Computer Vision

Gustavo Teodoro Laureano
gustavo@inf.ufg.br

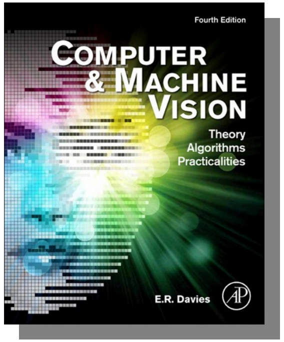
Programa de Pós-Graduação em Ciência da Computação
Instituto de Informática – Universidade Federal de Goiás

Outline

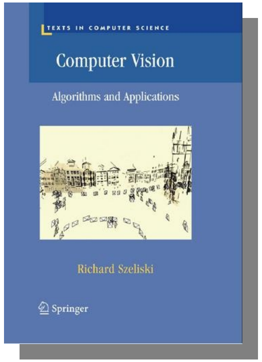
- Thresholding
  - Global and Local Methods
- Hough Transform

Course Introduction

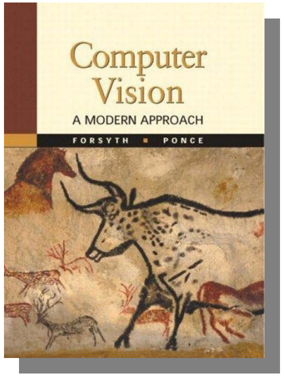
- Many of the words of this course are taken from the books:



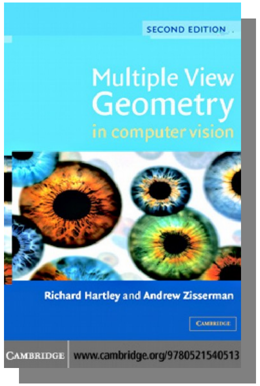
Computer & Machine Vision – Theory, Algorithms, Practicalities.
Fourth Edition, 2012. Elsevier Inc.
E. Roy Davies



Computer Vision – Algorithm and Applications.
2010. Springer.
Richard Szeliski



Computer Vision – A modern Approach.
2003. Prentice Hall.
David Forsyth and Jean Ponce



Multiple View Geometry.
Second Edition, 2012. Cambridge.
Richard Hartley & Andrew Zisserman

Image Binarization

Image Binarization

- Image Thresholding ...

T

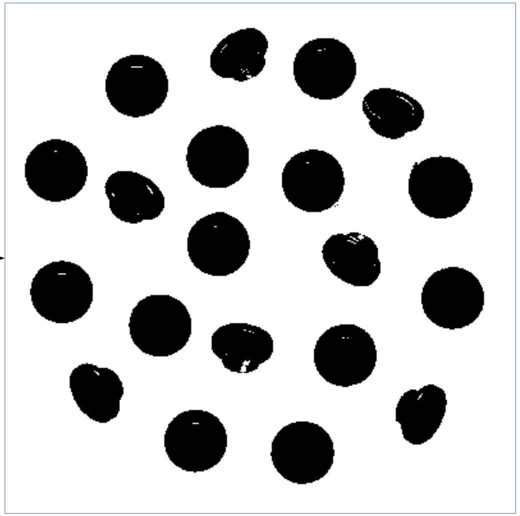


Image Binarization

- Image Thresholding ...

