Some Applications of Aperture Filters

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Outline

- Introduction
- Aperture Operators
- Statistical Design of Image Operators
- Apertures for Deblurring
- Resolution Enhancement
- Markers for Segmentation

Introduction

- 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

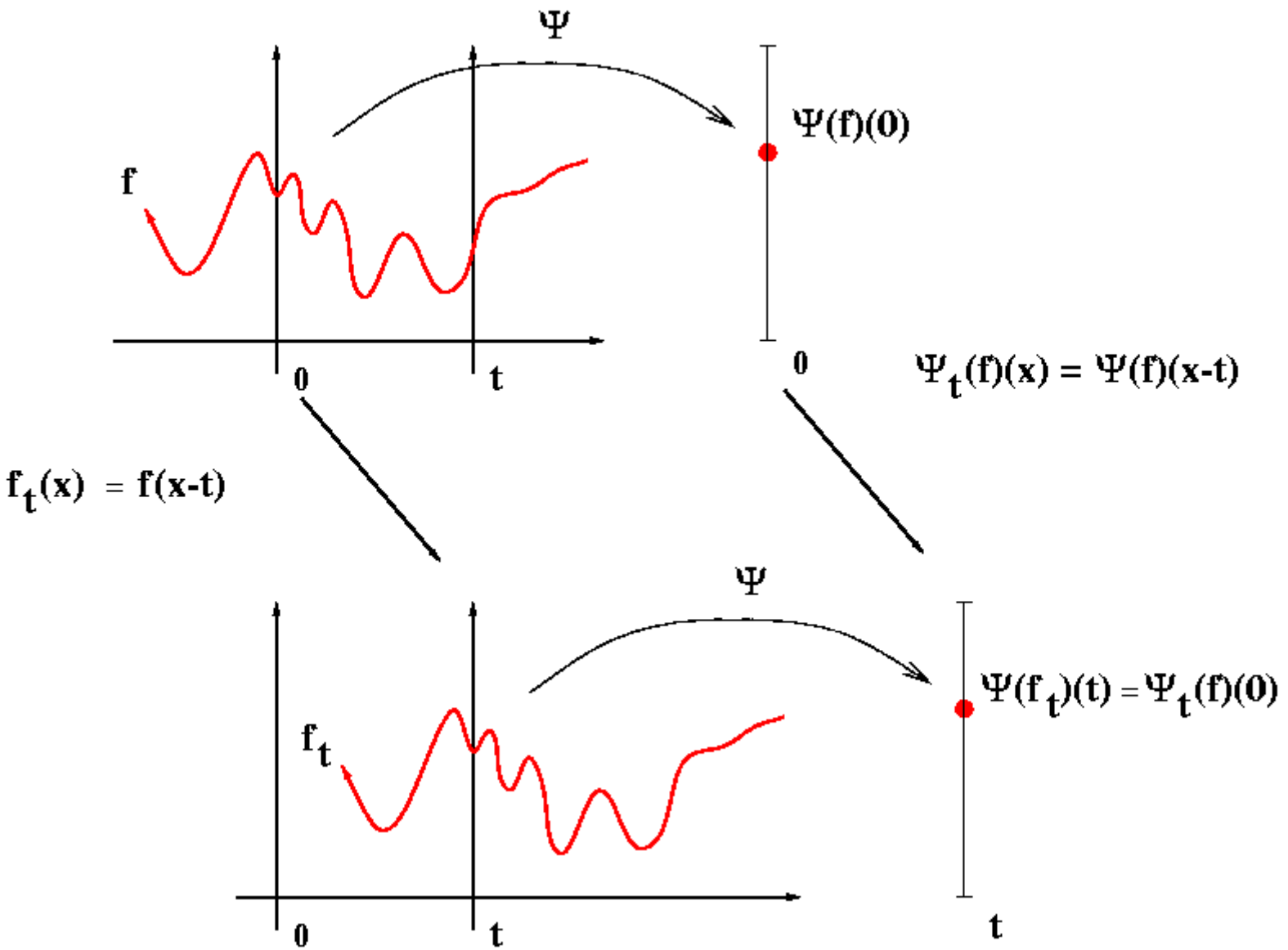
Introduction

- 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

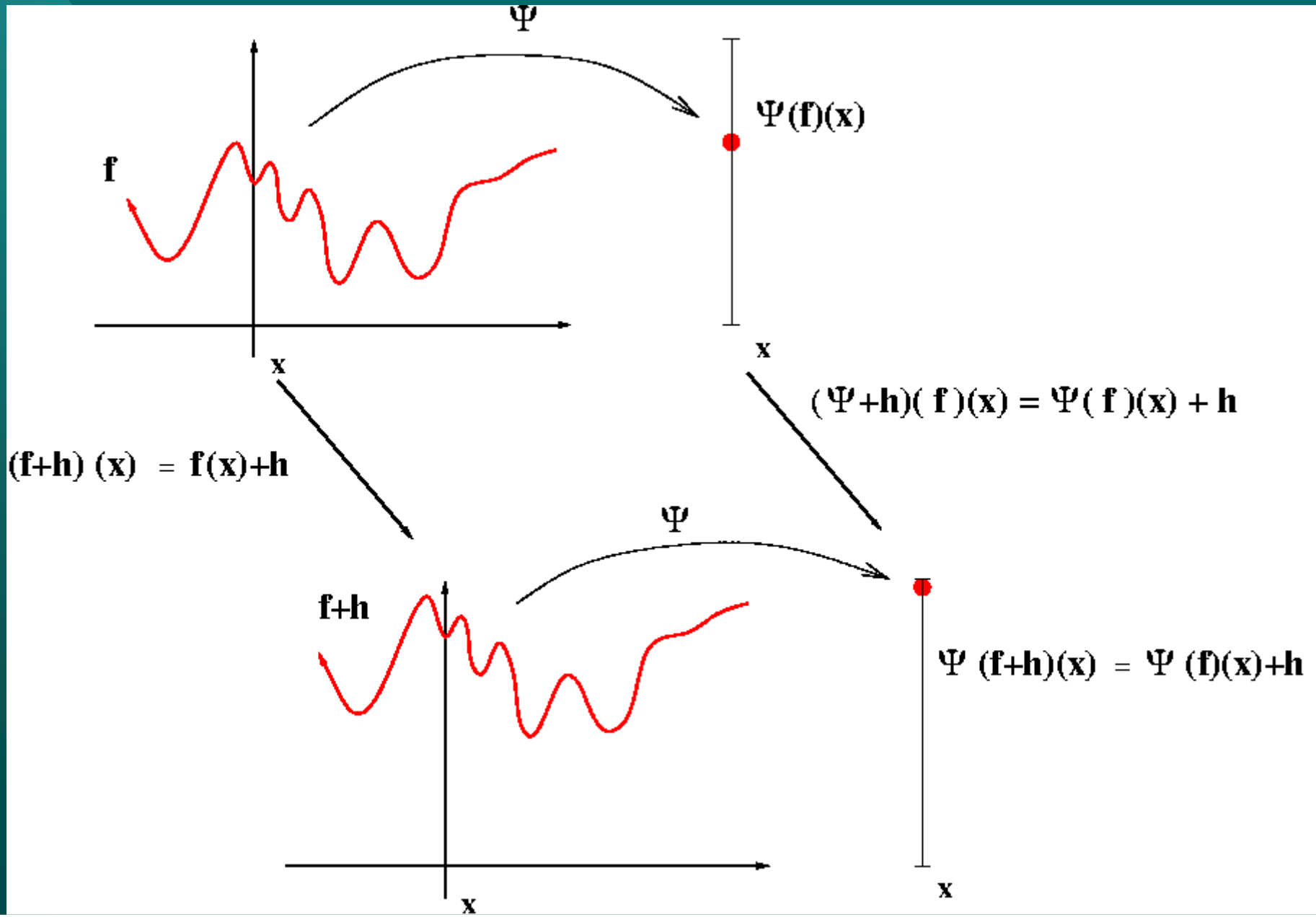
Introduction

- The family of **Aperture operators** depends on a spatial window **W** and a gray-scale window **K=[-k,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, ... and |W| = 9, 25, 49, ...

