

2019 MMILAB.DIP Seminar

Week3(1/16~1/22)

Seong Su Kim

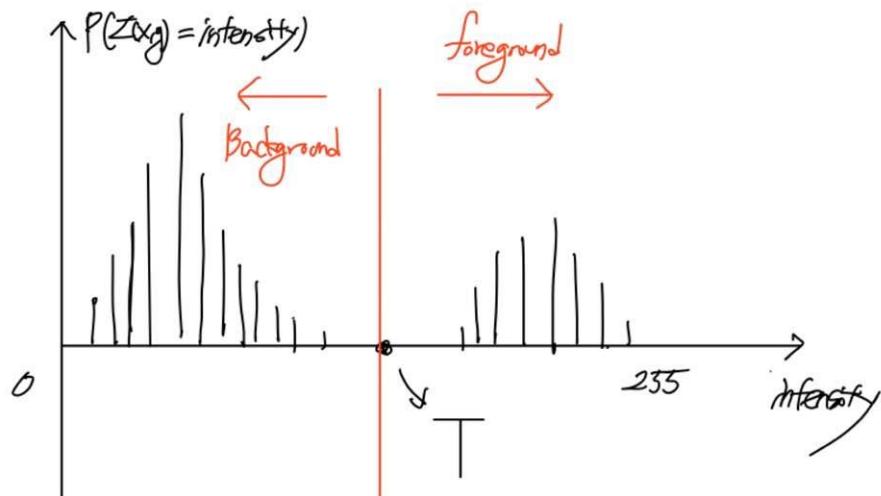
Contents

- Thresholding
 - Global Thresholding (Basic, Otsu)
 - Improvement (Smoothing, Using Edges)
 - Multiple Threshold
 - Image Partitioning
 - Variable Thresholding(Local image properties)
 - Moving Average Thresholding
- Morphological image processing
 - Erosion, Dilation, Opening, Closing
 - Boundary Extraction

Thresholding

Thresholding : Image segmentation → Separating background and foreground

Histogram of image



$$g(x, y) = \begin{cases} 1 & \text{if } I(x, y) > T \\ 0 & \text{if } I(x, y) \leq T \end{cases}$$

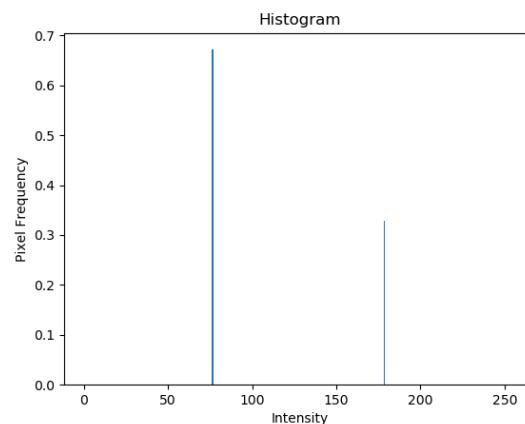
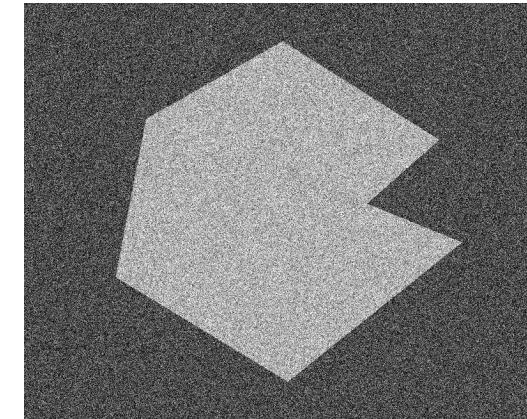
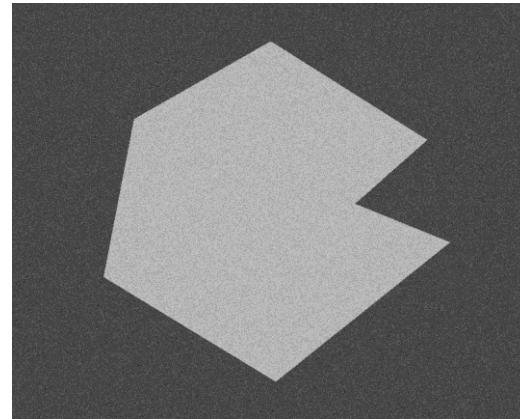
$g(x, y)$ = Segmented image
 $I(x, y)$ = Original image
 T = Threshold

How to choose T ?

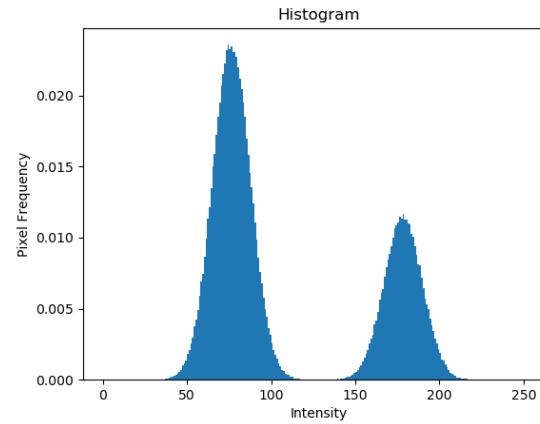
1. Try to choose T that works for **entire** image (global threshold)
2. Choose **local** threshold

Noise can change foreground and background of image

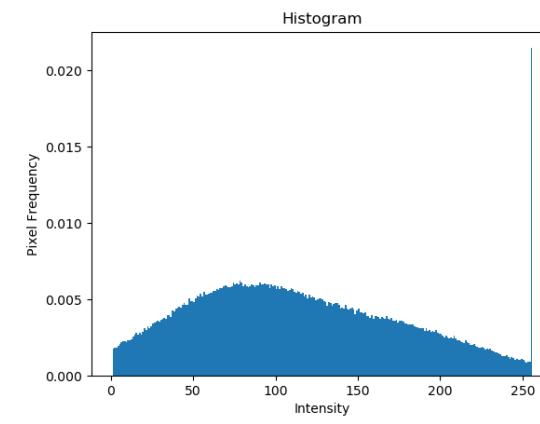
Effect of noise



Original



Mean = 0, Std = 10
Gaussian noise



Mean = 0, Std = 50
Gaussian noise

Basic Global Thresholding

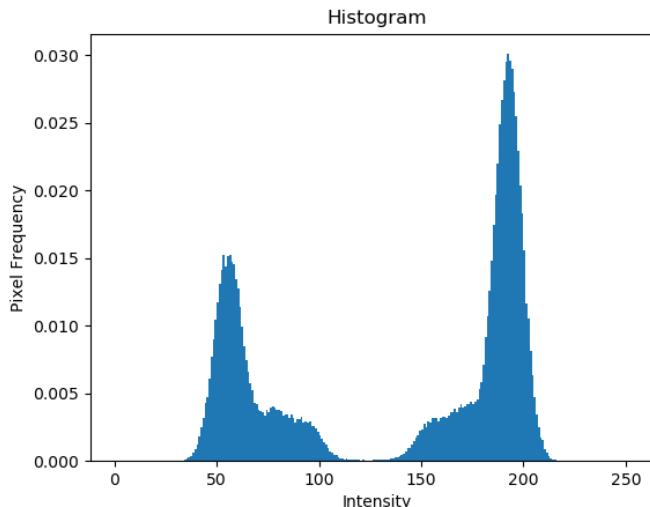
1. Select arbitrary value of T
2. Segment the image using T
3. Compute the mean value of each segment (m_1, m_2)
4. Compute the 'New T '
: $\text{New } T = \frac{1}{2}(m_1 + m_2)$
5. Repeat step 2 ~4 until difference between T and 'New T ' is smaller than predefined parameter ΔT

Basic Global Thresholding

Initial T = mean of entire image intensity, $\Delta T=0$



Original



Histogram



$T = 125.38$

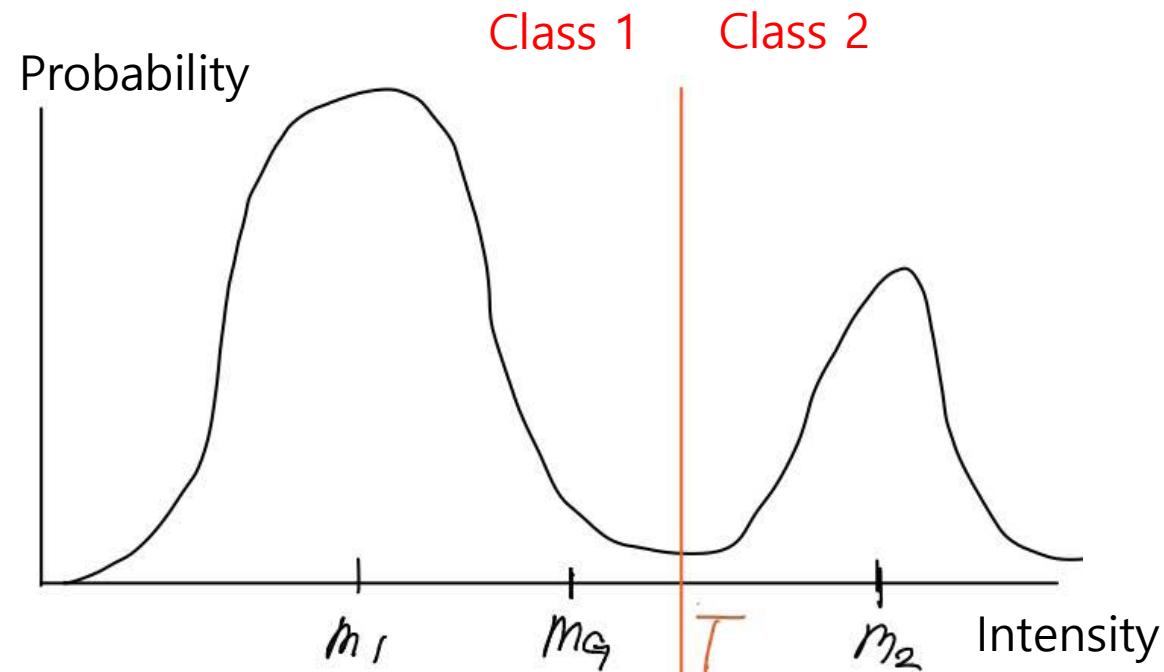
Otsu Algorithm

Idea : Maximize the between-class variance σ_B^2

$P_i = \text{probability that } (I(x, y) = i) \quad (i = 0, 1 \dots L - 1)$

$$m_G = \sum_{i=0}^{L-1} iP_i, m_1 = \frac{\sum_{i=0}^K iP_i}{P_1}, m_2 = \frac{\sum_{i=K+1}^{L-1} iP_i}{P_2}$$

$$\sigma_B^2 = P_1(m_1 - m_G)^2 + P_2(m_2 - m_G)^2$$



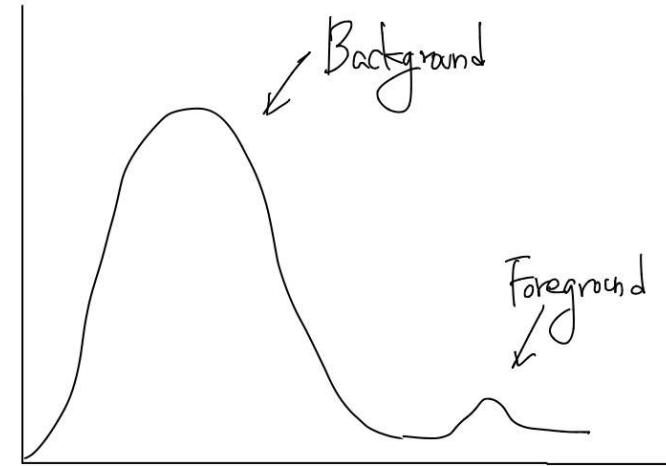
The ratio $\eta = \frac{\sigma_B^2}{\sigma_G^2}$ is a good measure of separability. Higher is better(more separable)

We just consider all possible threshold(T), and choose T that maximizes σ_B^2

Otsu Algorithm

Otsu can fail when :

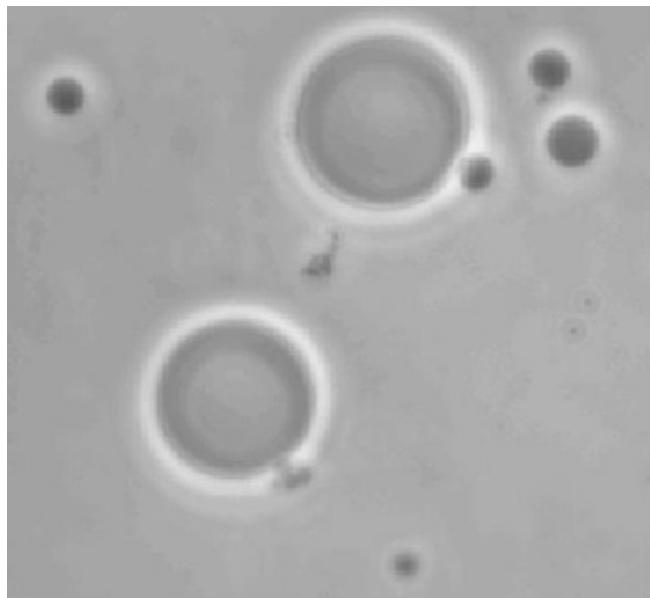
1. There is no strong peaks in histogram
2. Object is too small with respect to background