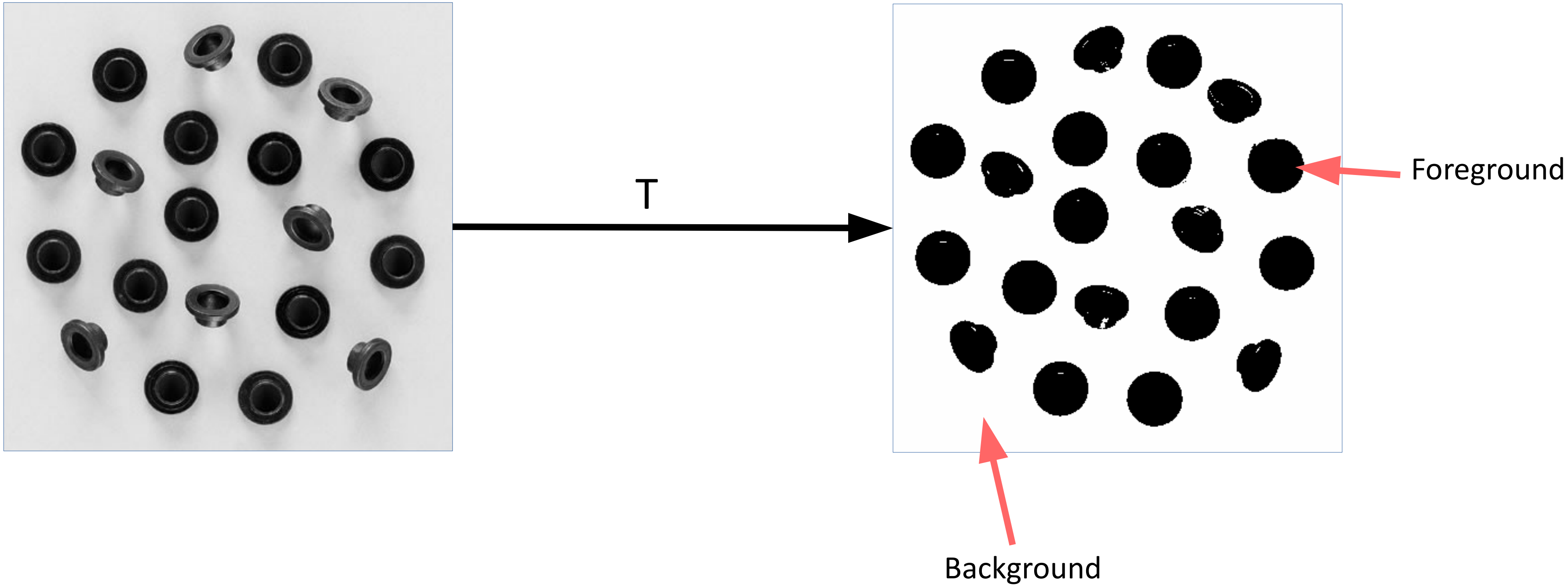
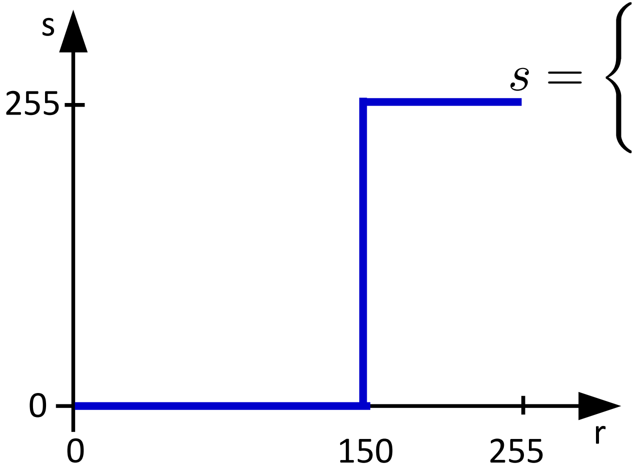
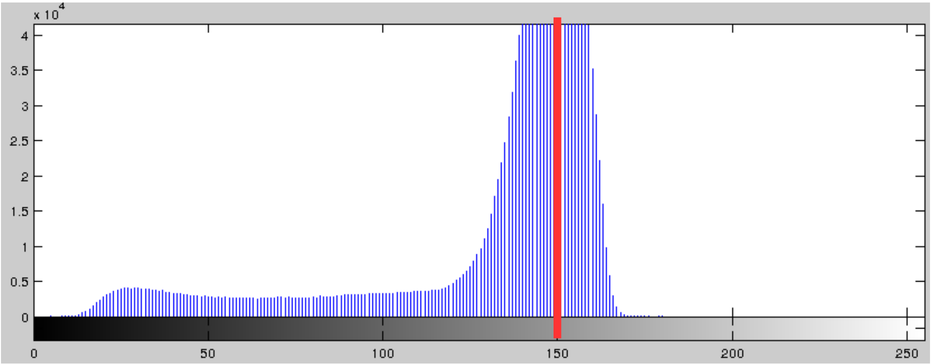