Aperture Operators - Horizontal Translation Invariance

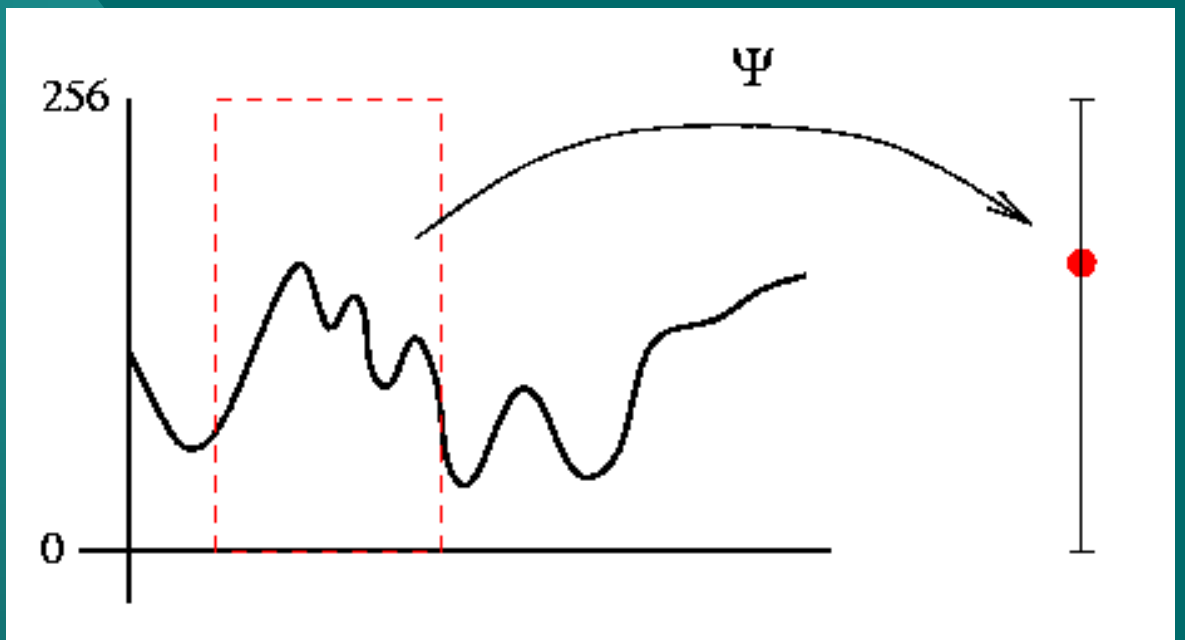


Aperture Operators - Vertical Translation Invariance



Aperture Operators

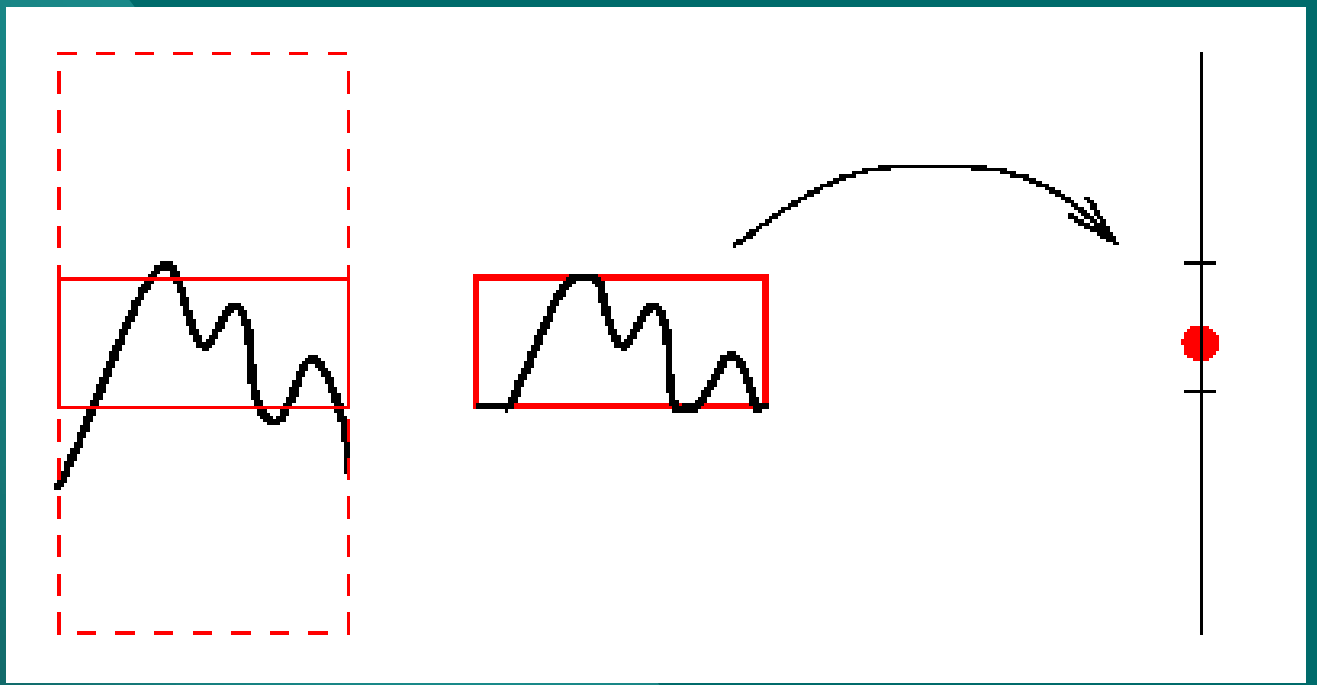
- Locally defined in W



$$\Psi(f)(x) = \Psi(f / W_x)(x)$$

Aperture Operators

- Locally defined in W and K



$$(u / K_y)(z) = \wedge\{\vee\{-k, u(z) - y\}, k\}$$

Aperture Operators