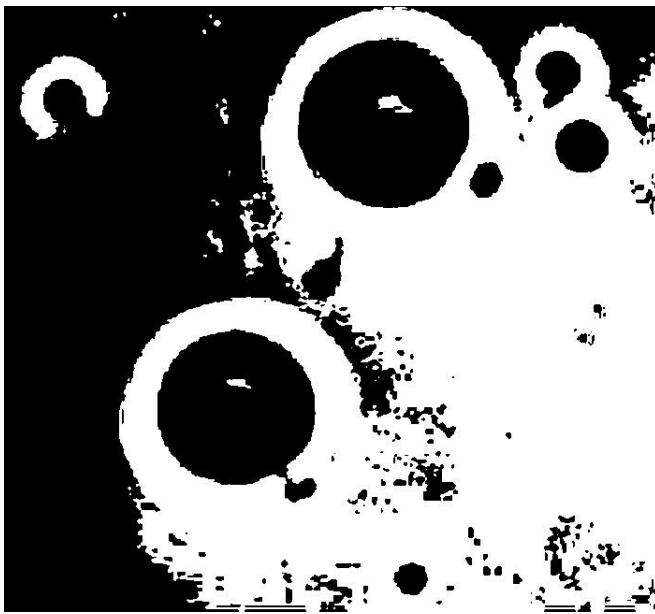
Remedies:

1. Apply low-pass filter to image, then apply otsu algorithm
2. Only consider pixels near edges when computing the threshold

Otsu Thresholding

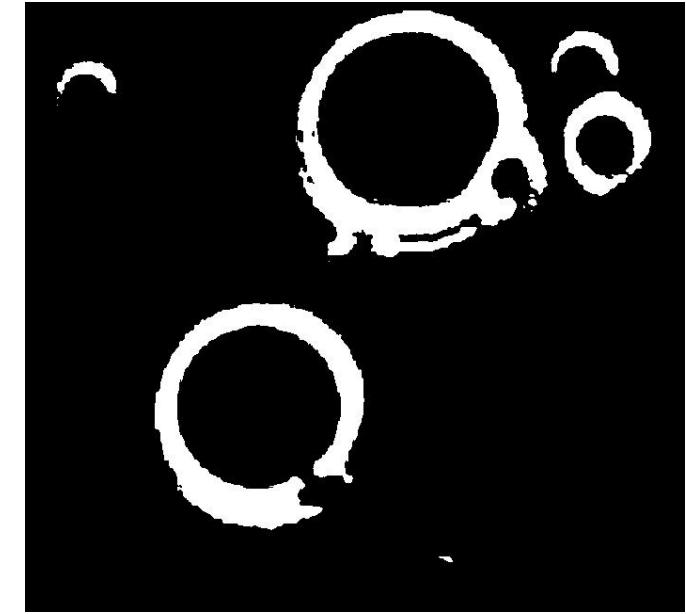


Original



Basic global thresholding

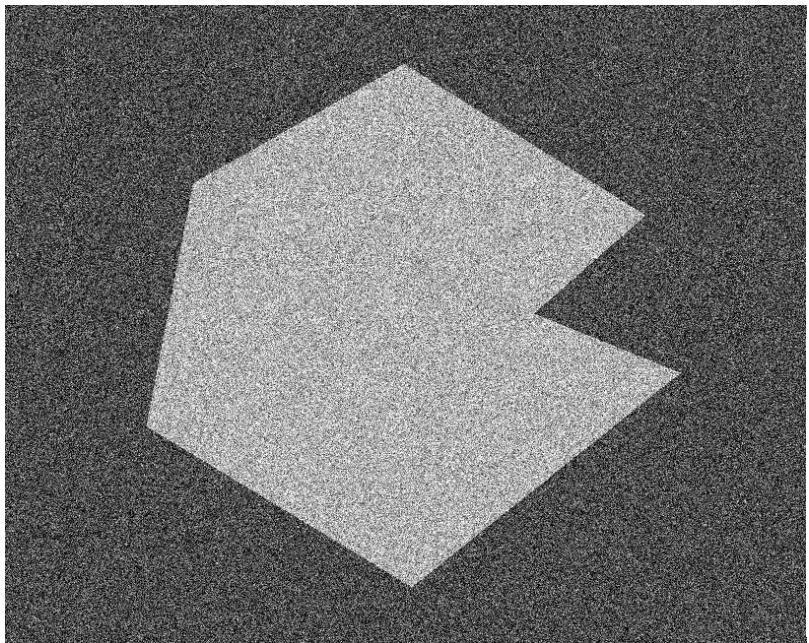
$T = 169.4$



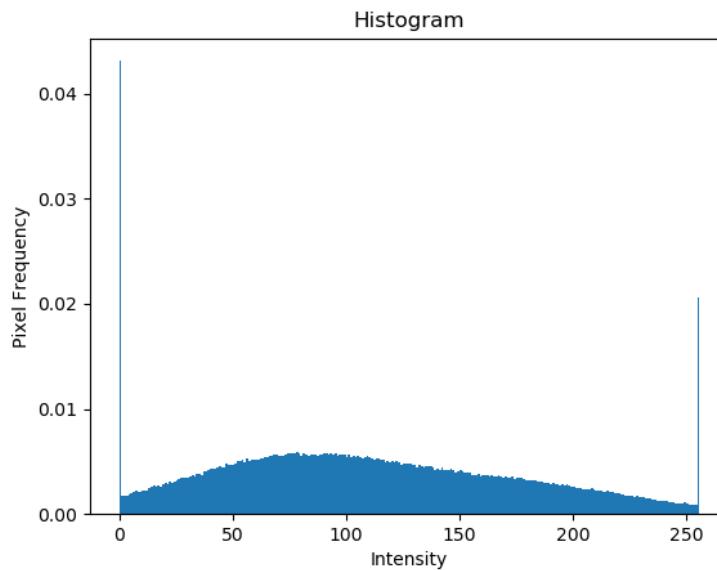
Otsu's method

$T = 182$

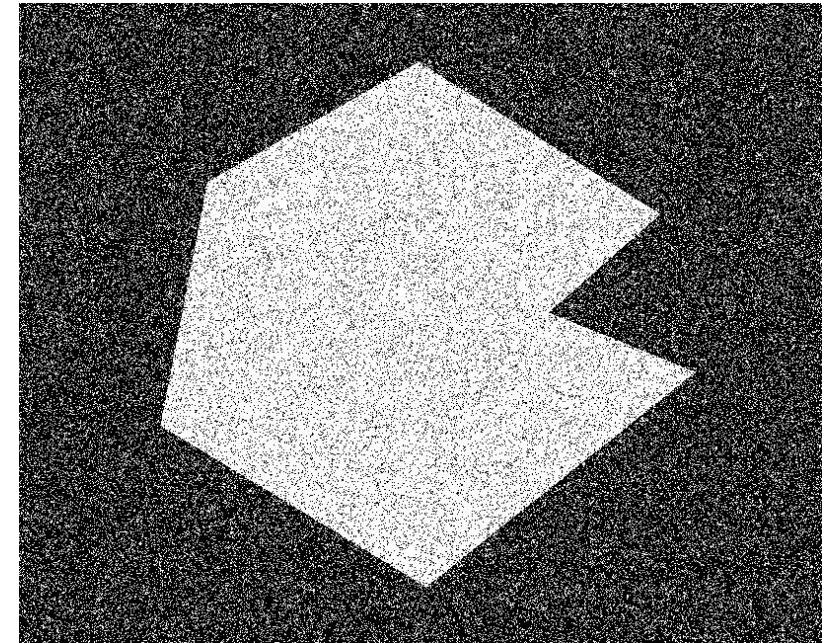
Improvement – Using Smoothing



Gaussian noise image

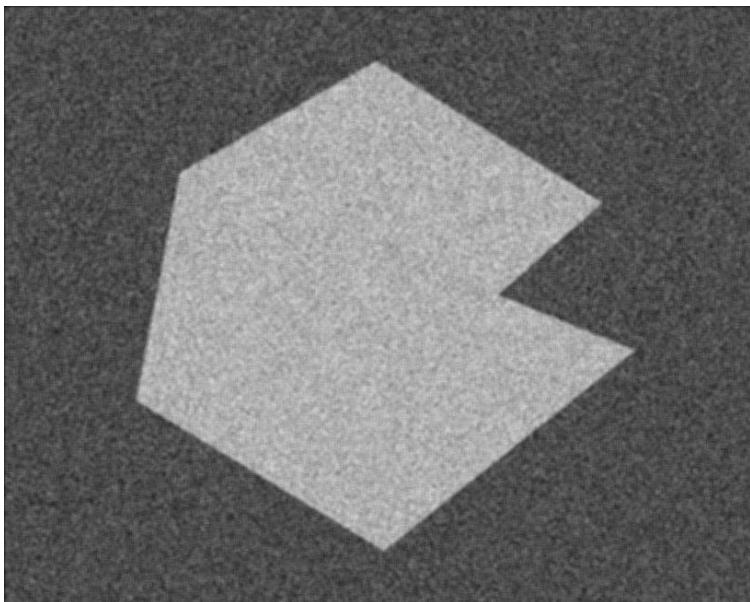


Histogram

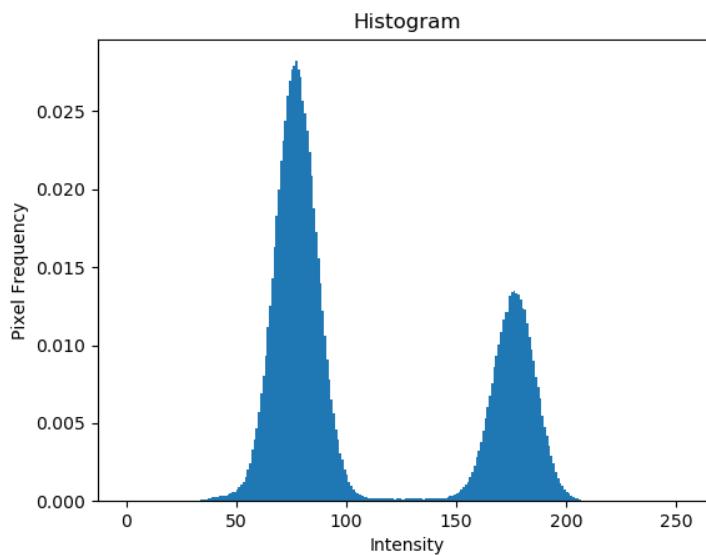


Otsu ($T_{\text{opt}} = 119$, Sep= 0.69)

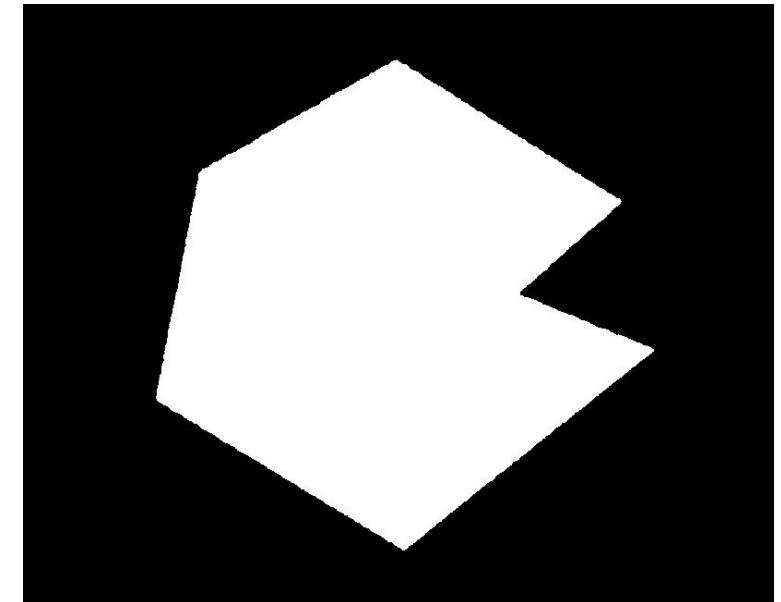
Improvement – Using Smoothing



5 X 5 smoothing image

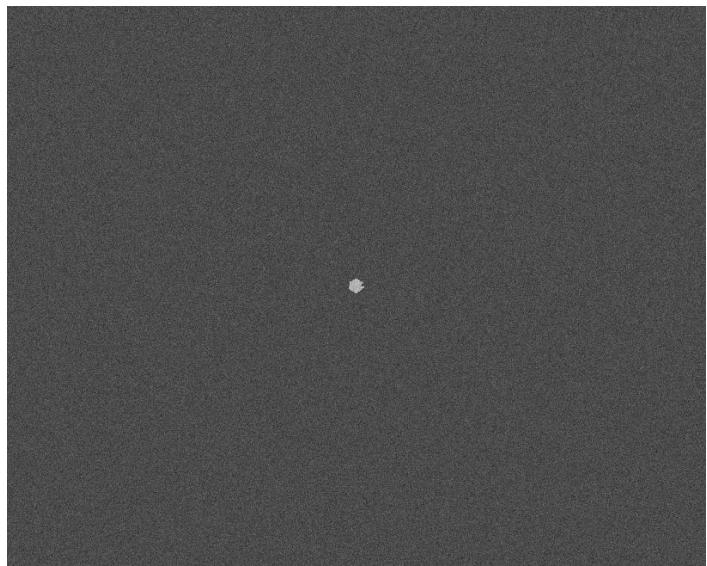


Histogram

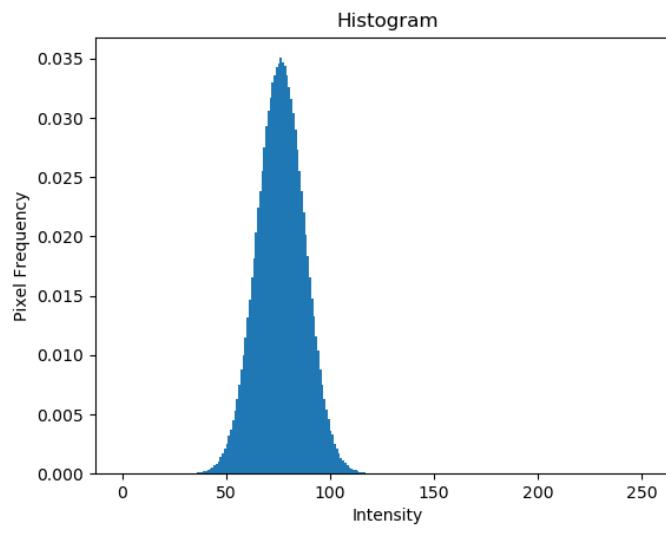


Otsu ($T_{\text{opt}} = 127$, Sep= 0.95)

