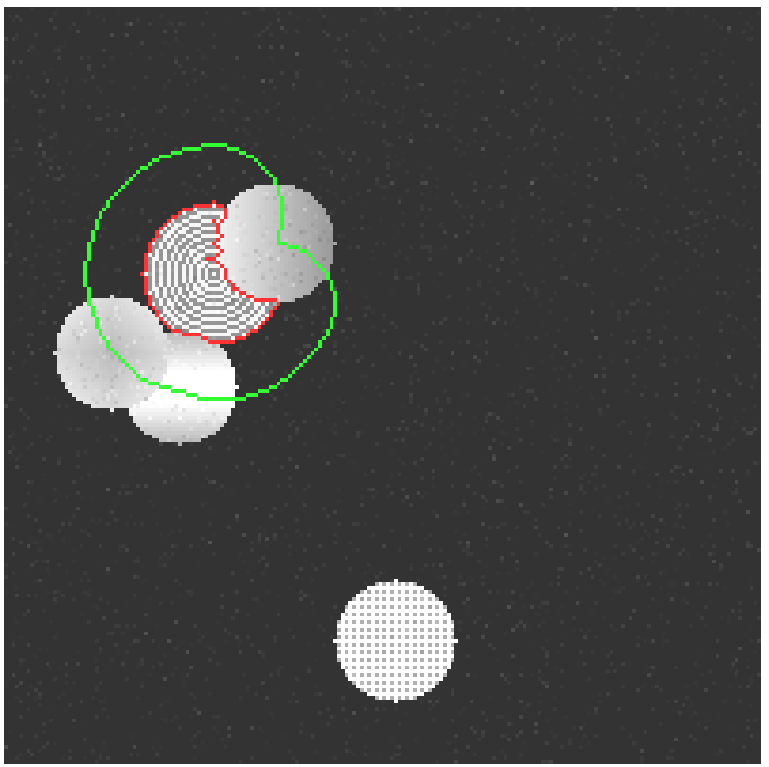
Applications - simulation

Tracking disks

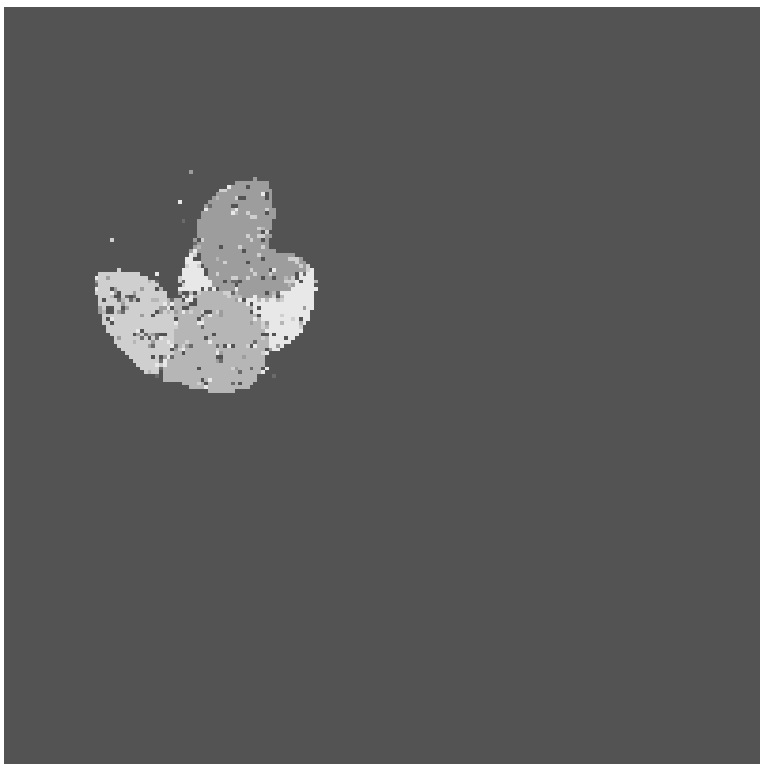


Applications

Mask

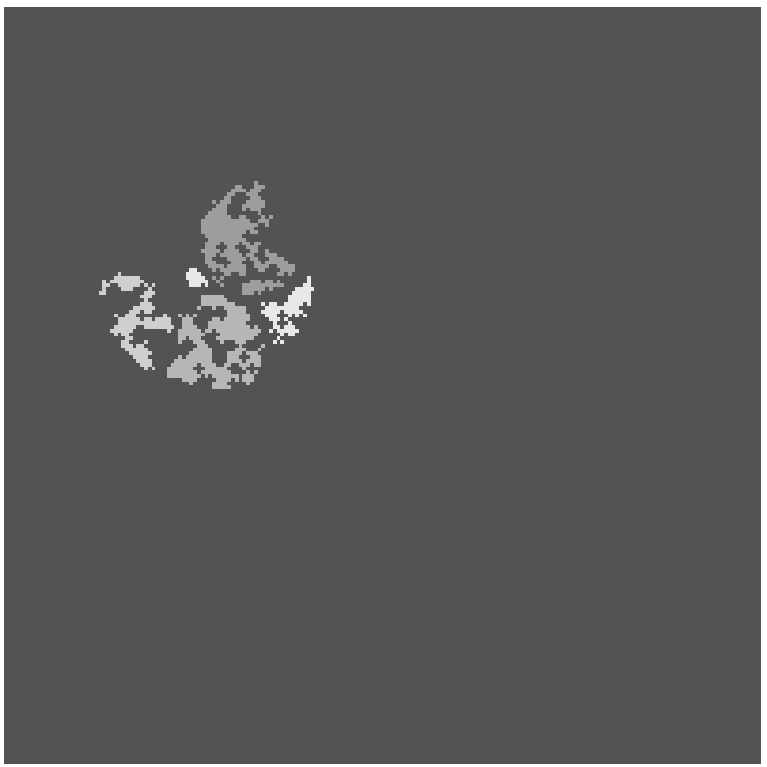