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

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

$=$

$u(o)$

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

$+$

β_ψ

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

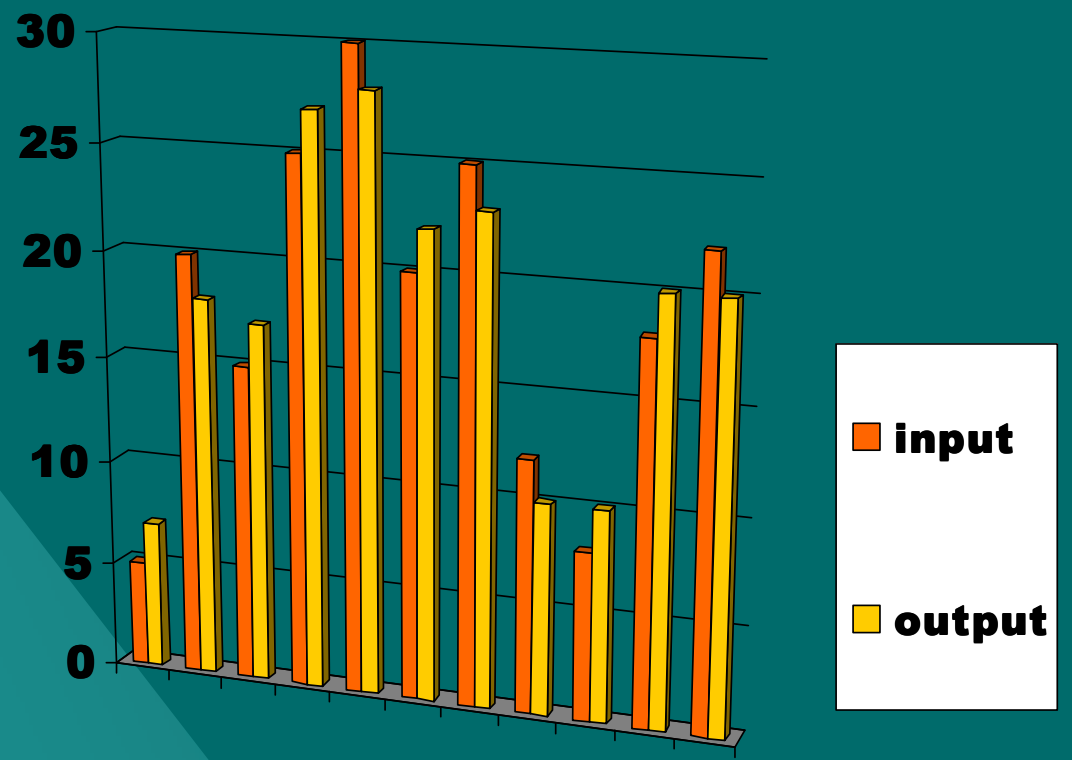
Aperture Operators

W 

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

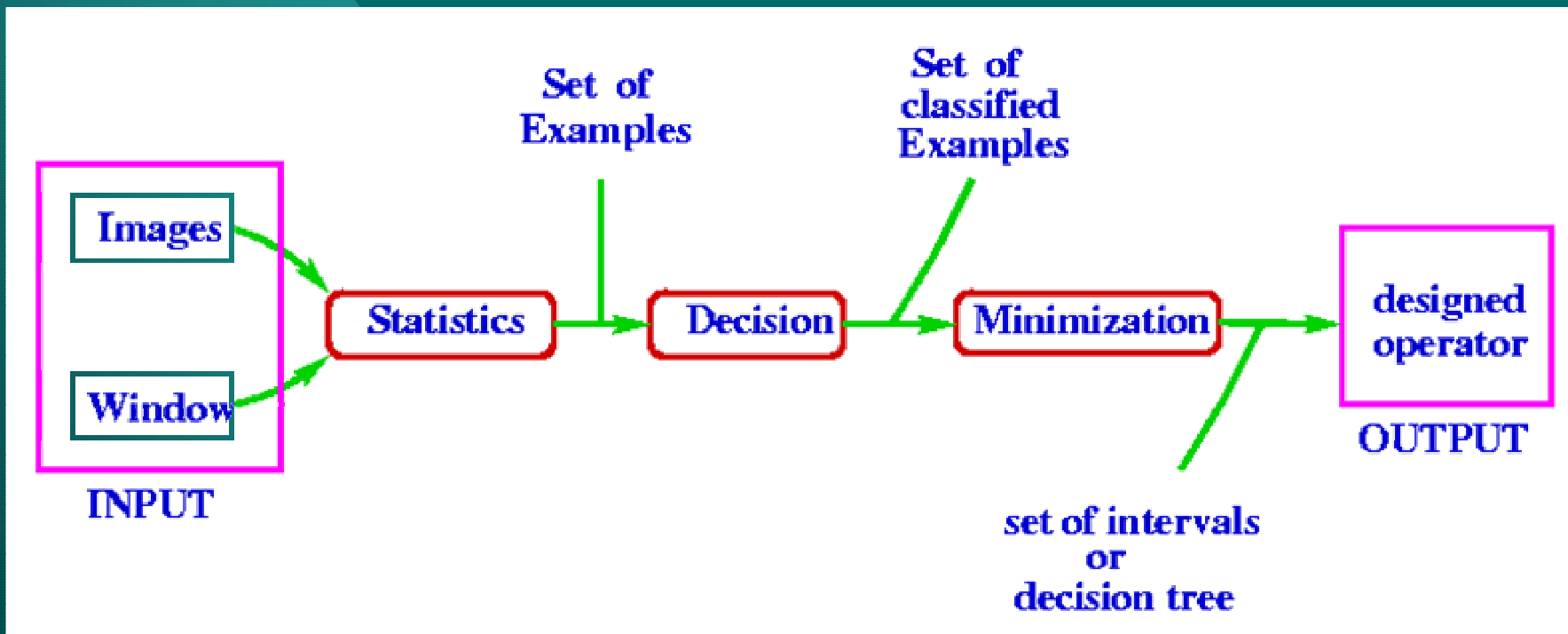
β_ψ

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