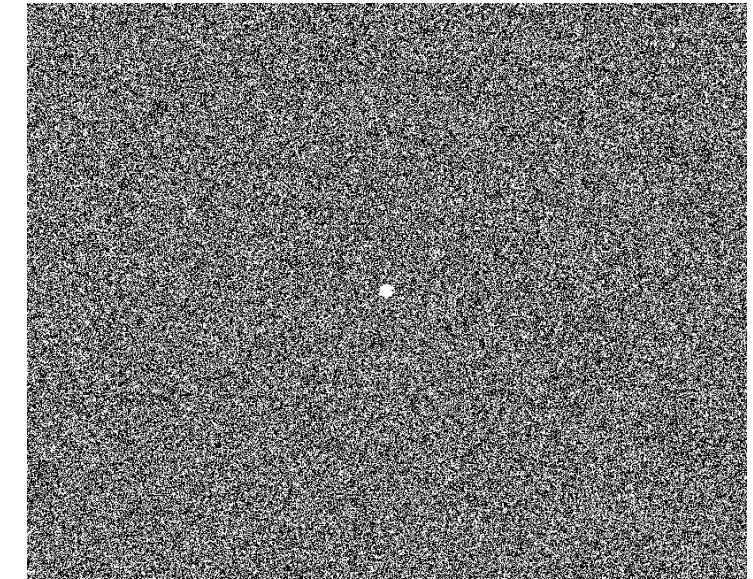
Improvement – Using Smoothing



Original



Histogram

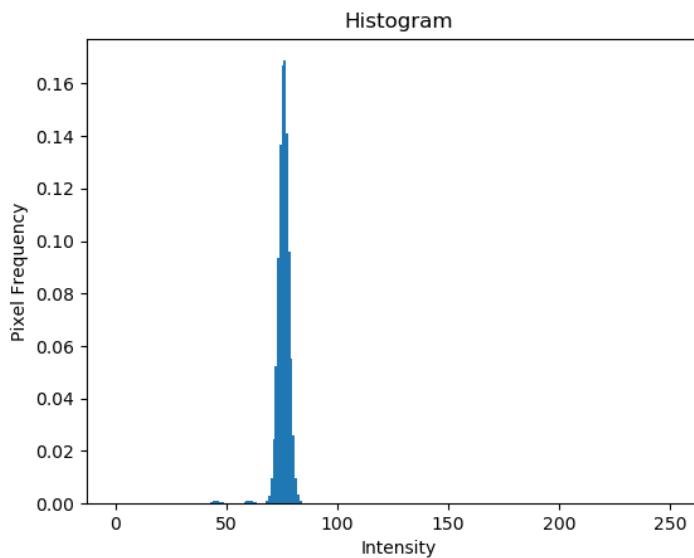


Otsu ($T_{\text{opt}} = 77$, Sep= 0.62)

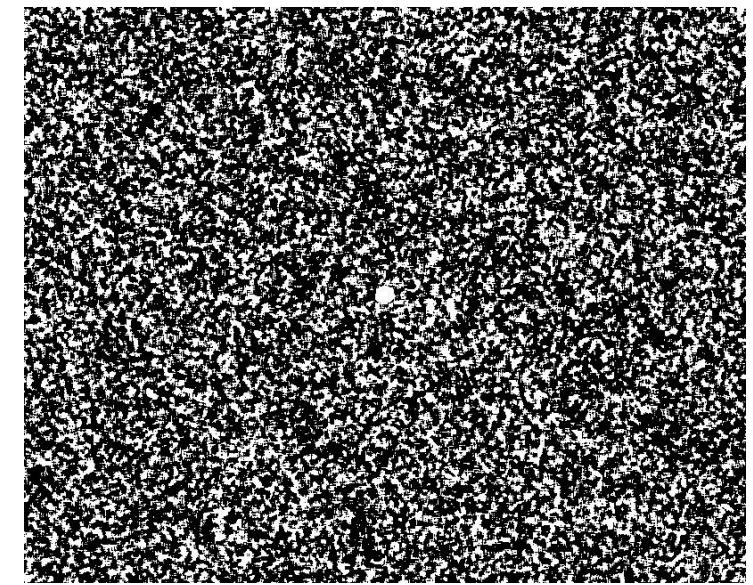
Improvement – Using Smoothing



5 X 5 smoothing image



Histogram

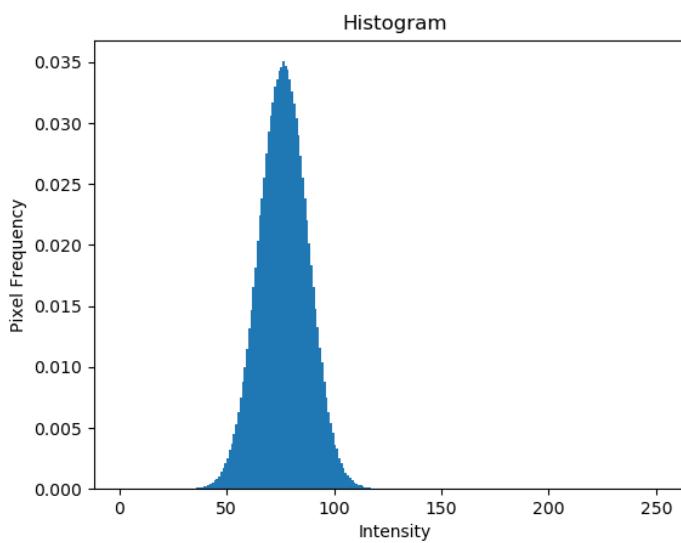


Otsu ($T_{\text{opt}} = 76$, Sep= 0.42)

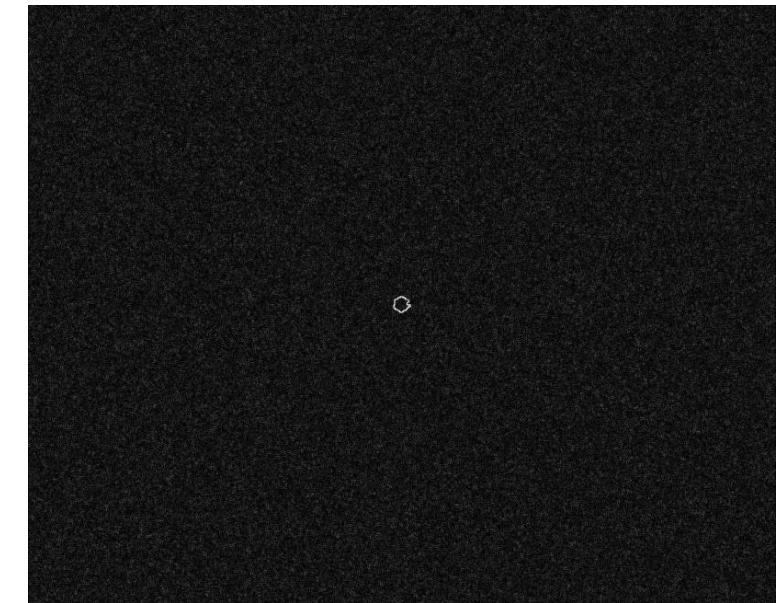
Improvement – Using Edges(Sobel)



Original

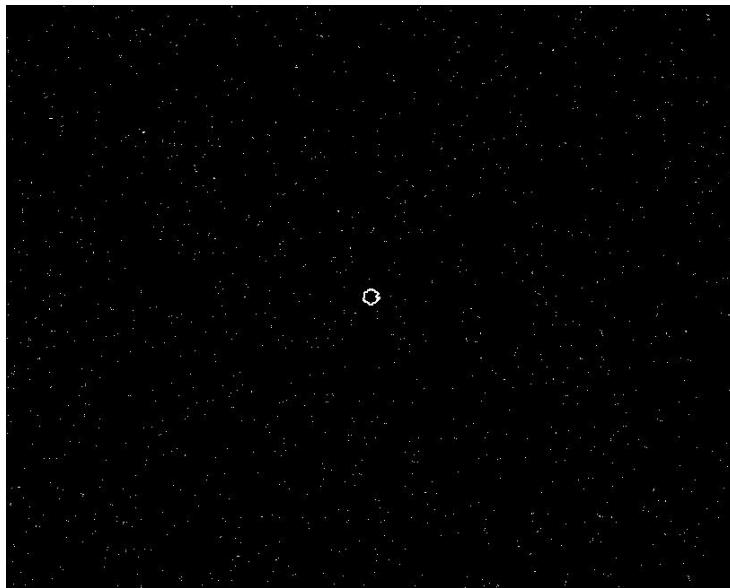


Histogram

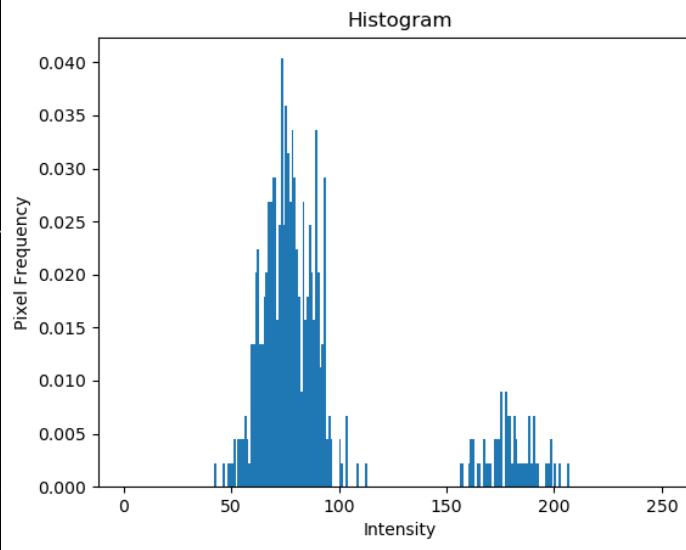


Sobel (edge image)

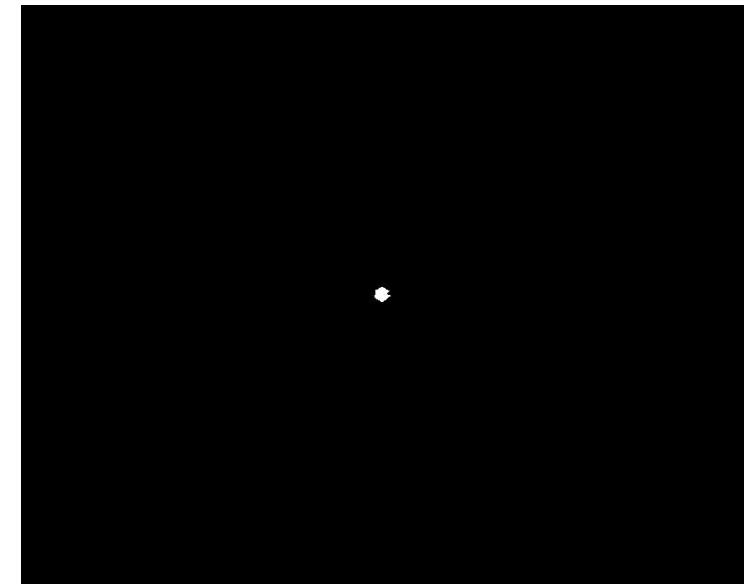
Improvement – Using Edges(Sobel)



Sobel (percentile 99.7 image)

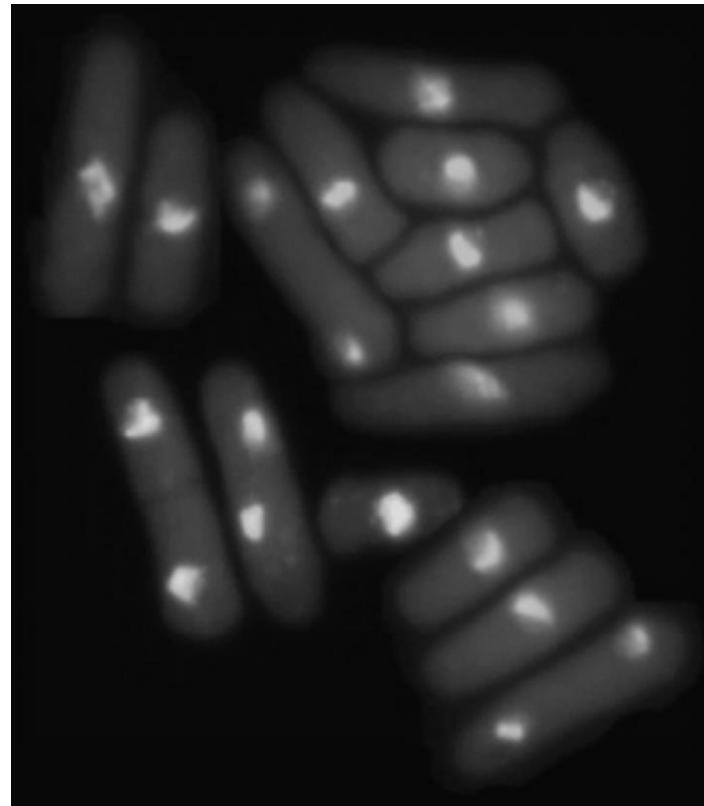


Histogram

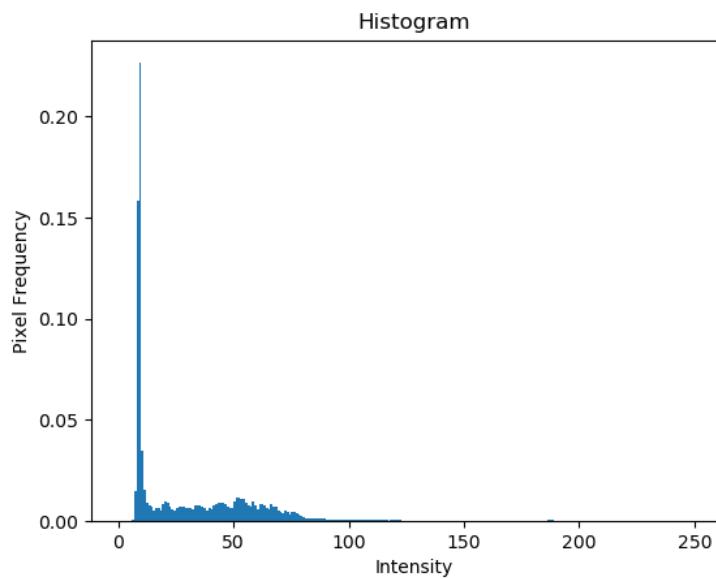


Otsu ($T_{opt} = 129$, $Sep = 0.42$)