Result of the application

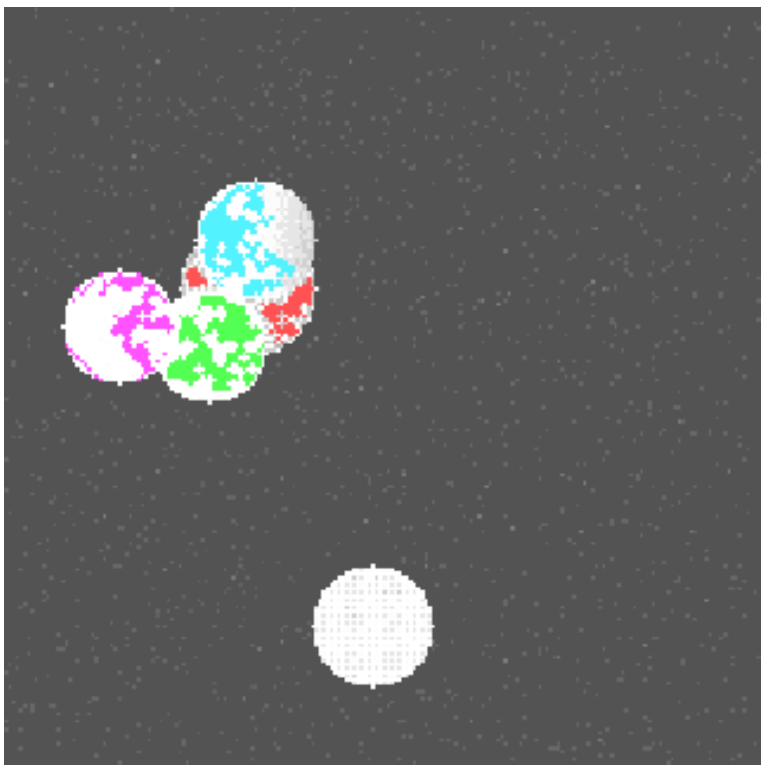


Applications

Result of the connected filter



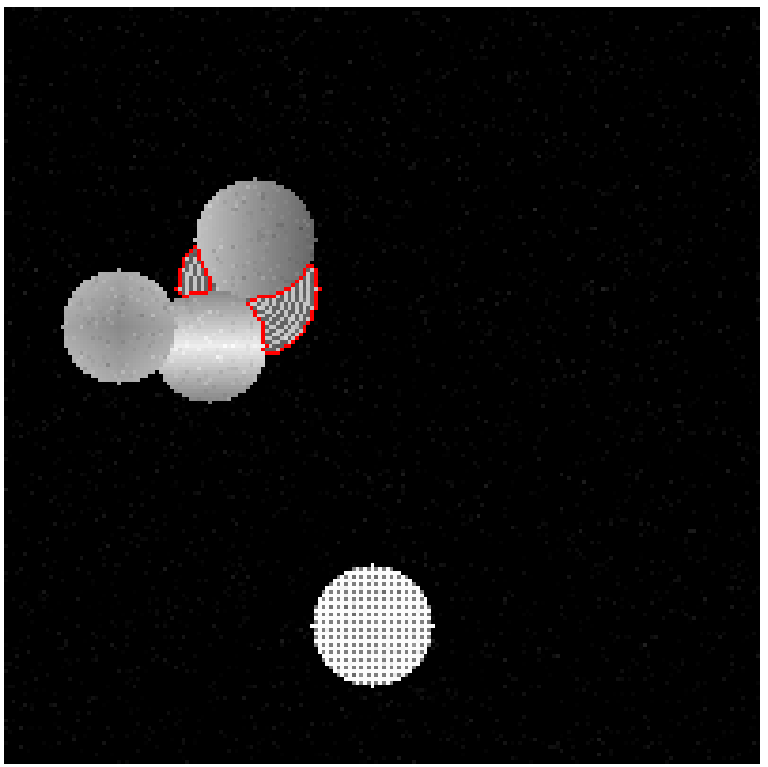
Composition