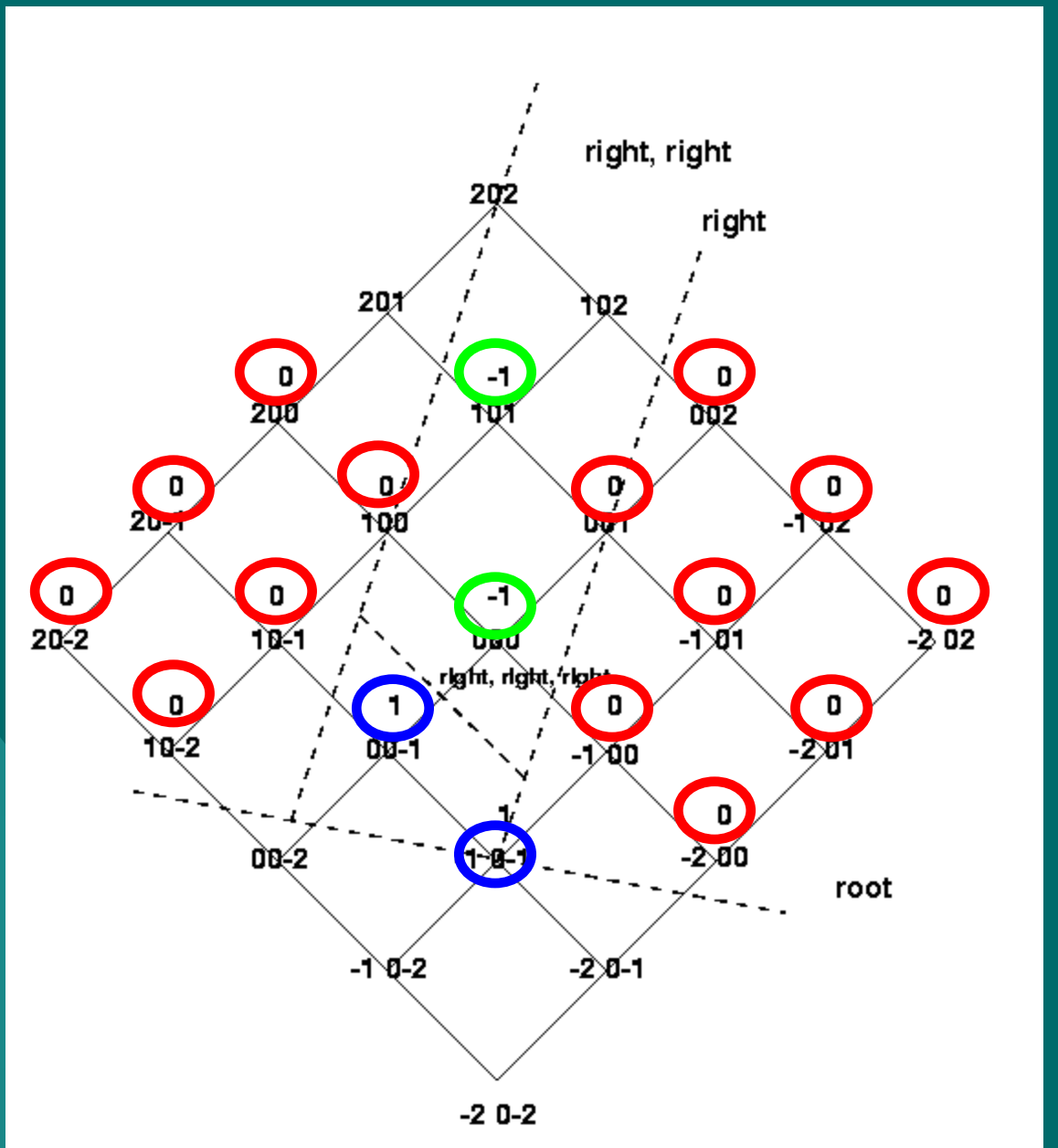
Design of Aperture Operators

Learning System



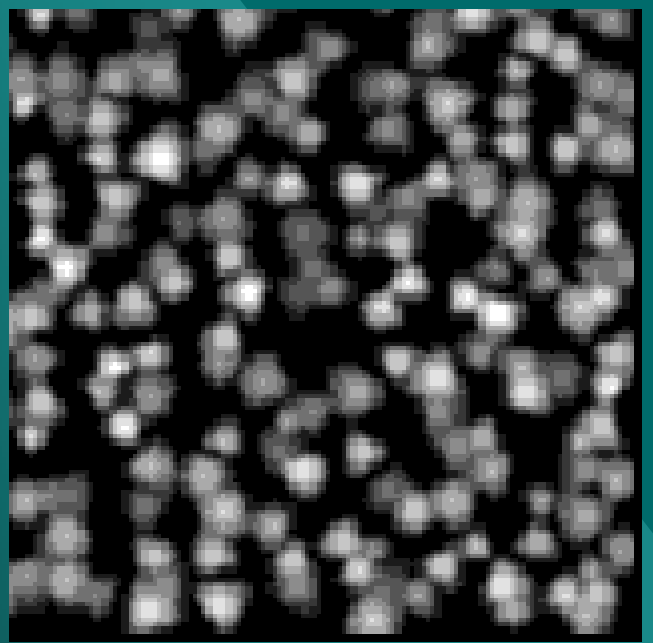
Design of Aperture Operators

Lattice representation of the kernel of the operator

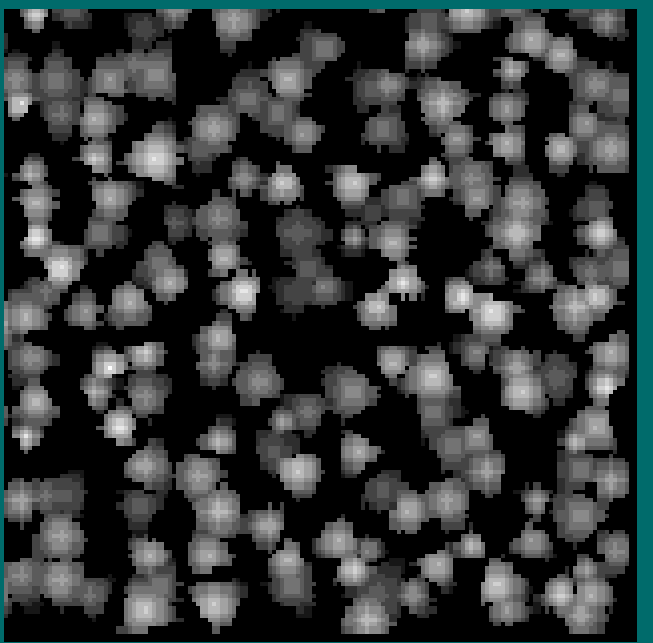


Apertures for Deblurring

Observed

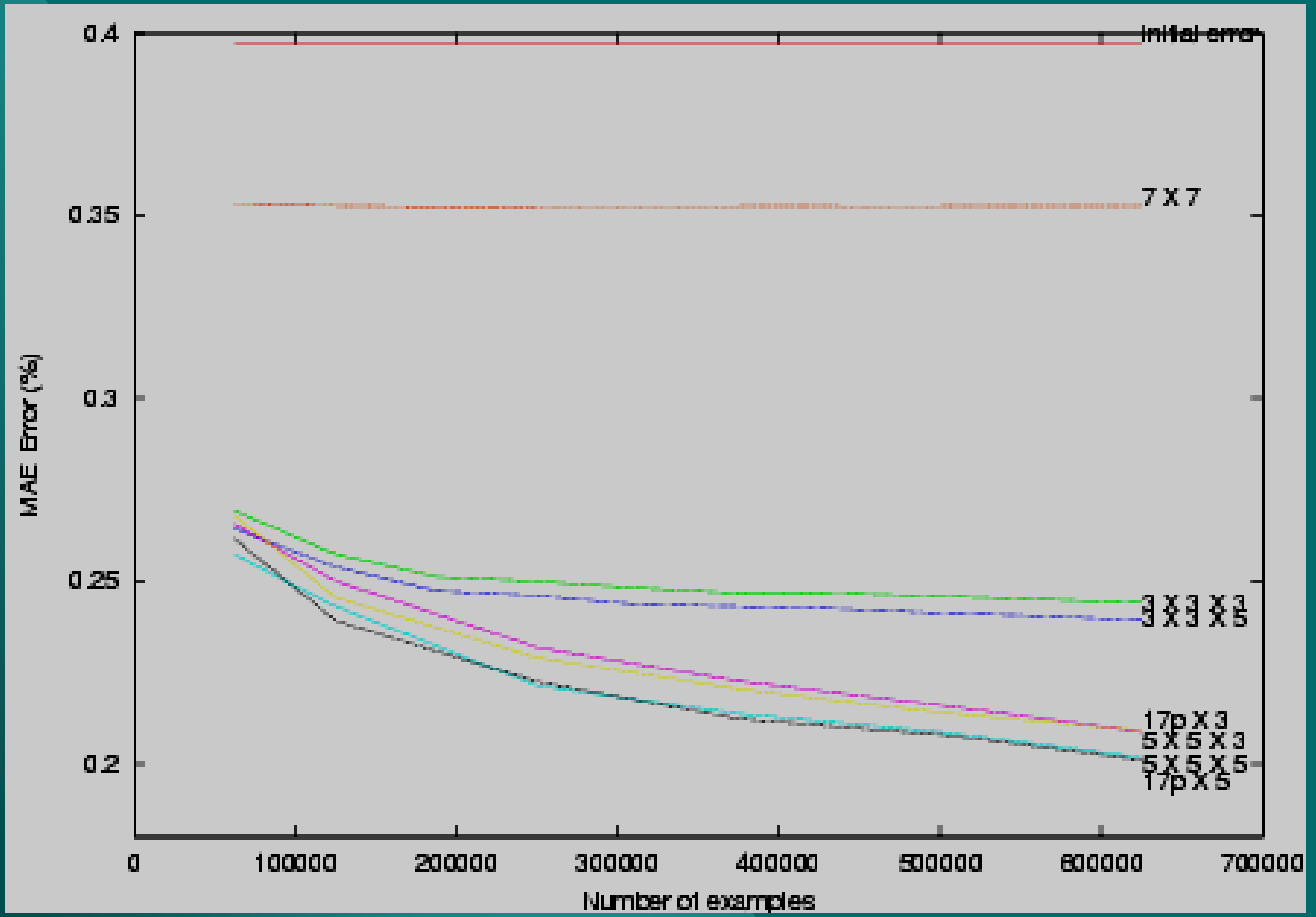


Ideal



These are part of the observed and ideal images (512x512)