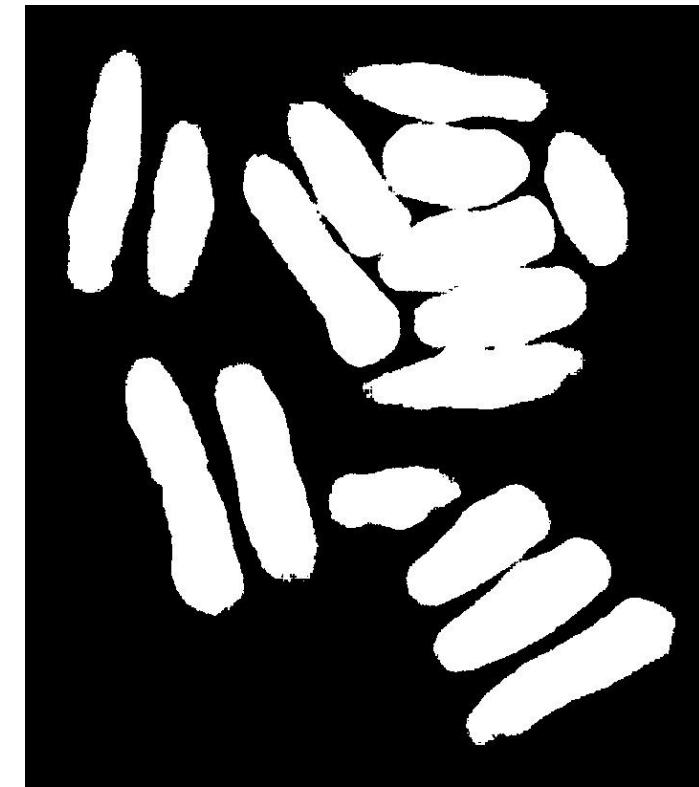
Improvement – Using Edges(Laplacian)



Original

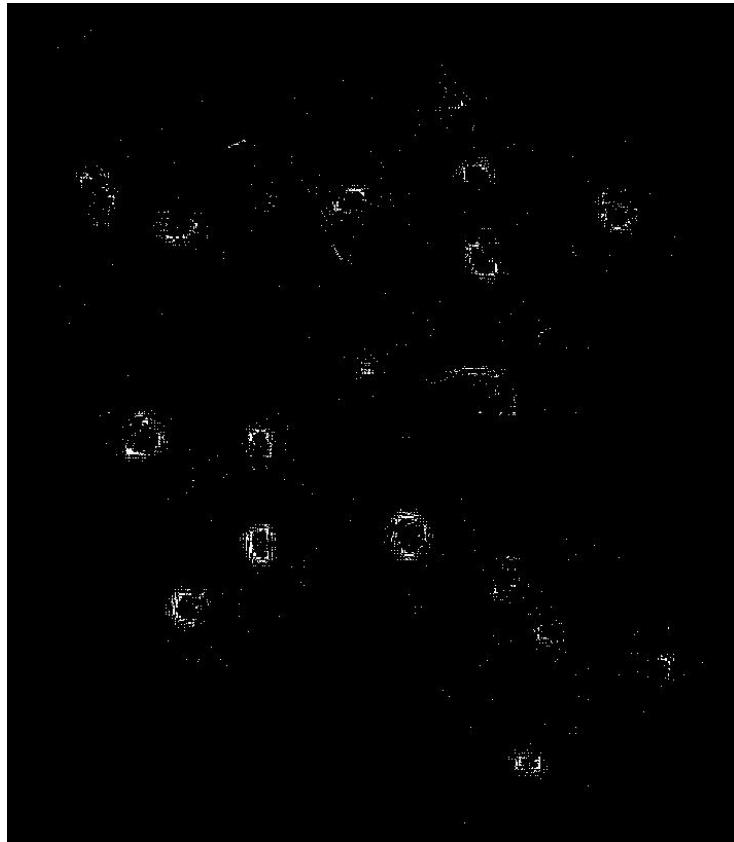


Histogram

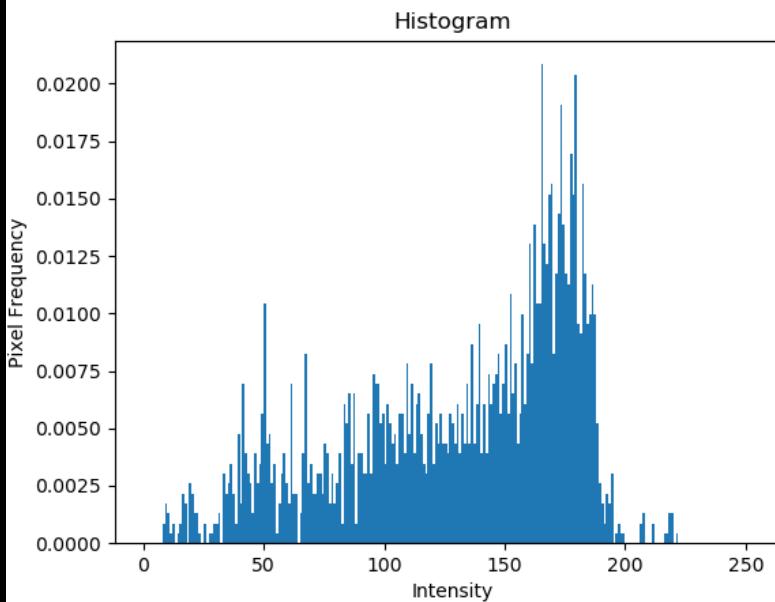


Otsu thresholding
($T=43$, Sep =0.636)

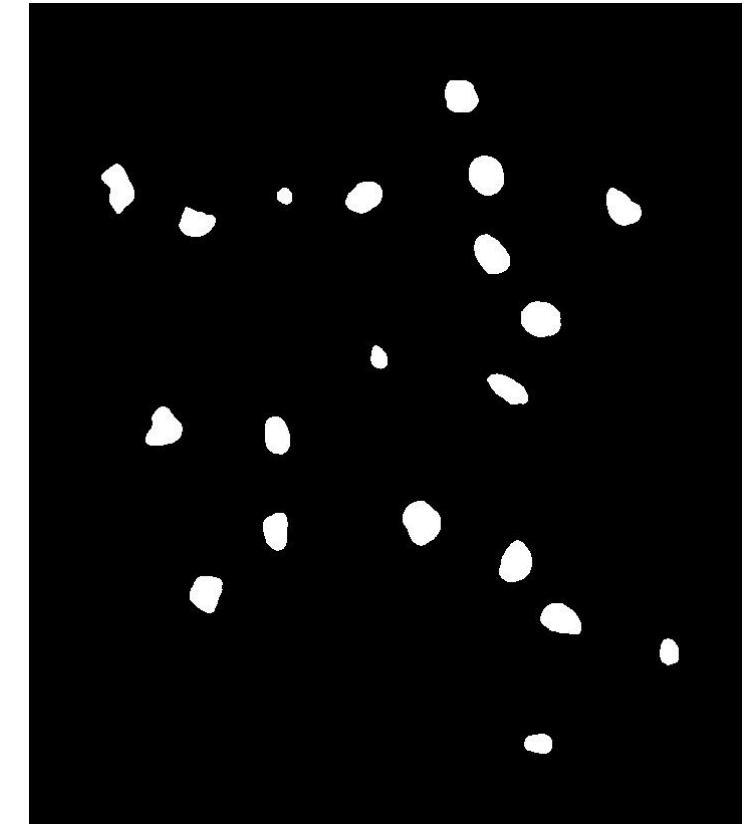
Improvement – Using Edges(Laplacian)



Laplacian



Histogram

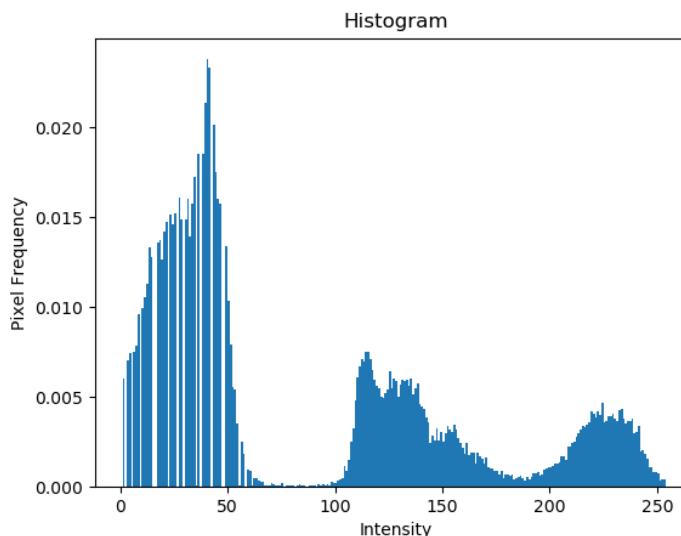


Otsu thresholding
($T=115$, Sep =0.76)

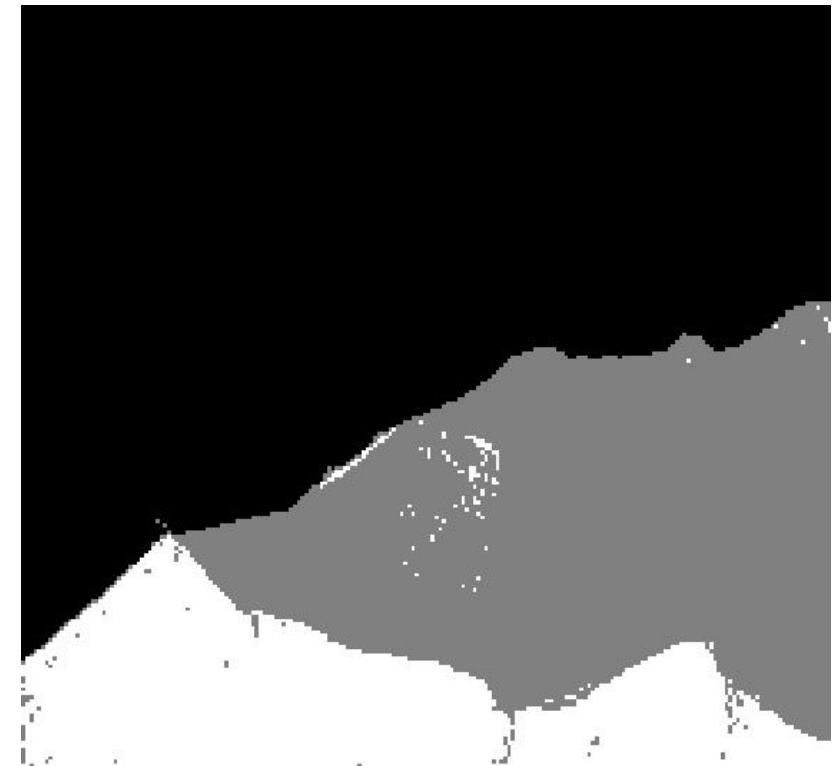
Multiple Thresholding



Original

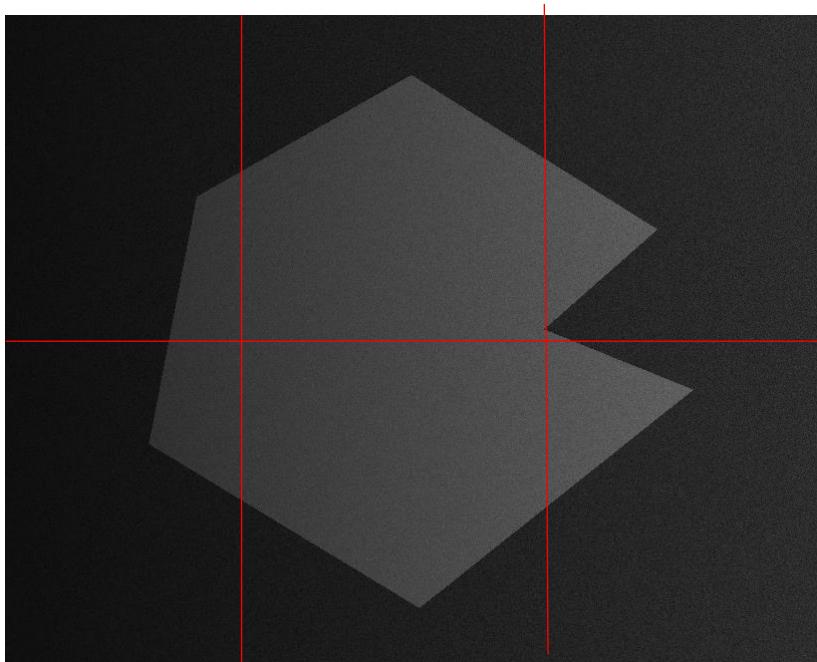


Histogram

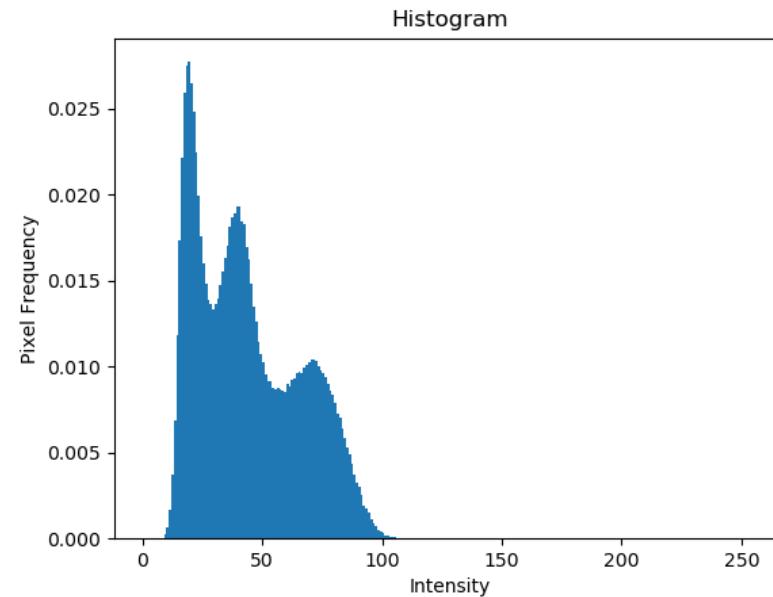


Multiple thresholding

Image Partitioning

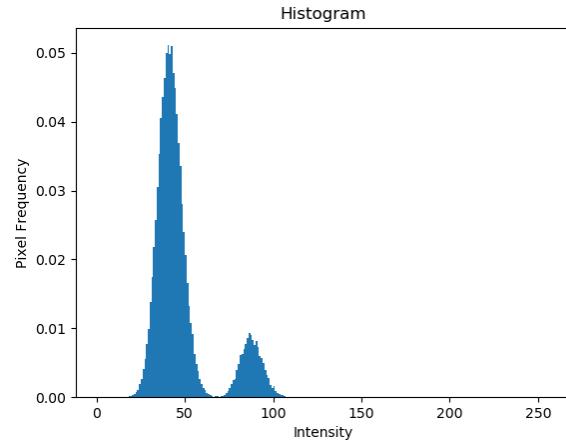


Original (Noisy shade)