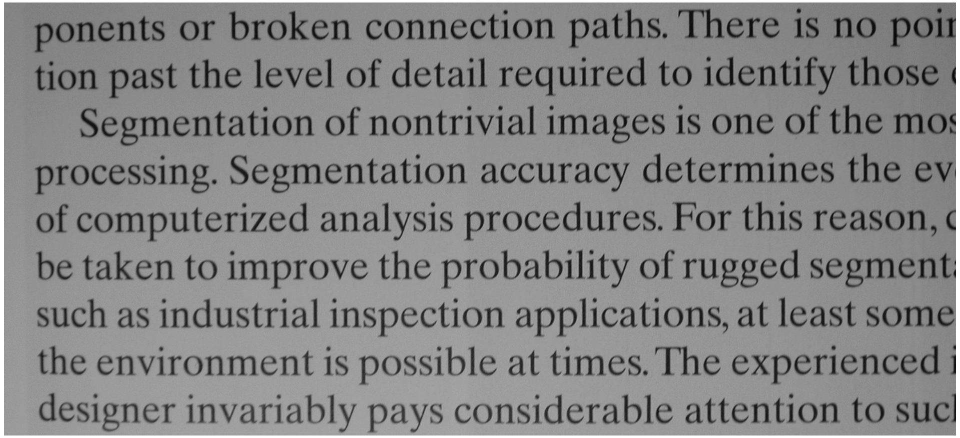
Image Binarization

- Manual Thresholding



$$s = \begin{cases} 0, r <= Th \\ 255, \text{otherwise} \end{cases}$$




ponents or broken connection paths. There is no poi
tion past the level of detail required to identify those
Segmentation of nontrivial images is one of the mos
processing. Segmentation accuracy determines the ev
of computerized analysis procedures. For this reason,
be taken to improve the probability of rugged segment
such as industrial inspection applications, at least some
the environment is possible at times. The experienced
designer invariably pays considerable attention to suc

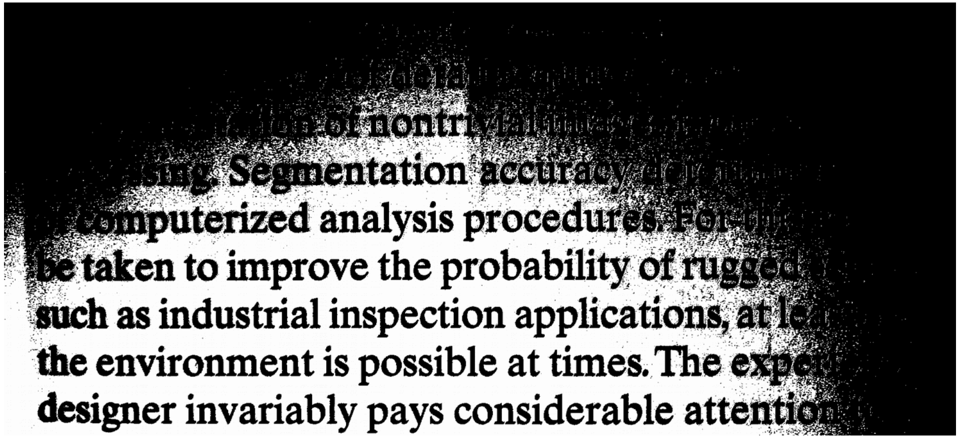
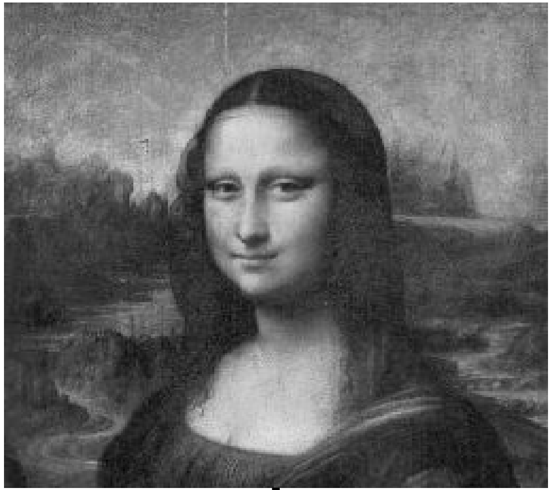
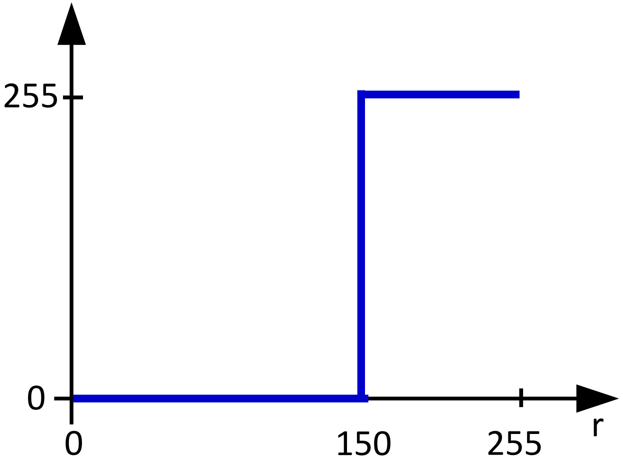
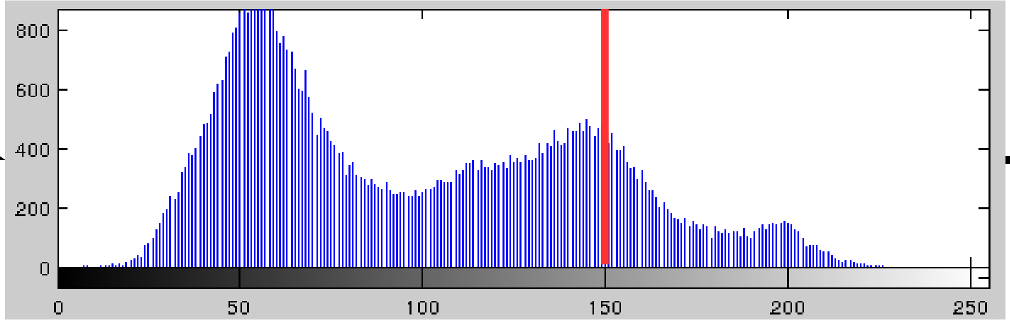