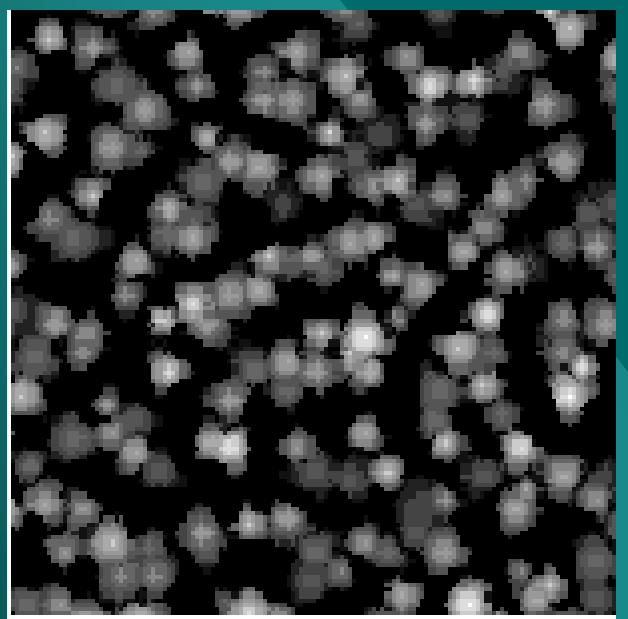
MAE x Number of Examples



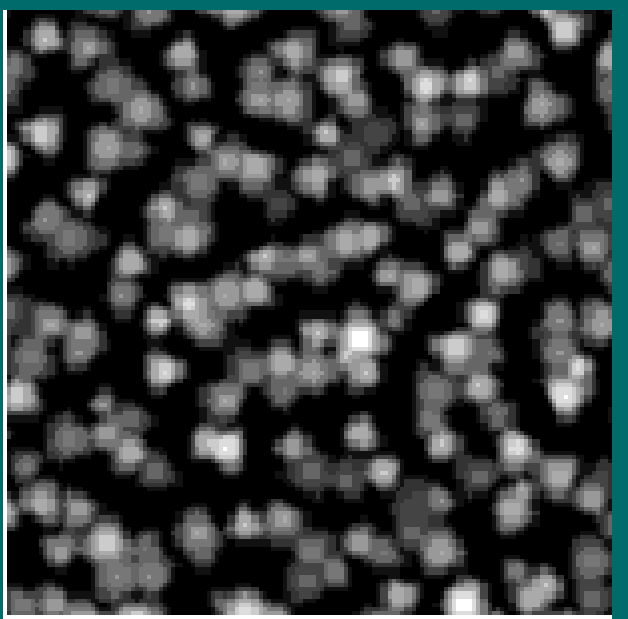
Apertures for Deblurring

Deblurring - Aperture x Optimal linear

Aperture 17p x 5 x 5



Optimal linear 7x7



Apertures for Deblurring

CBERS simulation

413x413

SPOT

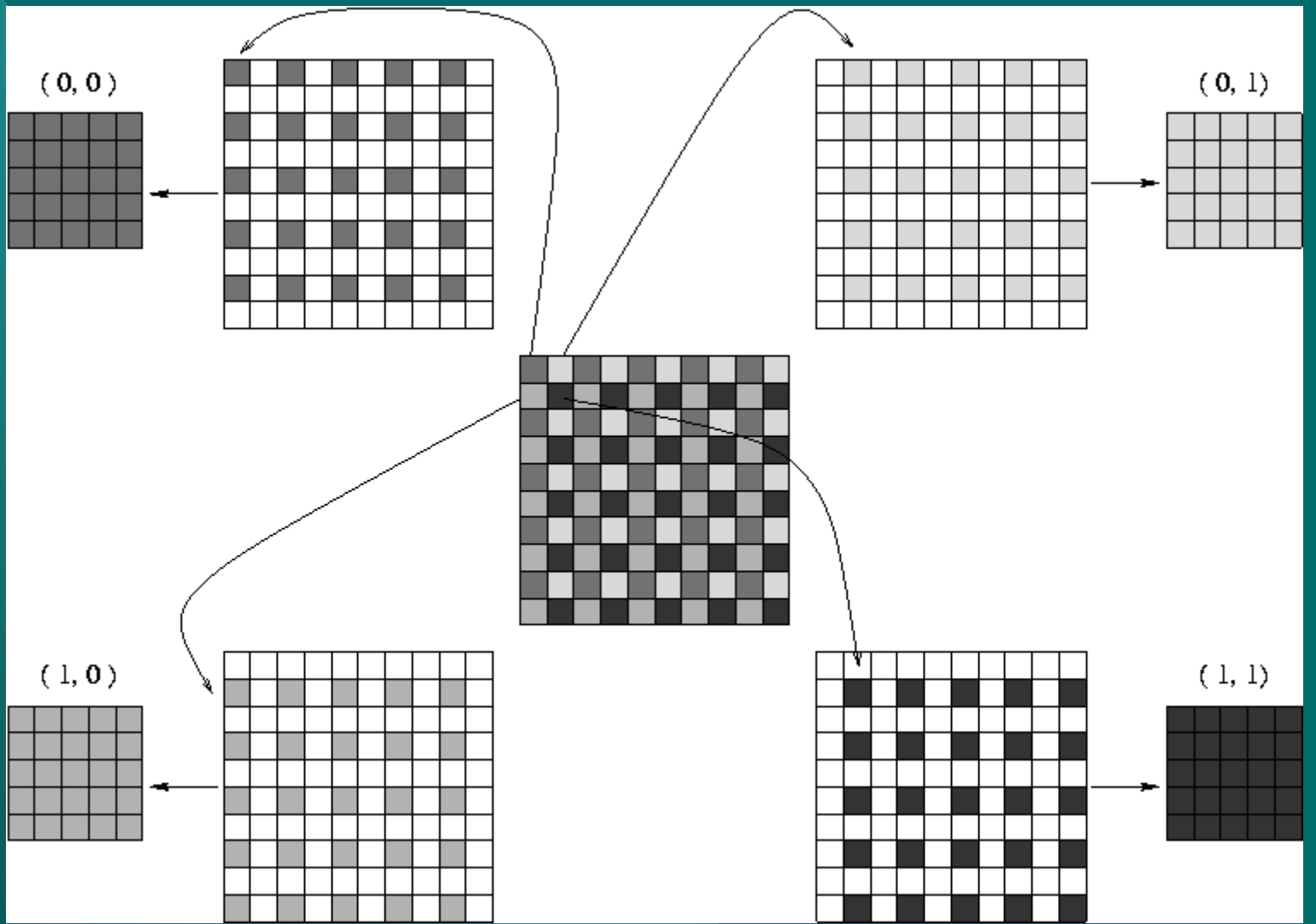
Apertures for Deblurring

- Training with 50% of the image (points randomly choosen)
- Aperture result is visually slightly better