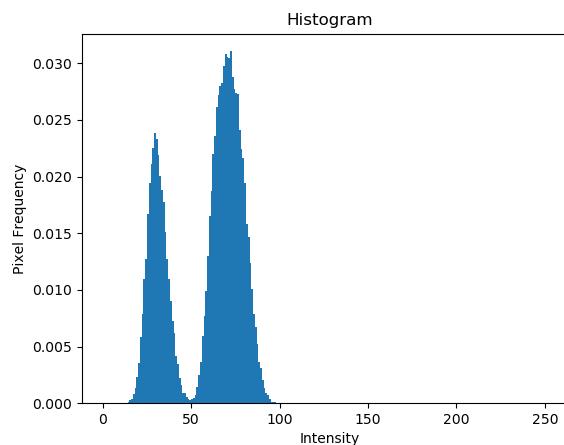


Histogram

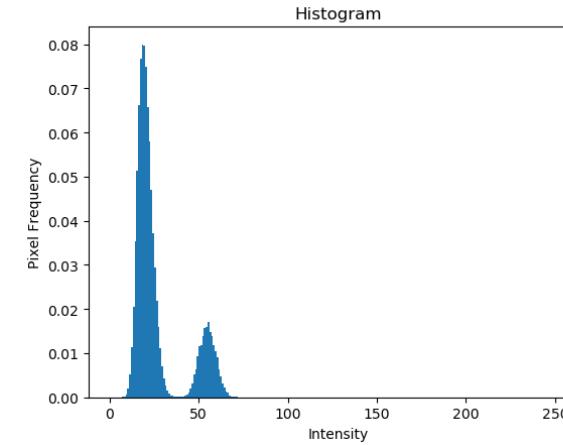
Image Partitioning



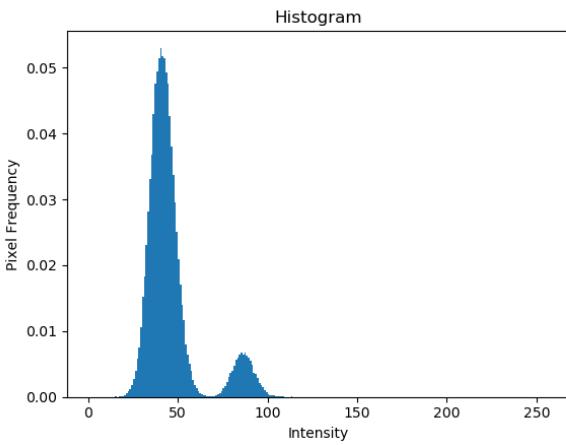
$T_{opt} = 40$



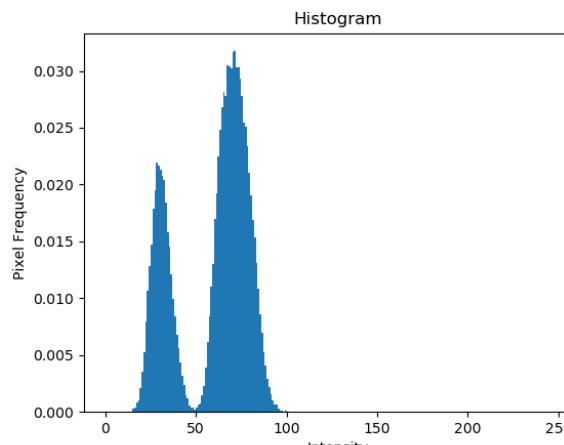
$T_{opt} = 51$



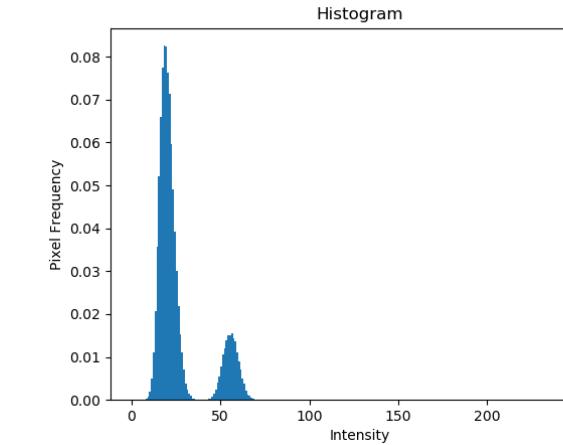
$T_{opt} = 64$



$T_{opt} = 38$

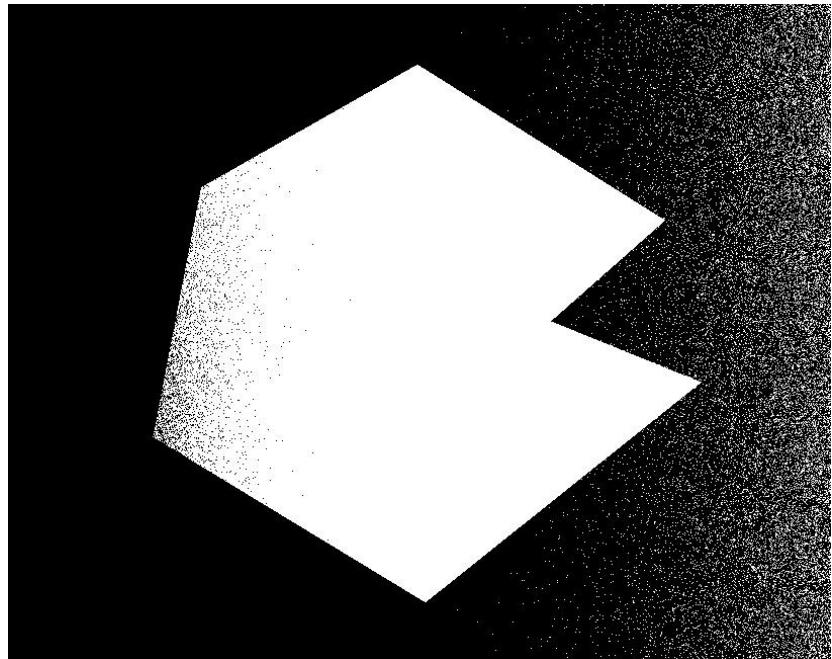


$T_{opt} = 51$

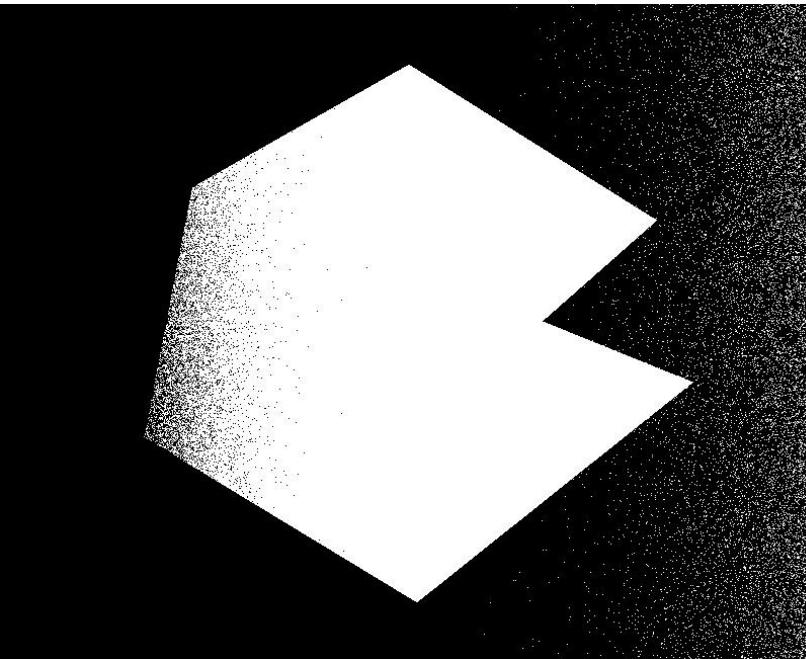


$T_{opt} = 65$

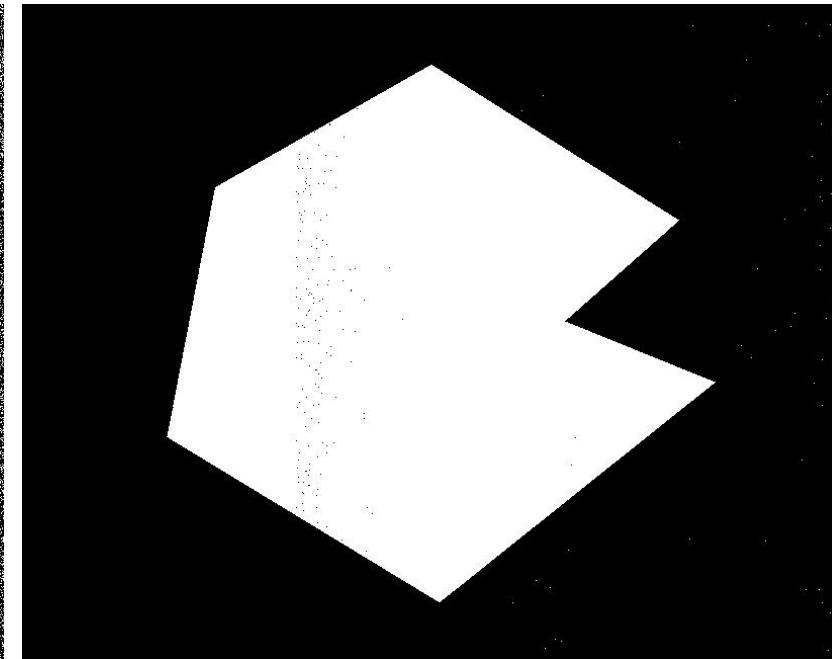
Image Partitioning



Basic Global Thresholding
 $T = 48.8$



Otsu Thresholding
 $T_{opt} = 50$



Partitioned Thresholding

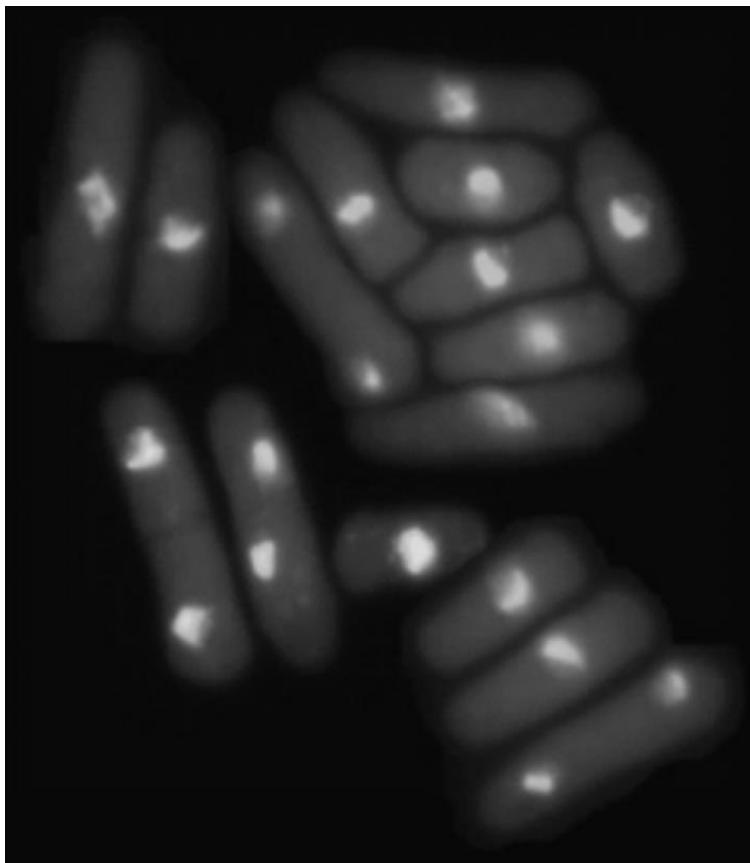
Variable Thresholding(Local properties)

$I(x-1, y-1)$	$I(x, y-1)$	$I(x+1, y-1)$
$I(x-1, y)$	$I(x, y)$	$I(x+1, y)$
$I(x-1, y+1)$	$I(x, y+1)$	$I(x+1, y+1)$