computerized analysis procedures.
be taken to improve the probability of rugged
such as industrial inspection applications, at le
the environment is possible at times. The expe
designer invariably pays considerable attention

Image Binarization

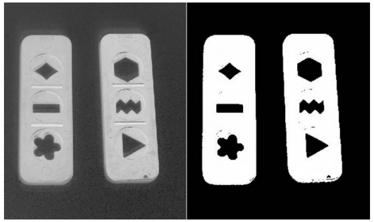
- Manual Thresholding







- When use an empirical threshold value?
  - In controlled conditions, an empirical threshold may be usefully.
    - Illumination, Noise, Background must be known.
  - When the two distributions are reasonably well separated:
    - some overlap between classes but not too much.
  - Examples:
    - Industry
      - Assembly-line
      - Visual Inspection
    - Off-the-shelf products
      - Xerox machines
      - Optical Readers
      - QR Code Readers



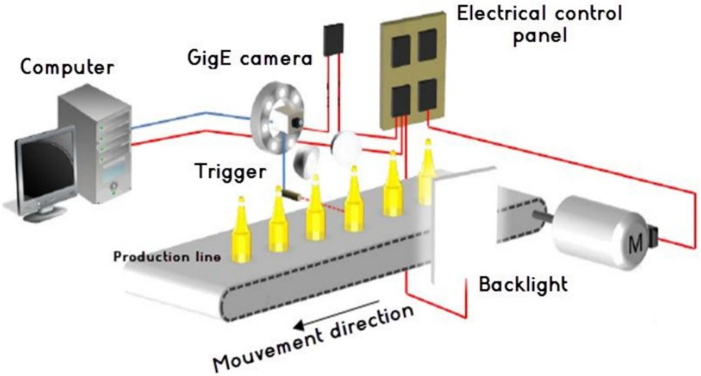


Image Binarization

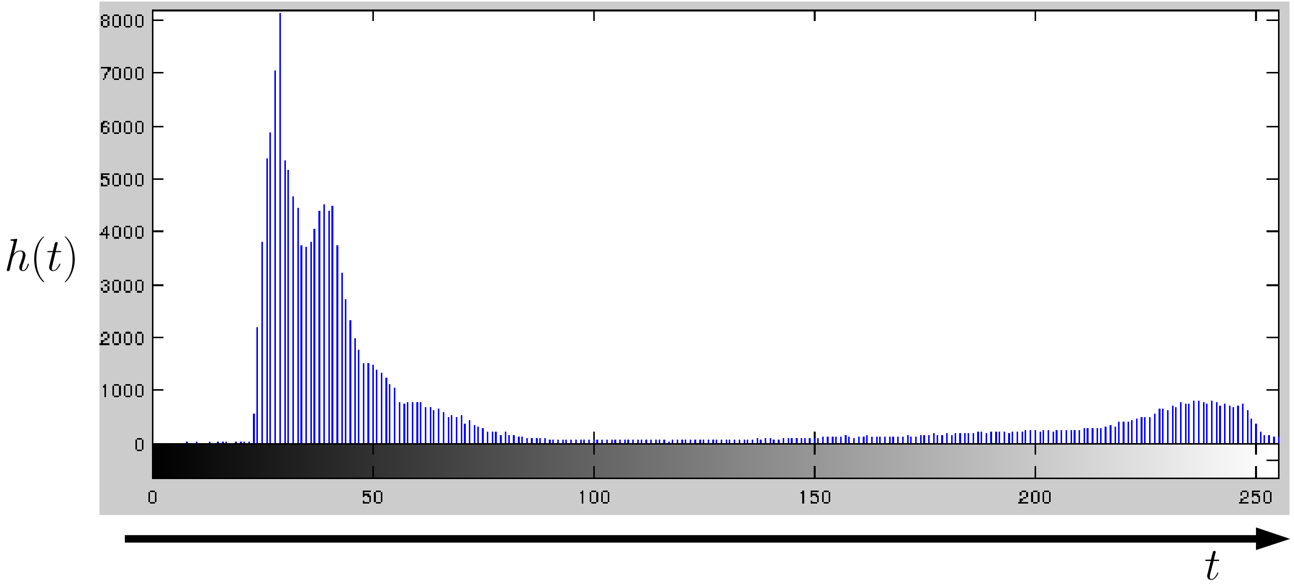
- Adaptive Thresholding:
  - Global Methods
  - Local Methods

- In both there is the question: **What the Best Threshold Value?**

- What the Best Threshold Value for this image?

Grayscale Image

Image Histogram



- How to compute histogram?

```
function [ h ] = histogram( I )
    h = zeros(1,256);
    for i = 1 : length( I(:) )
        h( I(i)+1 ) = h( I(i)+1 ) + 1;
    end
end
```