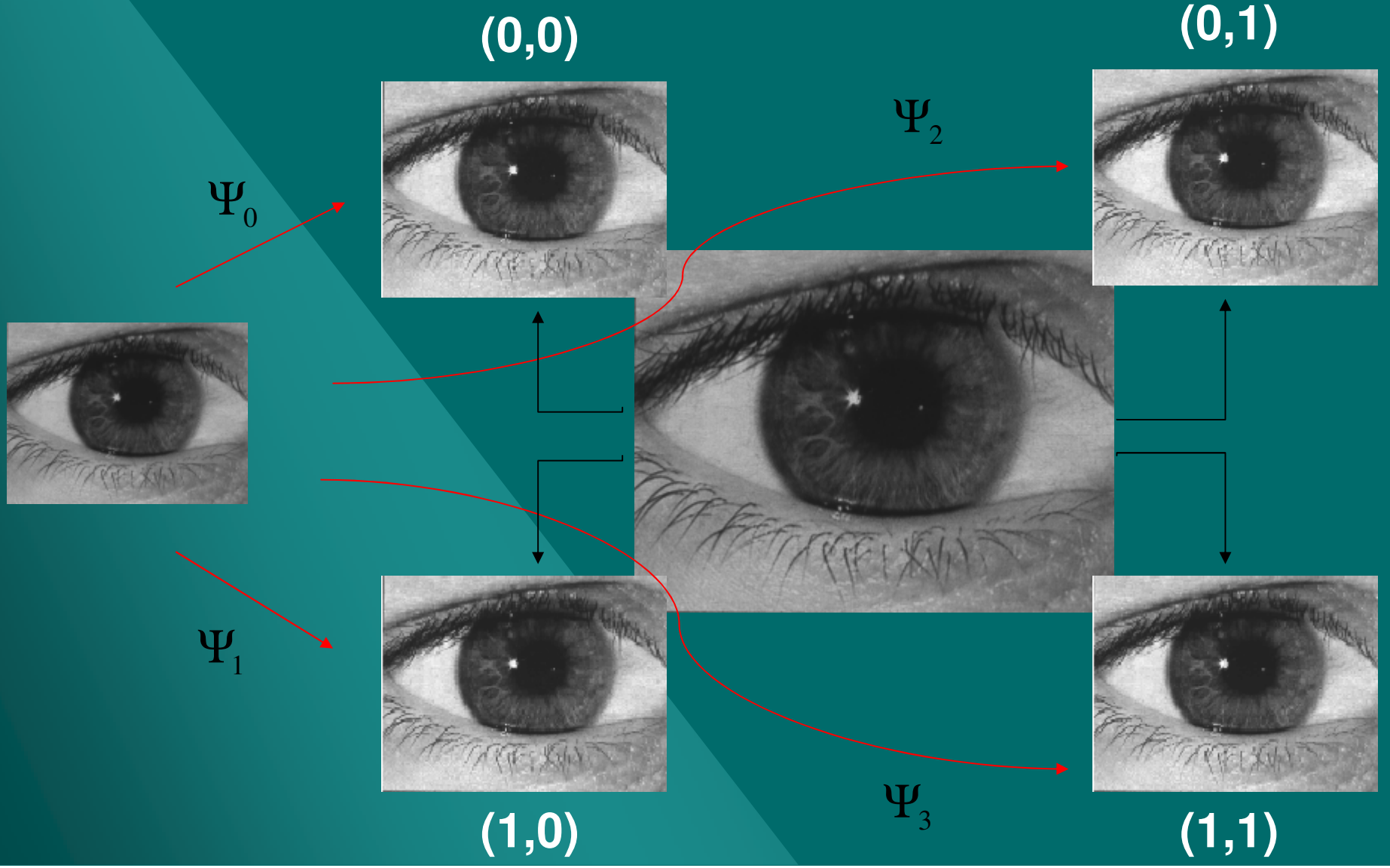
Aperture: 13 points x 15 x 21

Optimal linear - same size

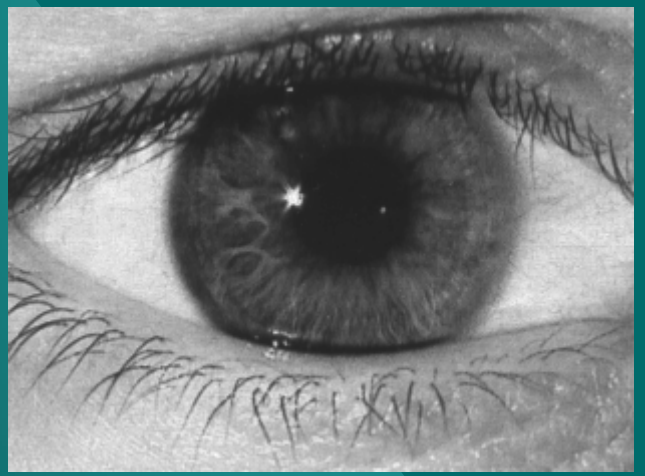
Resolution Enhancement



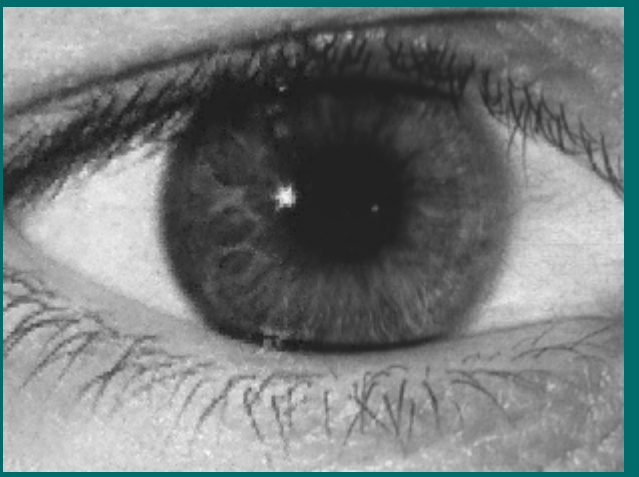
Resolution Enhancement



Resolution Enhancement - Results



Original



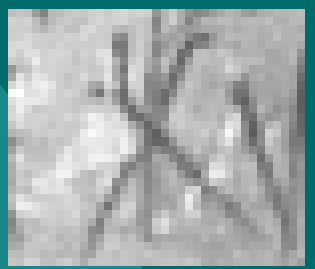
Aperture: 3x3x21x51

Linear

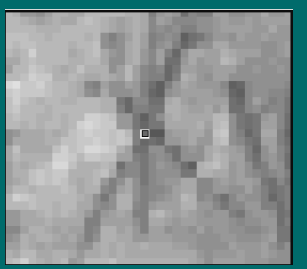
Bilinear

Resolution Enhancement - Results

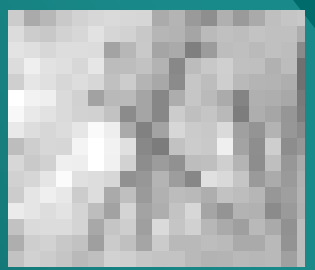
Zoom



Original



Aperture: 3x3x21x51



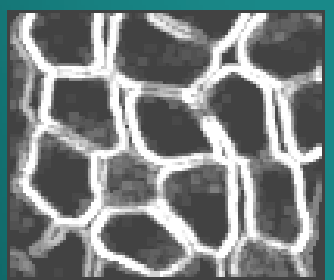
Linear

Bilinear

Beucher-Meyer Paradigm

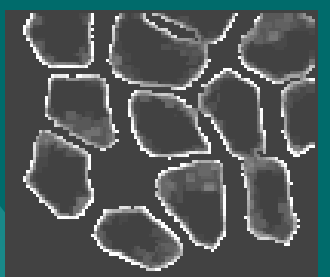
A powerful segmentation method to find the borders of specified objects in an image.