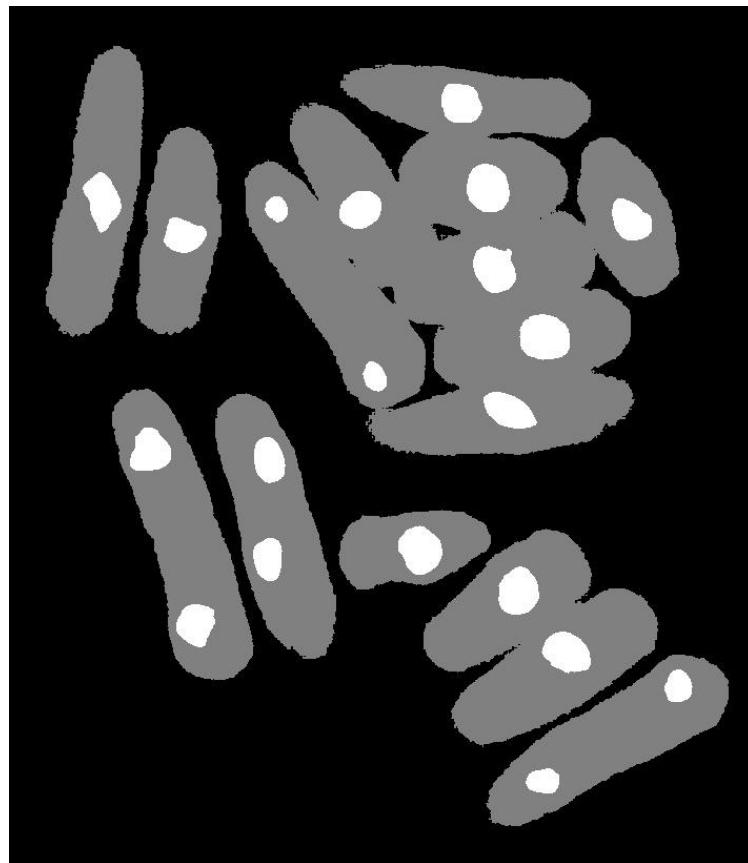
$$T_{xy} = a\sigma_{xy} + b m_{xy}$$

$$g(x, y) = \begin{cases} 1 & \text{if } I(x, y) > T_{xy} \\ 0 & \text{if } I(x, y) \leq T_{xy} \end{cases}$$

Variable Thresholding(Local properties)

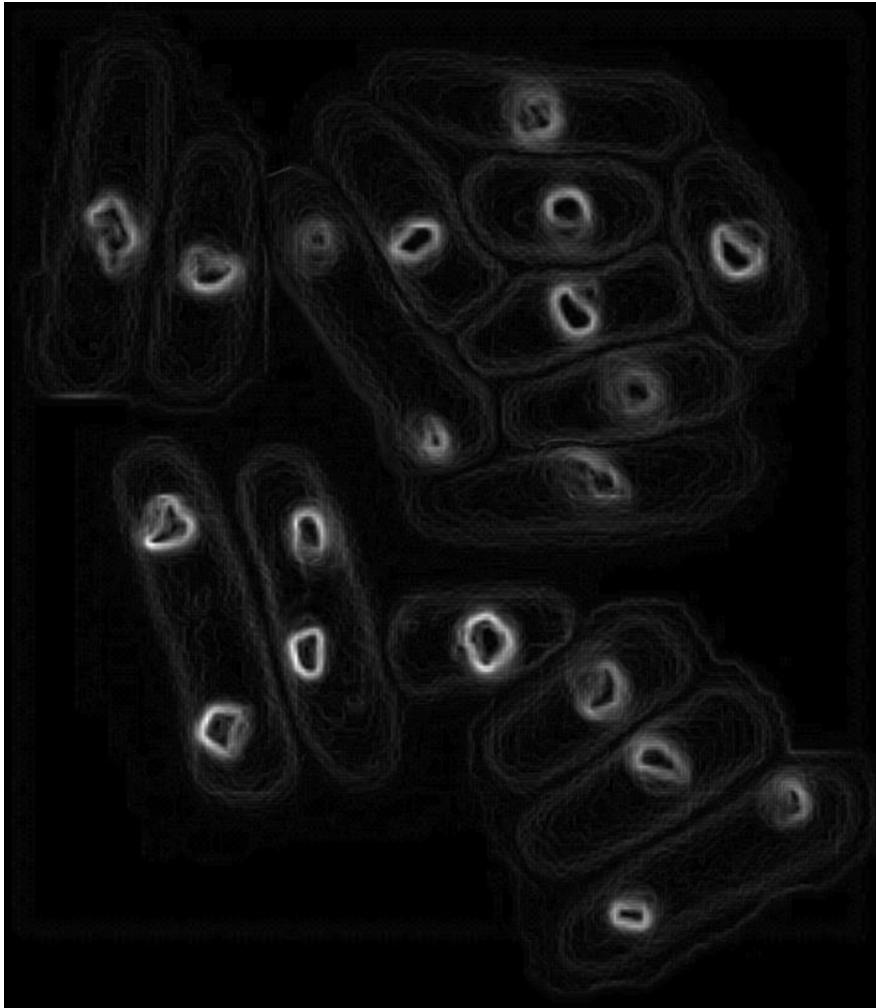


Original

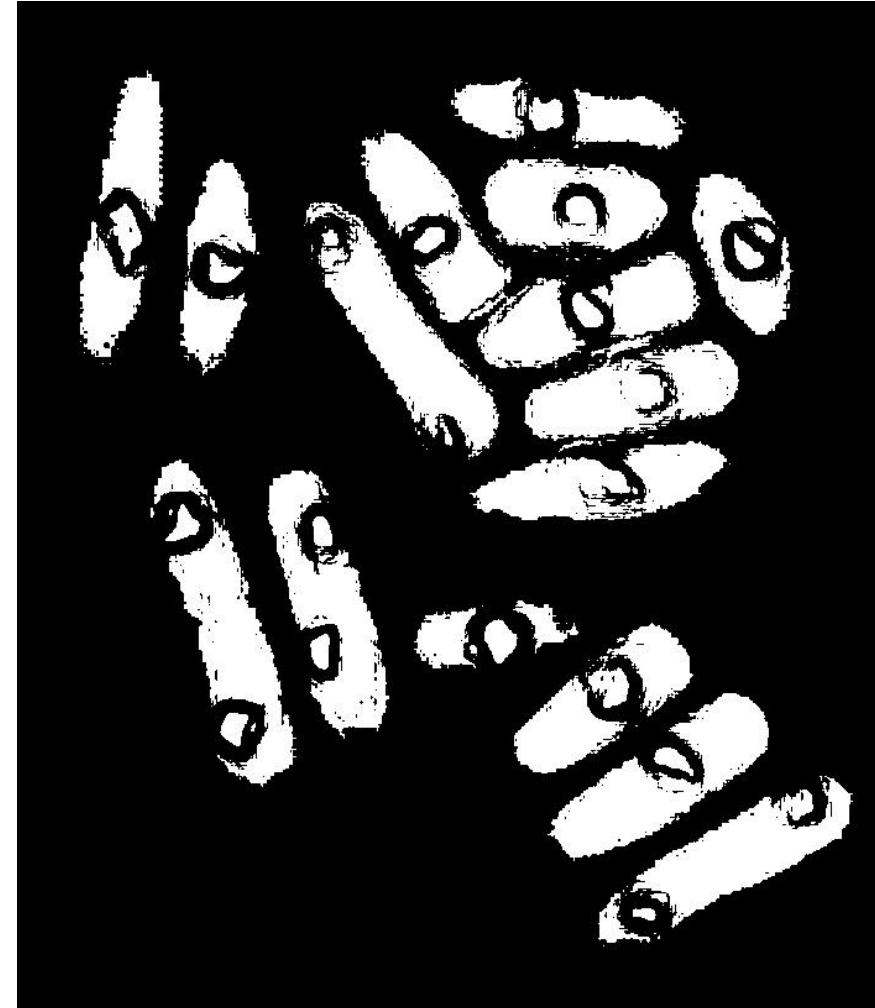


Multiple Thresholding

Variable Thresholding(Local properties)



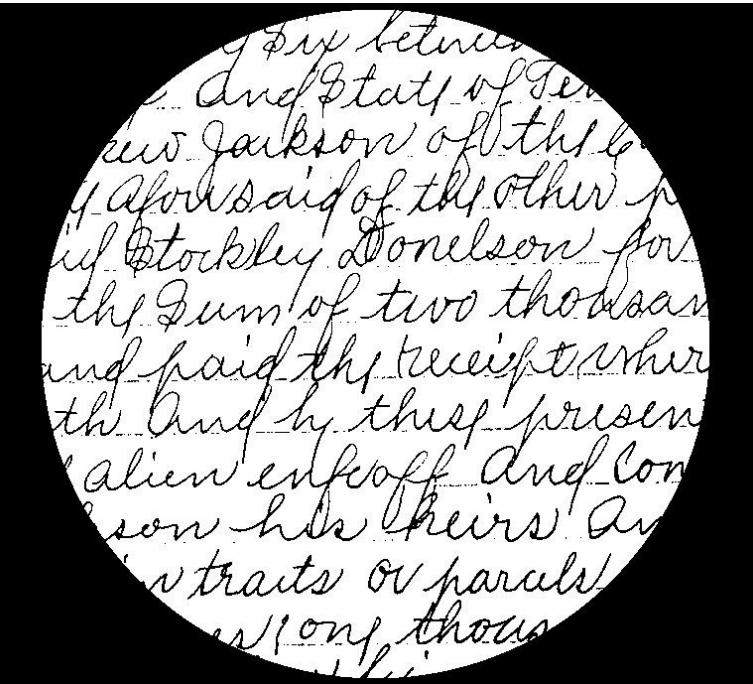
Local variance image (after scaling)



After thresholding by $T = 30\sigma_{xy} + 1.5m_{xy}$

Moving average Thresholding

Indininty Six between Stockley
of Knyx And State of Tennessee
Andrew Jackson off the Count
tats Aforesaid of the Other part
said Stockley Donelson for A
of the Sum of two thousand
and paid thy receipt wher
rath And by these presents
all alien encoff And Confir
Jackson his Heirs And A
certain traits or parals of La
sand Acre(s) one thousand payre
and a half And his wife



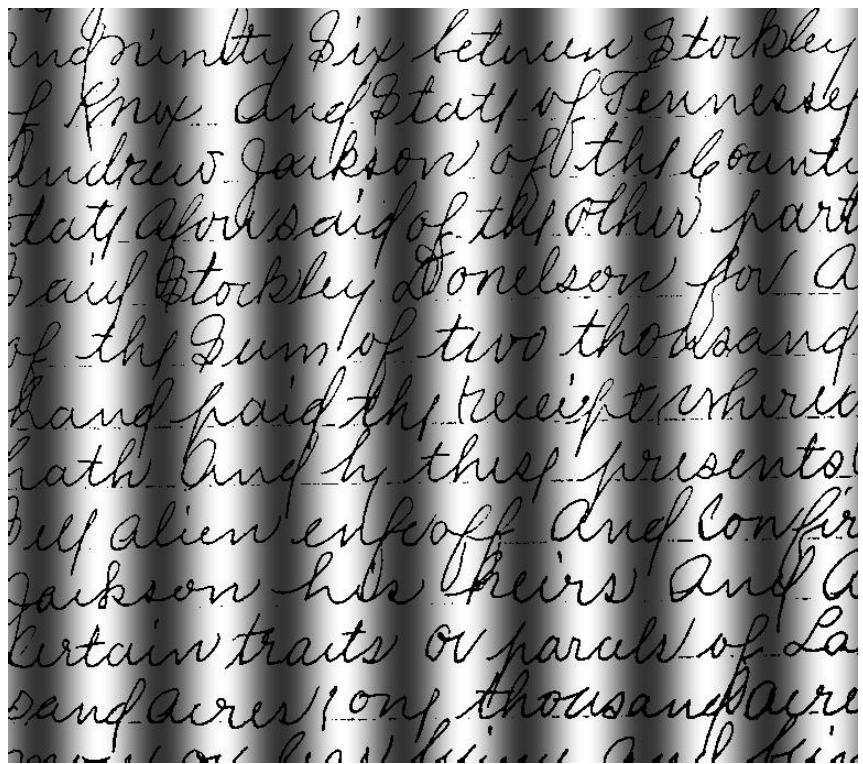
Original

Otsu

Moving Average Thresholding
 $n = 20, b=0.5$

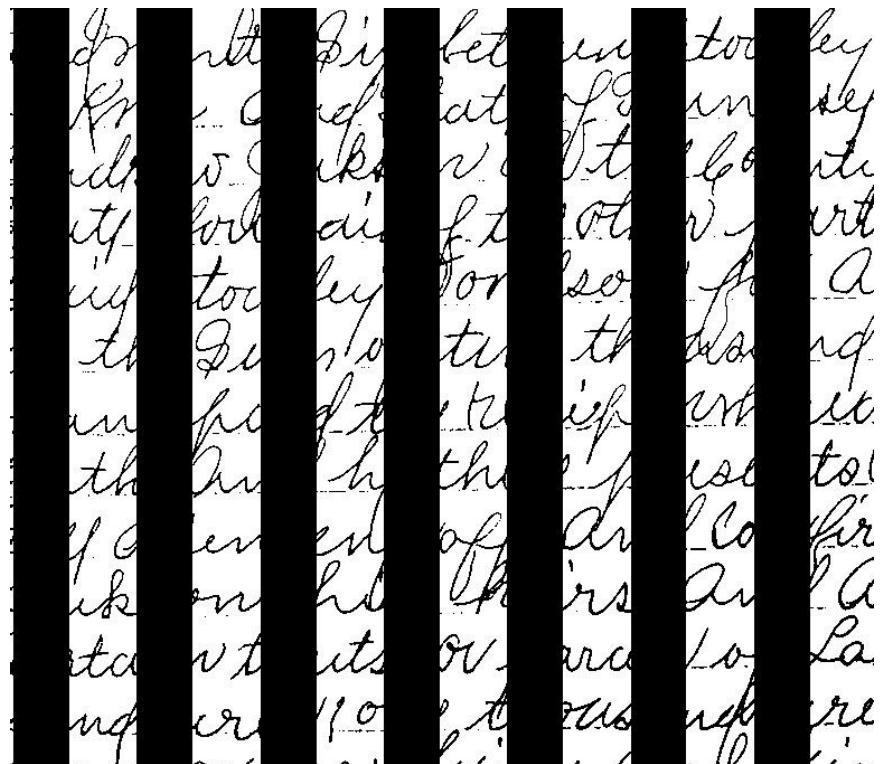
$$m(k) = \frac{1}{n} \sum_{i=k+1-n}^k z_i \quad T_{xy} = bm_{xy}$$