or

```
h = imhist( I );
```

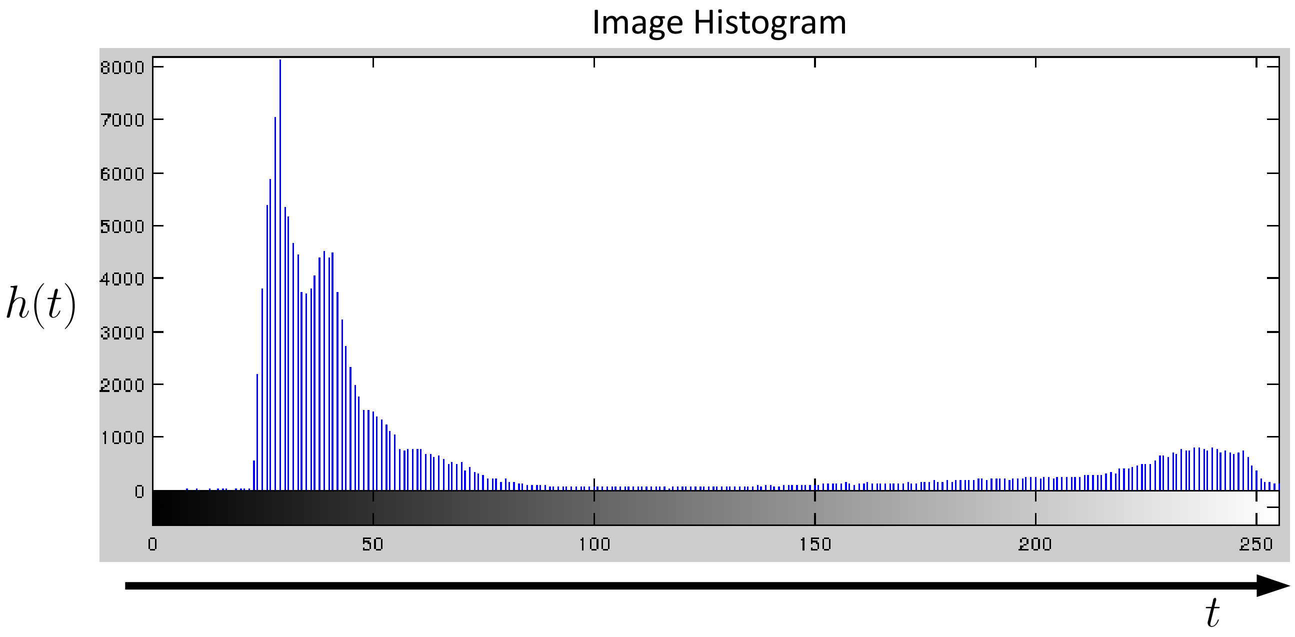
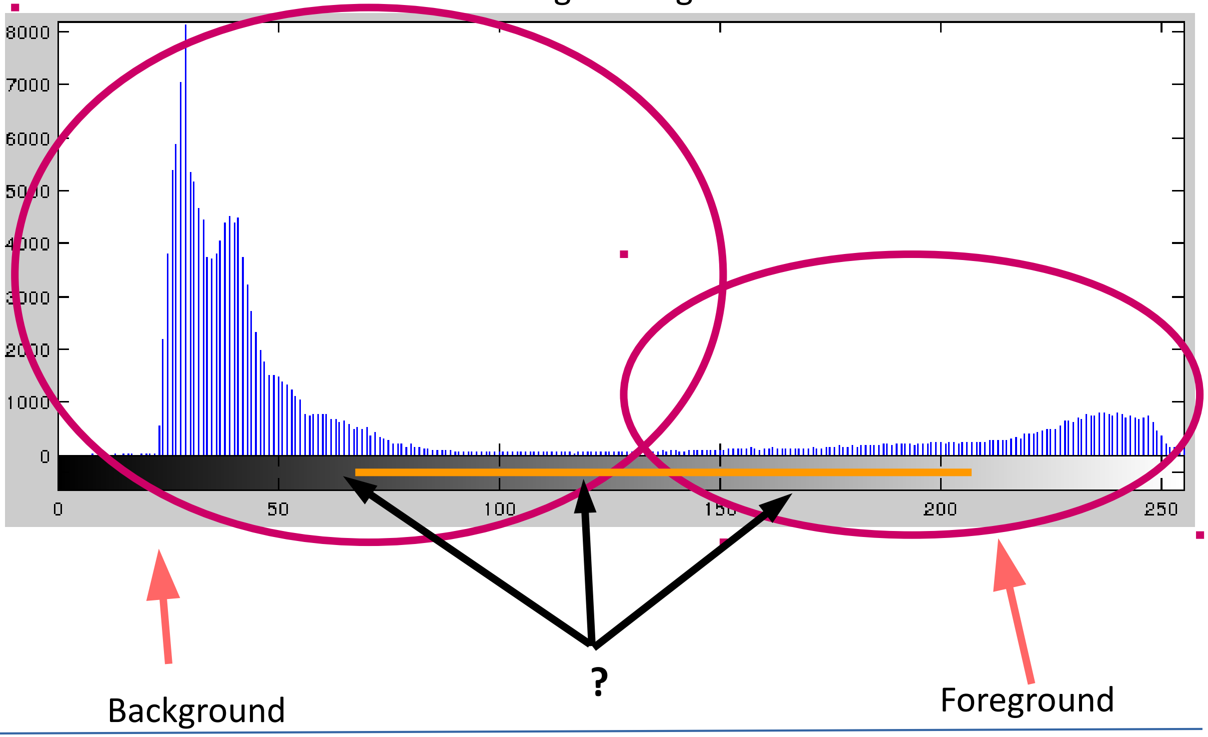