Gradient

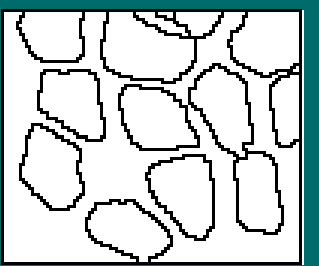


Markers

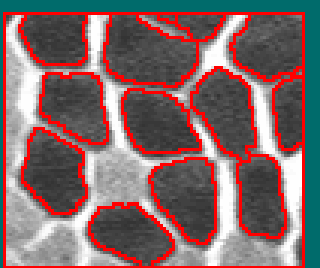
Filtered Gradient



Watershed lines



Composed Image

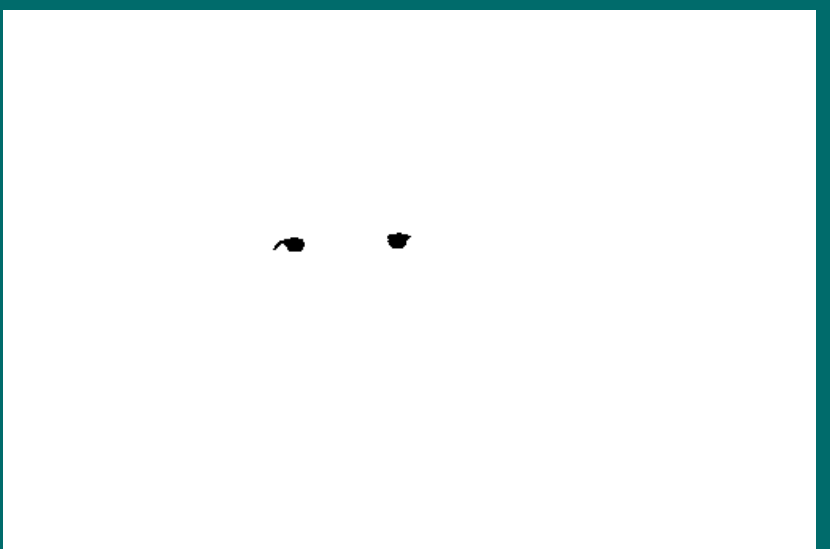


Markers for Segmentation

Some images are manually segmented and used to train an operator

Observed → **Ideal**

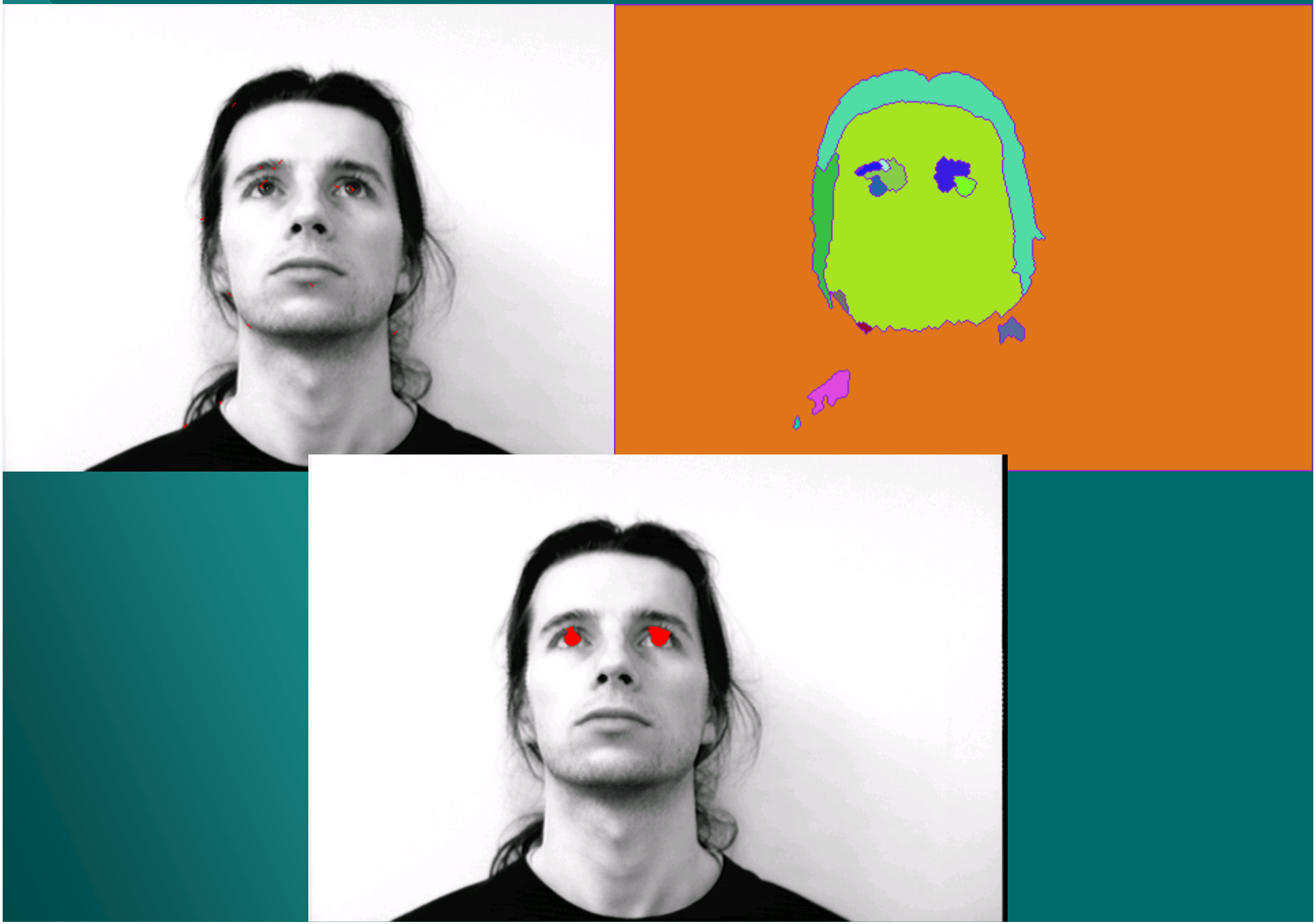
512x342



aperture: 3x5x21x21

Markers for Segmentation Results