Moving average Thresholding



Ind Ninety Six between Stockley
of Knox. And State of Tennessee
Andrew Jackson of the County
that above said of the Other part
Paid Stockley Donelson for A
of the sum of two thousand
and paid the receipt where
hath And by these presents
full alien en scoff And confirm
Jackson his heirs And a
certain tract or parcels of La
and acres one thousand acre
more or less and in full

Original



Ind Ninety Six between Stockley
of Knox. And State of Tennessee
Andrew Jackson of the County
that above said of the Other part
Paid Stockley Donelson for A
of the sum of two thousand
and paid the receipt where
hath And by these presents
full alien en scoff And confirm
Jackson his heirs And a
certain tract or parcels of La
and acres one thousand acre
more or less and in full

Otsu

Moving average Thresholding

n=20

Indentity Six between Stockley
f Knox And State of Tennessee
Andrew Jackson off the County
Tats Alor said of the Other part
Paid Stockley Donelson for A
of the Sum of two thousand
hand paid the receipt wheret
rath And by these presents
Self alien enforff And Confir
Jackson his Heirs And A
certain traits or parcels of La
sand acres 1/01, thousand Ayre

b=0.5

n=30

Indentity Six between Stockley
f Knox And State of Tennessee
Andrew Jackson off the County
Tats Alor said of the Other part
Paid Stockley Donelson for A
of the Sum of two thousand
hand paid the receipt wheret
rath And by these presents
Self alien enforff And Confir
Jackson his Heirs And A
certain traits or parcels of La
sand acres 1/01, thousand Ayre

Indentity Six between Stockley
f Knox And State of Tennessee
Andrew Jackson off the County
Tats Alor said of the Other part
Paid Stockley Donelson for A
of the Sum of two thousand
hand paid the receipt wheret
rath And by these presents
Self alien enforff And Confir
Jackson his Heirs And A
certain traits or parcels of La
sand acres 1/01, thousand Ayre

b=0.3

Indentity Six between Stockley
f Knox And State of Tennessee
Andrew Jackson off the County
Tats Alor said of the Other part
Paid Stockley Donelson for A
of the Sum of two thousand
hand paid the receipt wheret
rath And by these presents
Self alien enforff And Confir
Jackson his Heirs And A
certain traits or parcels of La
sand acres 1/01, thousand Ayre

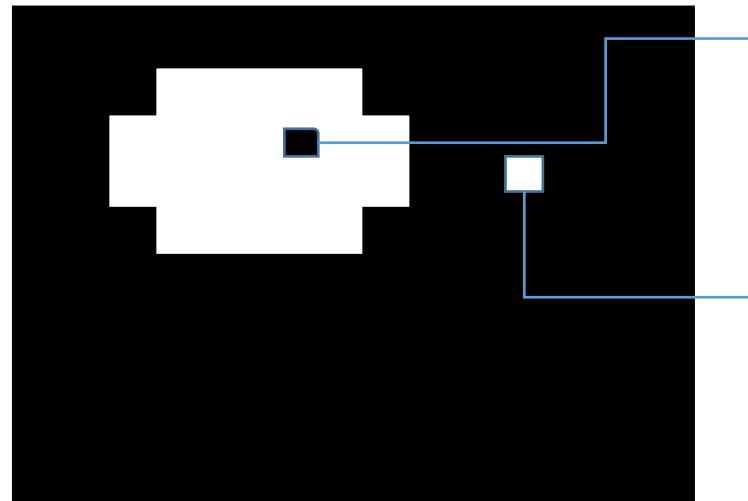
Indentity Six between Stockley
f Knox And State of Tennessee
Andrew Jackson off the County
Tats Alor said of the Other part
Paid Stockley Donelson for A
of the Sum of two thousand
hand paid the receipt wheret
rath And by these presents
Self alien enforff And Confir
Jackson his Heirs And A
certain traits or parcels of La
sand acres 1/01, thousand Ayre

b=0.1

Indentity Six between Stockley
f Knox And State of Tennessee
Andrew Jackson off the County
Tats Alor said of the Other part
Paid Stockley Donelson for A
of the Sum of two thousand
hand paid the receipt wheret
rath And by these presents
Self alien enforff And Confir
Jackson his Heirs And A
certain traits or parcels of La
sand acres 1/01, thousand Ayre

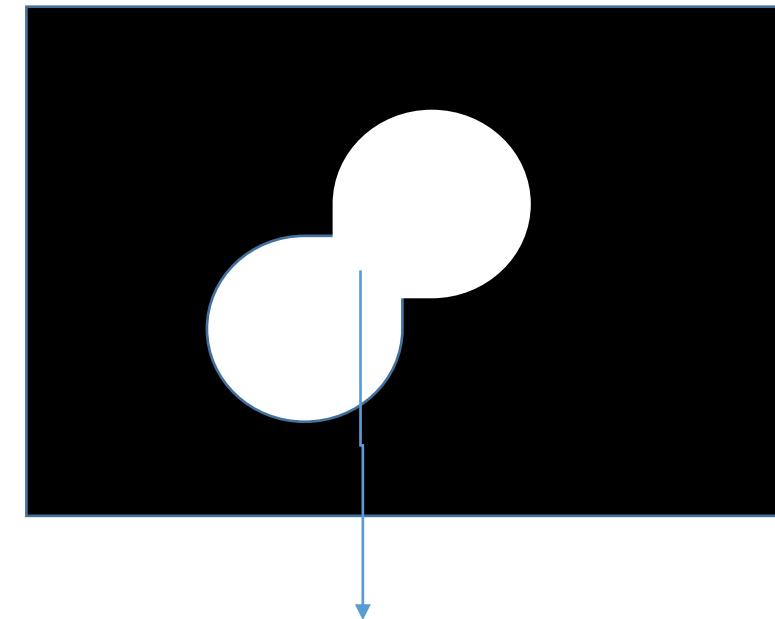
Morphological image processing

※Operate on a **Binary** image (After thresholding)



False negative

False positive



False positive
cause 2 objects to appear as 1

Morphological image processing

Structuring element :

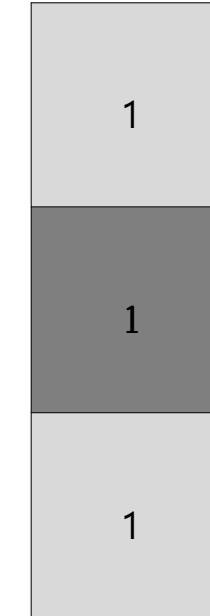
A small pixel template that helps to produce new image

0	1	0
1	1	1
0	1	0

Disk

1	1	1
1	1	1
1	1	1

Square

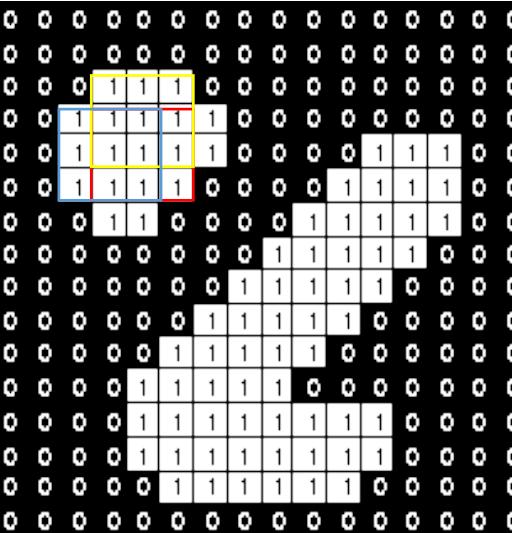


• • •

Erosion

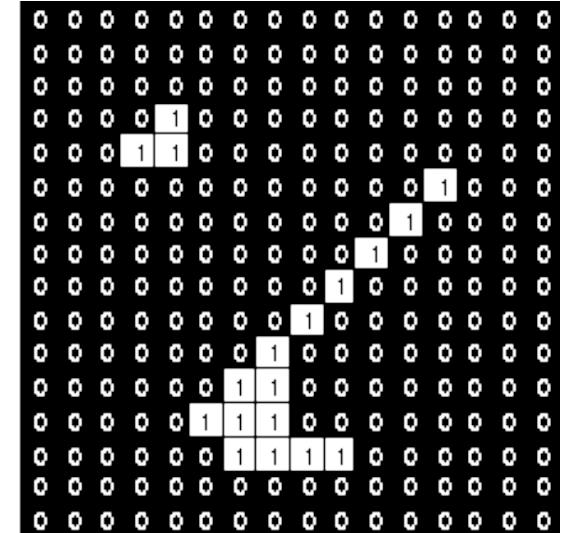
1	1	1
1	1	1
1	1	1

3 X 3 square structure



0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0
0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1	0	0	0
0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1