Image Binarization

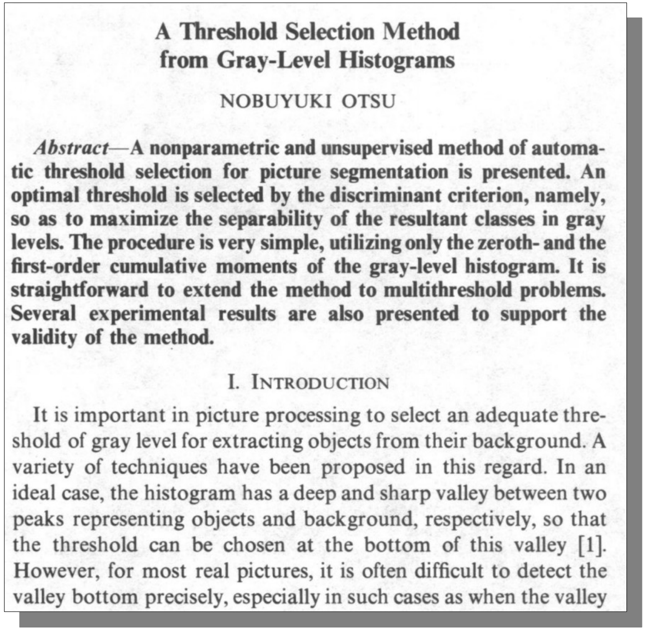
- What the Best Threshold Value for this image?

Grayscale Image

Image Histogram



- What the Best Threshold Value for this image?
  - Otsu 's Method



A Threshold Selection Method from Gray-Level Histograms

NOBUYUKI OTSU

Abstract—A nonparametric and unsupervised method of automatic threshold selection for picture segmentation is presented. An optimal threshold is selected by the discriminant criterion, namely, so as to maximize the separability of the resultant classes in gray levels. The procedure is very simple, utilizing only the zeroth- and the first-order cumulative moments of the gray-level histogram. It is straightforward to extend the method to multithreshold problems. Several experimental results are also presented to support the validity of the method.

I. Introduction

It is important in picture processing to select an adequate threshold of gray level for extracting objects from their background. A variety of techniques have been proposed in this regard. In an ideal case, the histogram has a deep and sharp valley between two peaks representing objects and background, respectively, so that the threshold can be chosen at the bottom of this valley [1]. However, for most real pictures, it is often difficult to detect the valley bottom precisely, especially in such cases as when the valley

OTSU, N. 1979. *A Threshold Selection Method from Gray-Level Histograms*. IEEE Transactions On Systrems, MAN, And Cybernetics, Vol. Smc-9, No. 1, January 1979