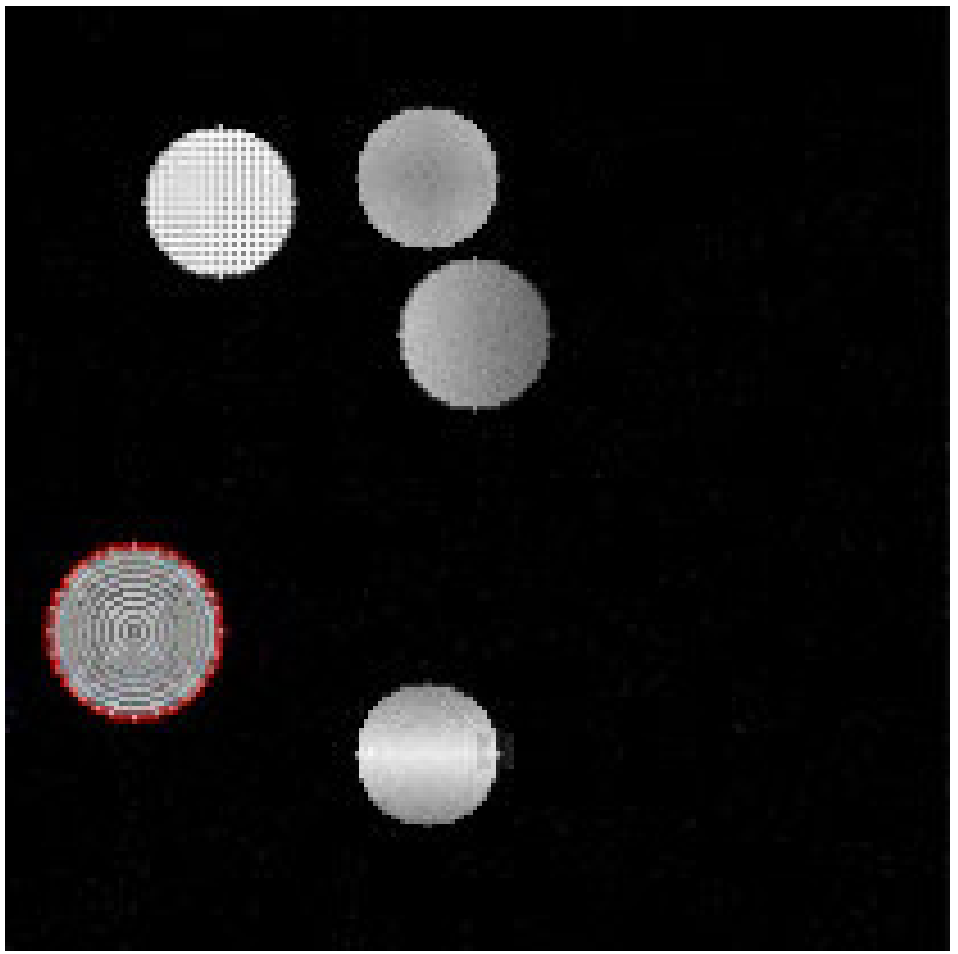
Applications

Watershed regions

Composed Result



Applications - tracking one disk



Applications

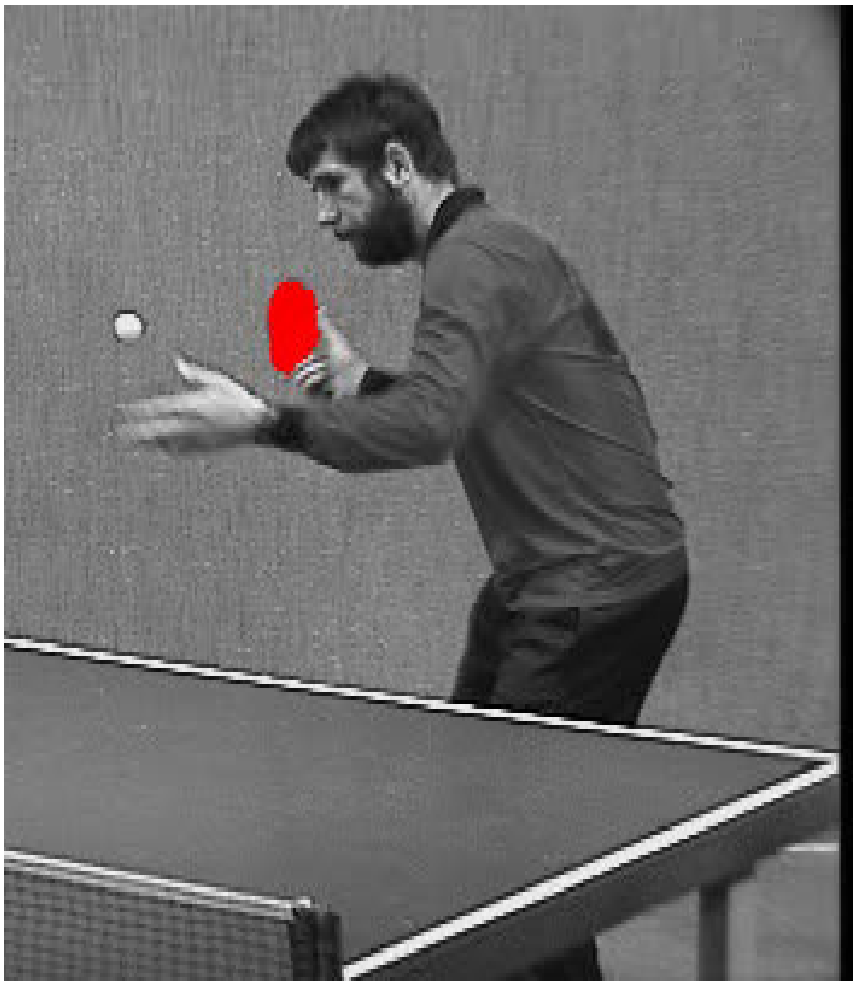