Original

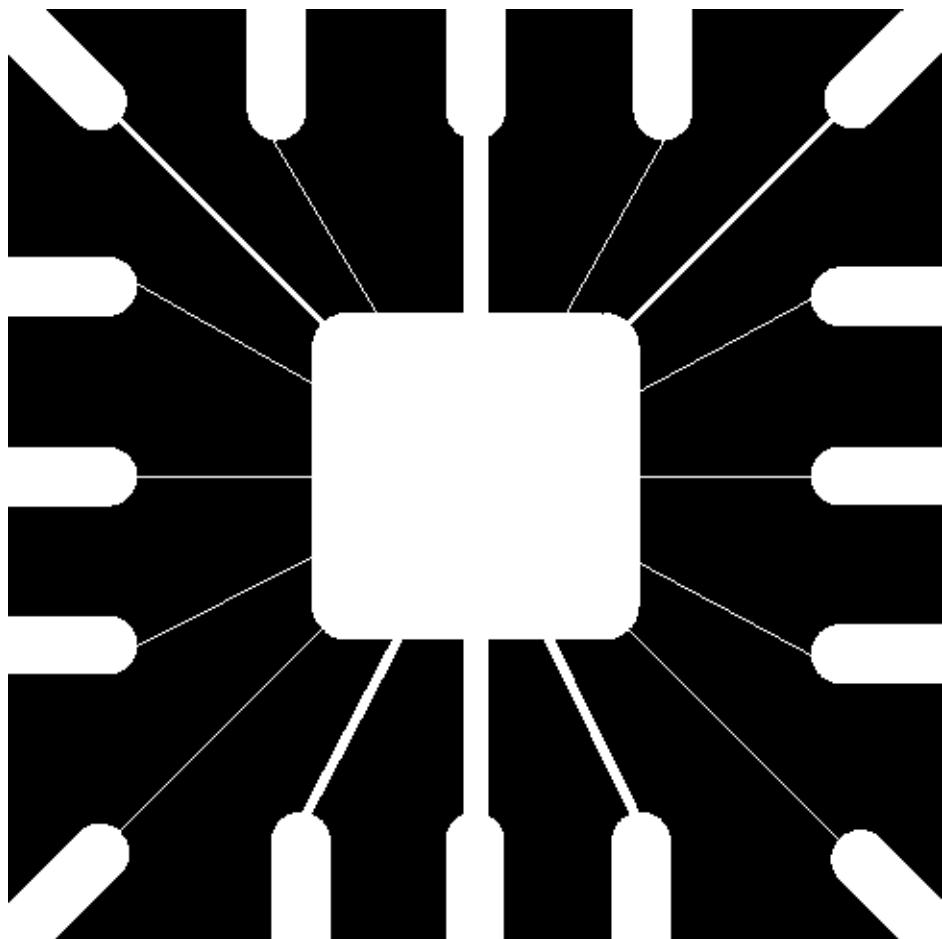


0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

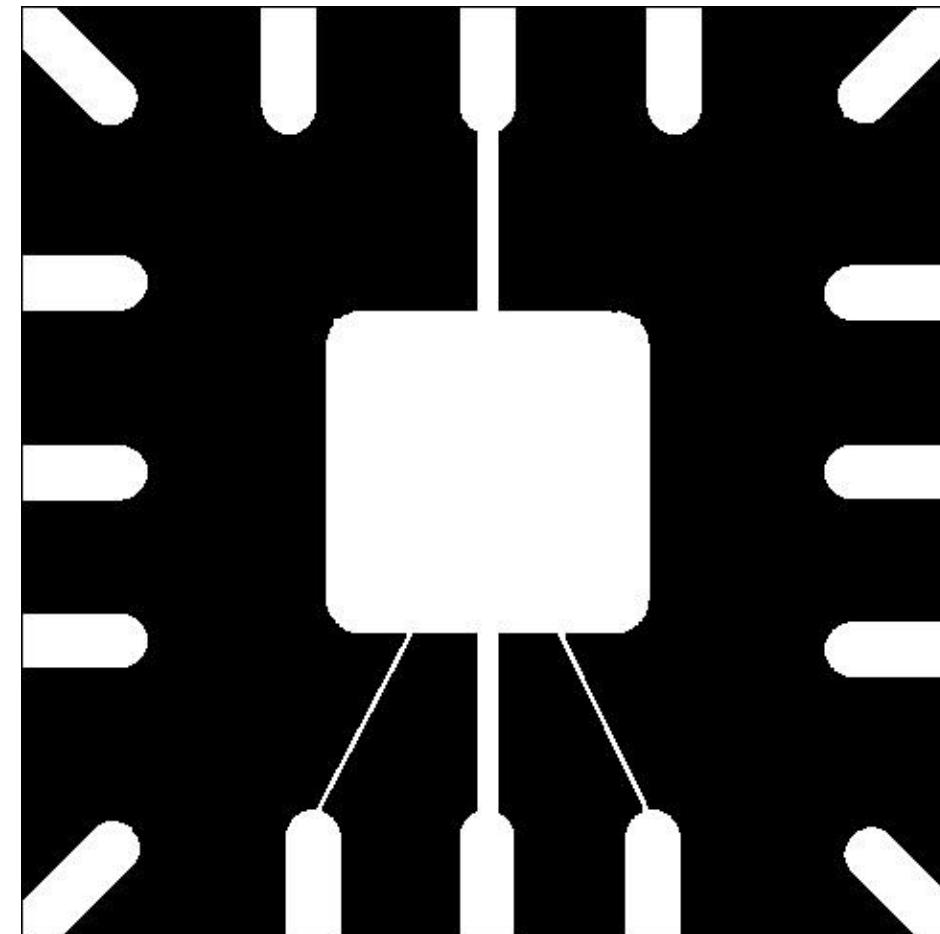


After Erosion

Erosion

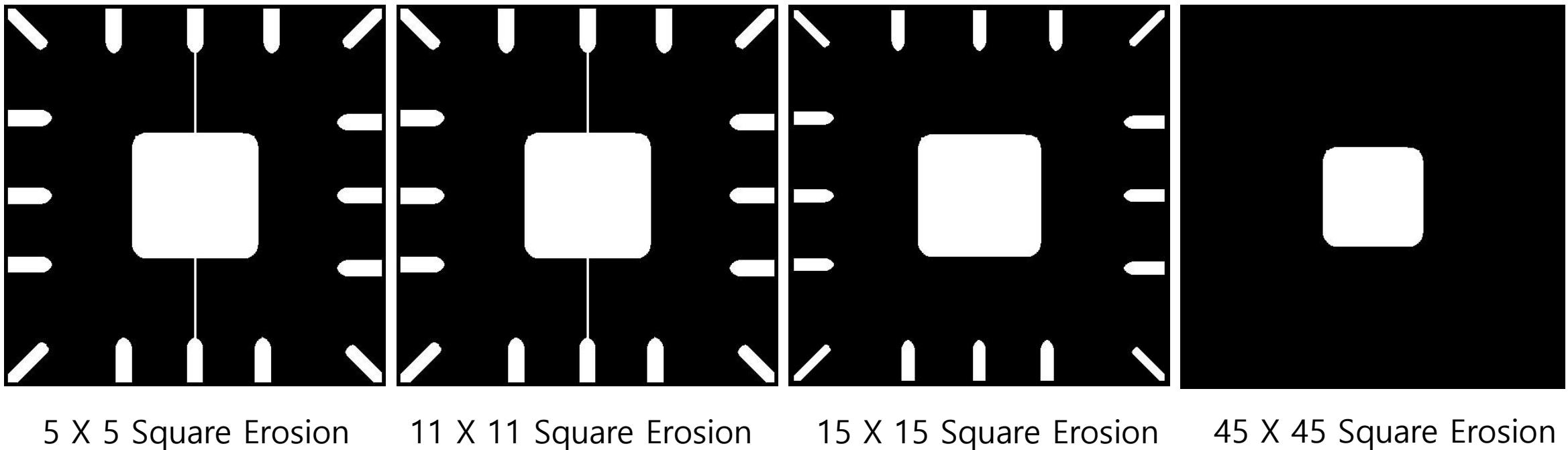


Original



3 X 3 Square Erosion

Erosion



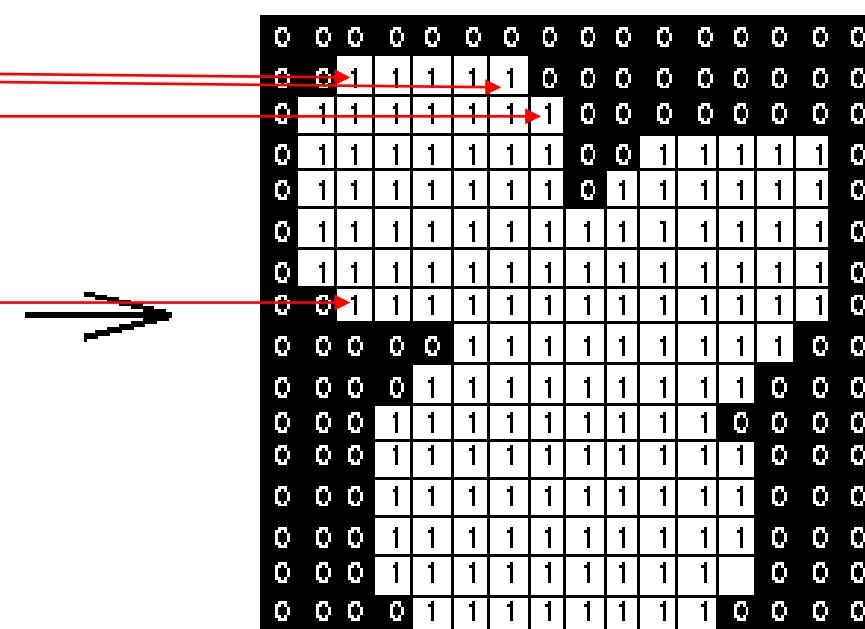
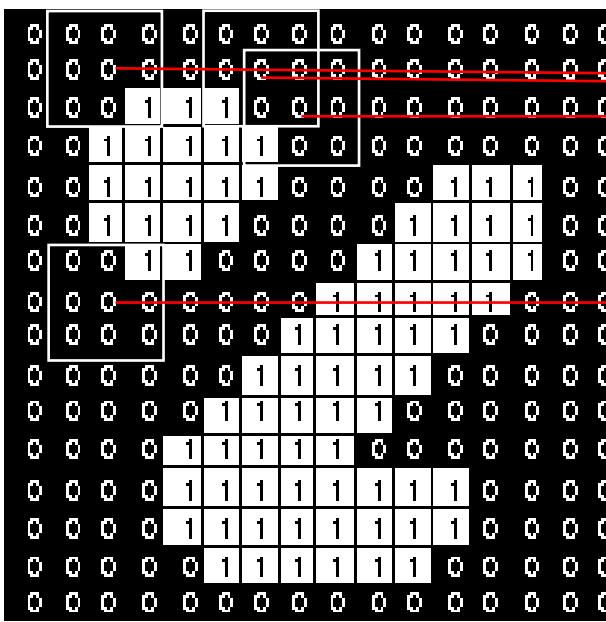
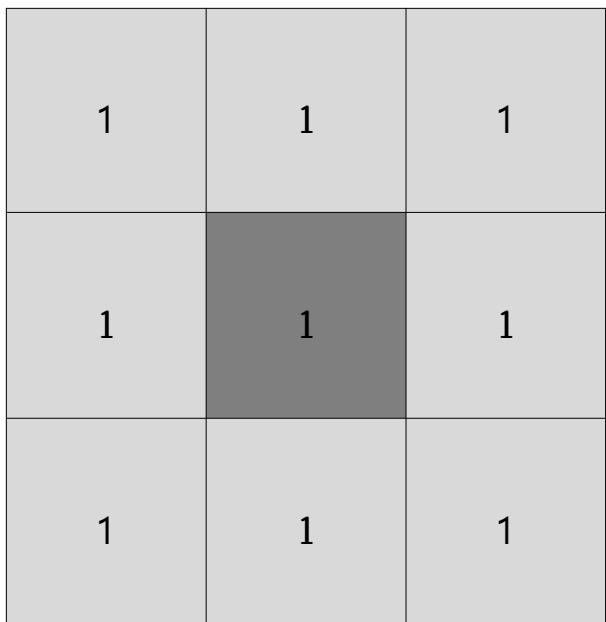
5 X 5 Square Erosion

11 X 11 Square Erosion

15 X 15 Square Erosion

45 X 45 Square Erosion

Dilation



3 X 3 square structure

Dilation

Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.

The image shows a black rectangular area containing the word "Historically" in a white, blocky, pixelated font. The letters are slightly slanted to the right.

Original

Dilation

Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.

Historically

Dilation

Historically, certain computer programs were written using only two digits rather than four to define the applicable year. Accordingly, the company's software may recognize a date using "00" as 1900 rather than the year 2000.

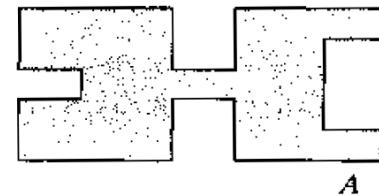
Historically

3 X 3 Square dilation

Opening and Closing

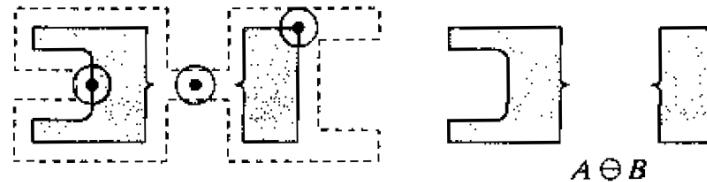
A : Original Image

B : Structure element



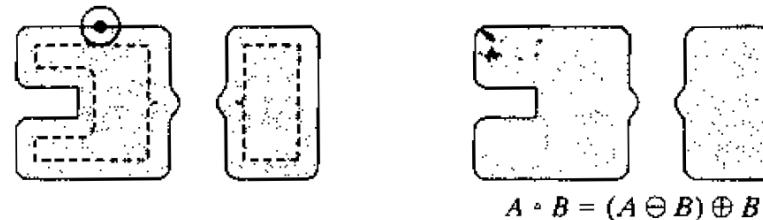
A

Erosion



$A \ominus B$

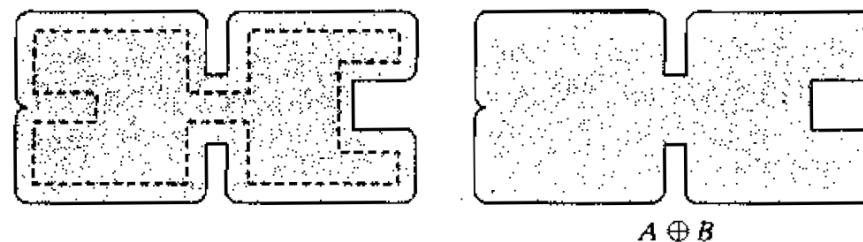
Dilation after Erosion



$A \circ B = (A \ominus B) \oplus B$

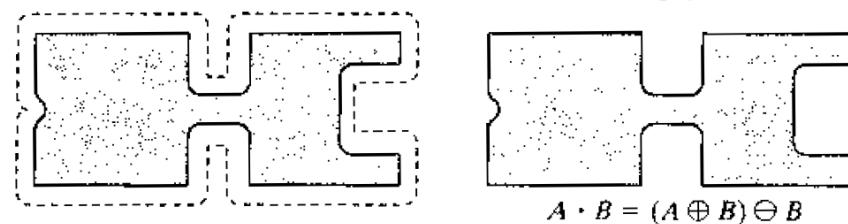
Opening

Dilation



$A \oplus B$

Erosion after Dilation



$A \cdot B = (A \oplus B) \ominus B$

Closing

Opening (3x3 square)



Original



Erosion



Opening(Dilation after Erosion)

Closing (3x3 square)



Opening



Dilation



Closing (Erosion after Dilation)

Opening and Closing



Original

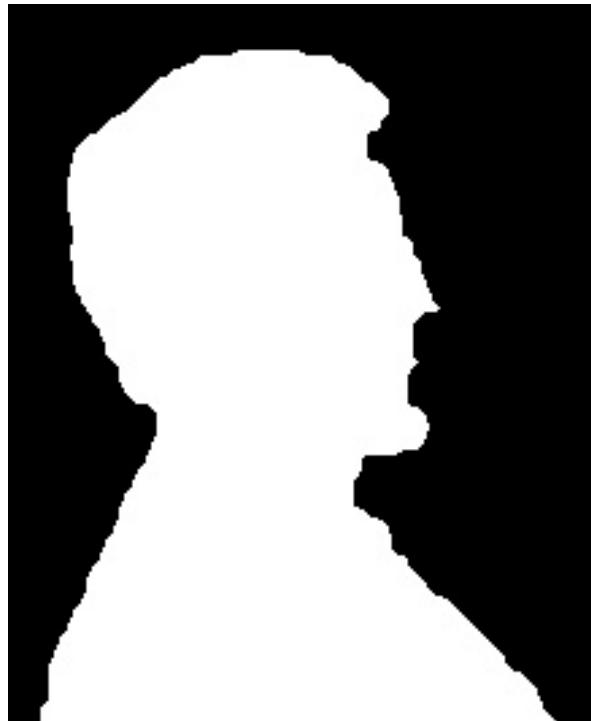


After Opening and Closing

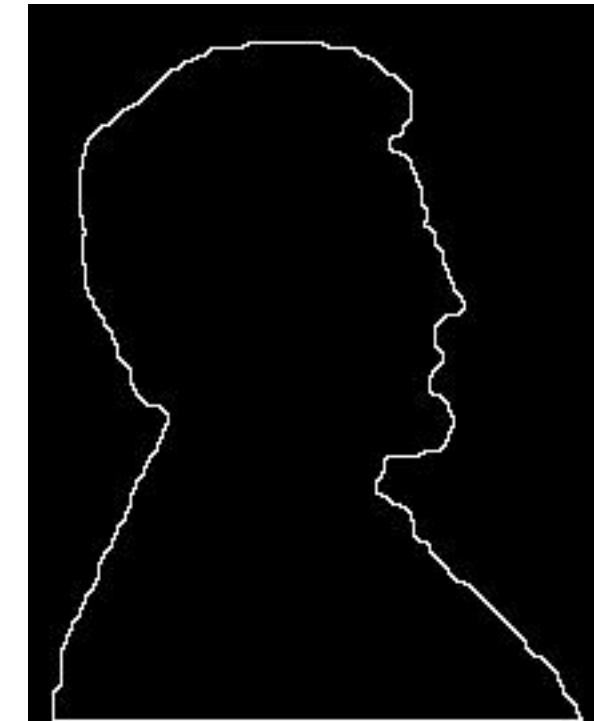
Boundary Extraction



Original



Erosion



Boundary Extraction

THANK YOU
for your attention