- One image to train the operator
- Nine images to test the designed operator
- Perfect segmentation: 6
- Missing one eye: 1
- Missing both eyes: 2

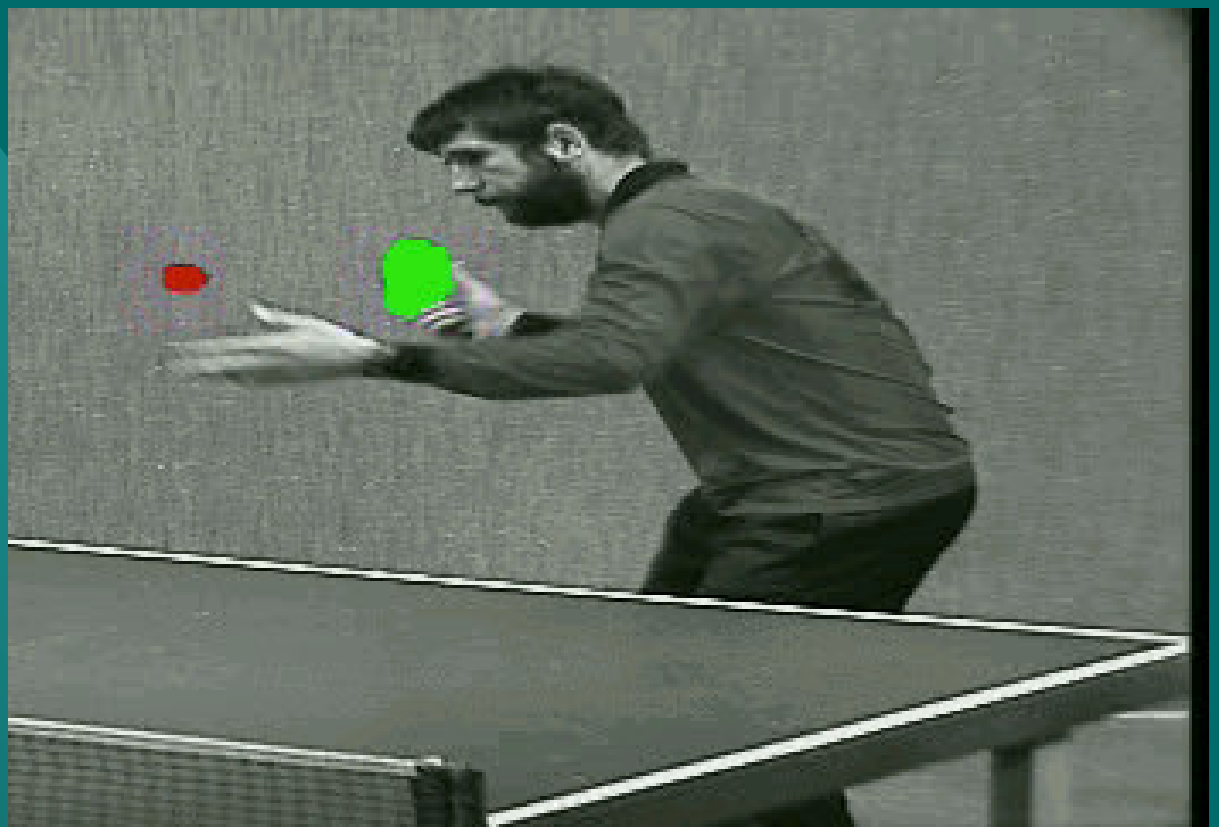


Segmenting a tennis racket

Observed

Ideal

Some result images



Experiments done by Franklin C. Flores - fcflores@ime.usp.br

http://www.vision.ime.usp.br/demos.html

Some result images

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