Tracking a table tennis ball

Two problems have been explored in this sequence

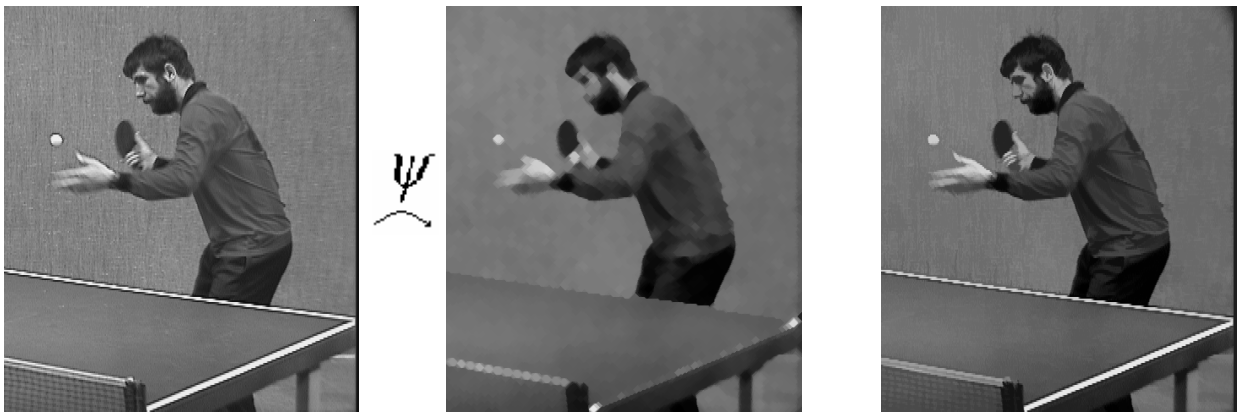
- **Track the ball**
- **Track the racquet**

Applications - Tracking the ball

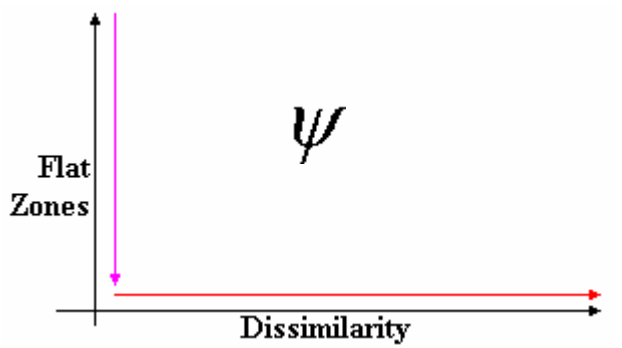
Applications - Tracking the racquet



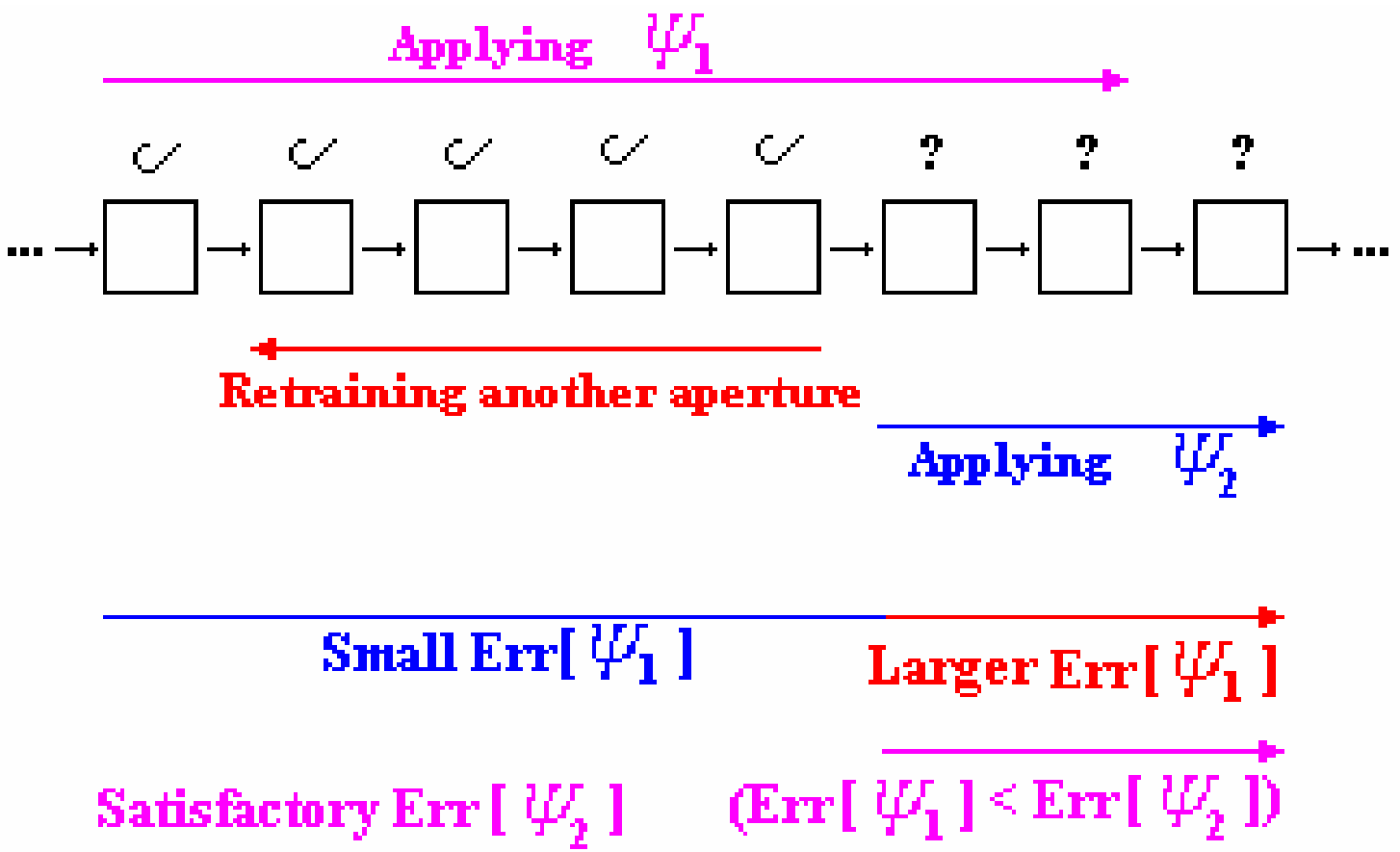
Future Research



Design of Aperture Operators for Image Simplification by Connected Filters

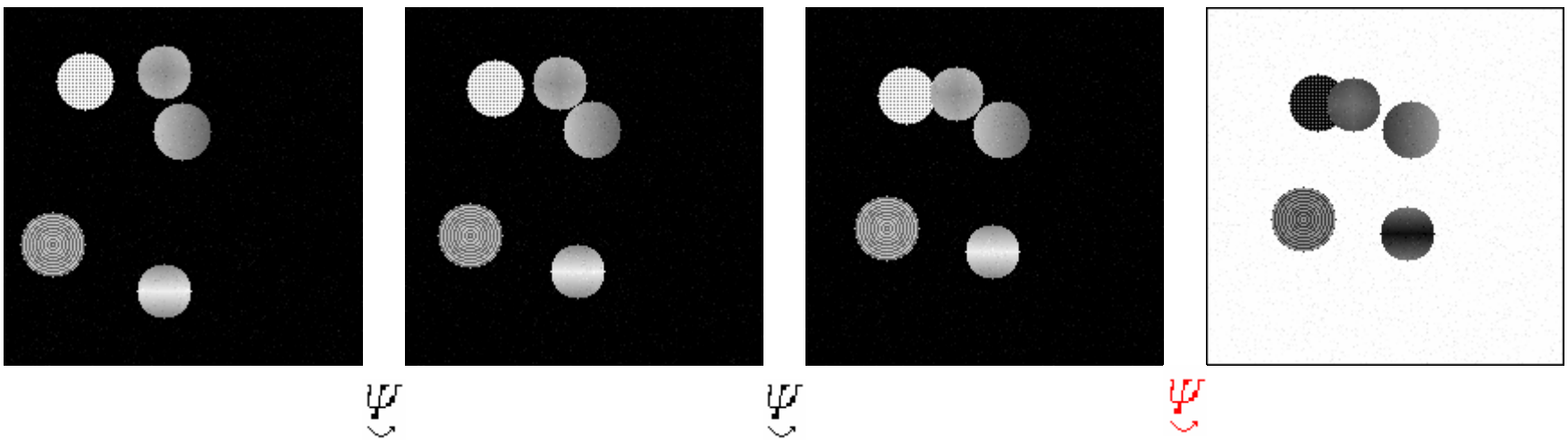


Future Research



Design of Adaptative Filters

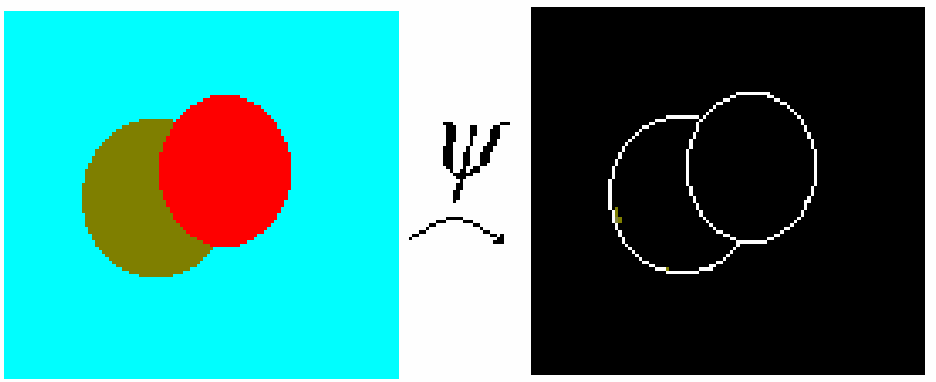
Future Research



Detection of Abrupt Changes in the Scene

Future Research

Design of Aperture Operators for Color Image

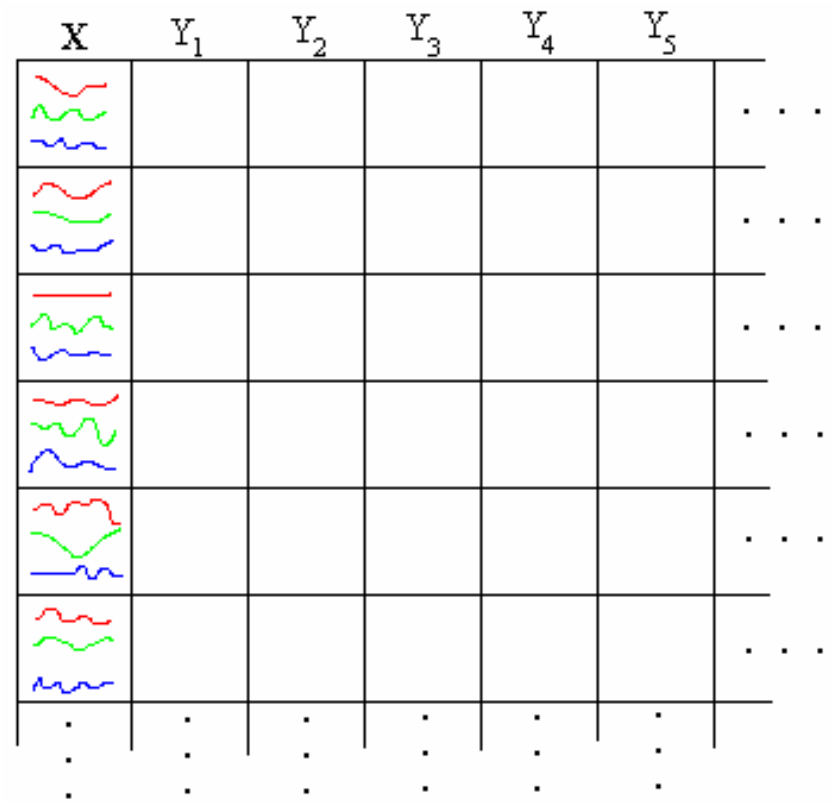


$N(x)$: neighbourhood of x

$d(a,b)$: a metric

$$\nabla G(x) = \max\{d(x, y): y \in N(x)\}$$

Future Research



Design of Aperture Operators for Color Image

Correlation