Image Histogram

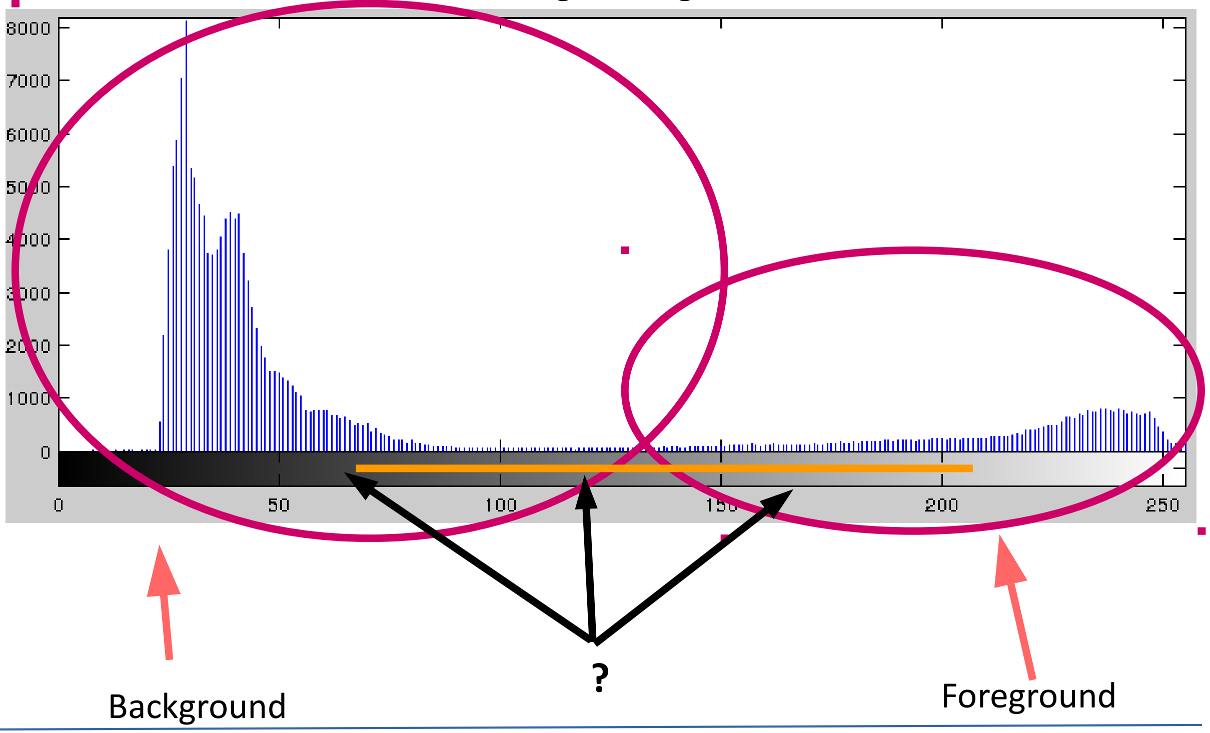


Image Binarization

- What the Best Threshold Value for this image?
  - Otsu 's Method
  - Exhaustive search for Th that:
    - Minimize intra-class variance (within class variance)

      or
    - Maximize inter-class variance (between class variance)

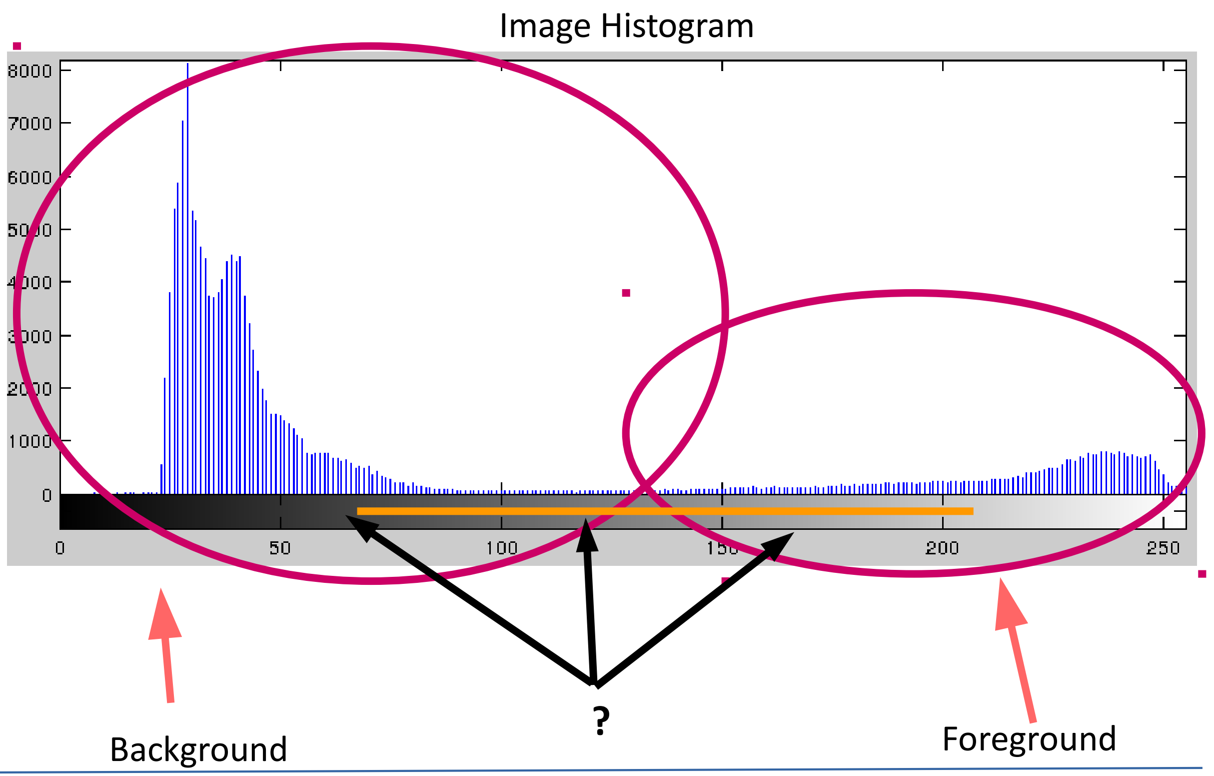


Image Binarization

- What the Best Threshold Value for this image?
  - Otsu 's Method
  - Exhaustive search for Th that:
    - Minimize intra-class variance (within class variance)

      or
    - Maximize inter-class variance (between class variance)

σ_1^2: background variance

σ_2^2: foreground variance

w_1: background weight

w_2: foreground weight

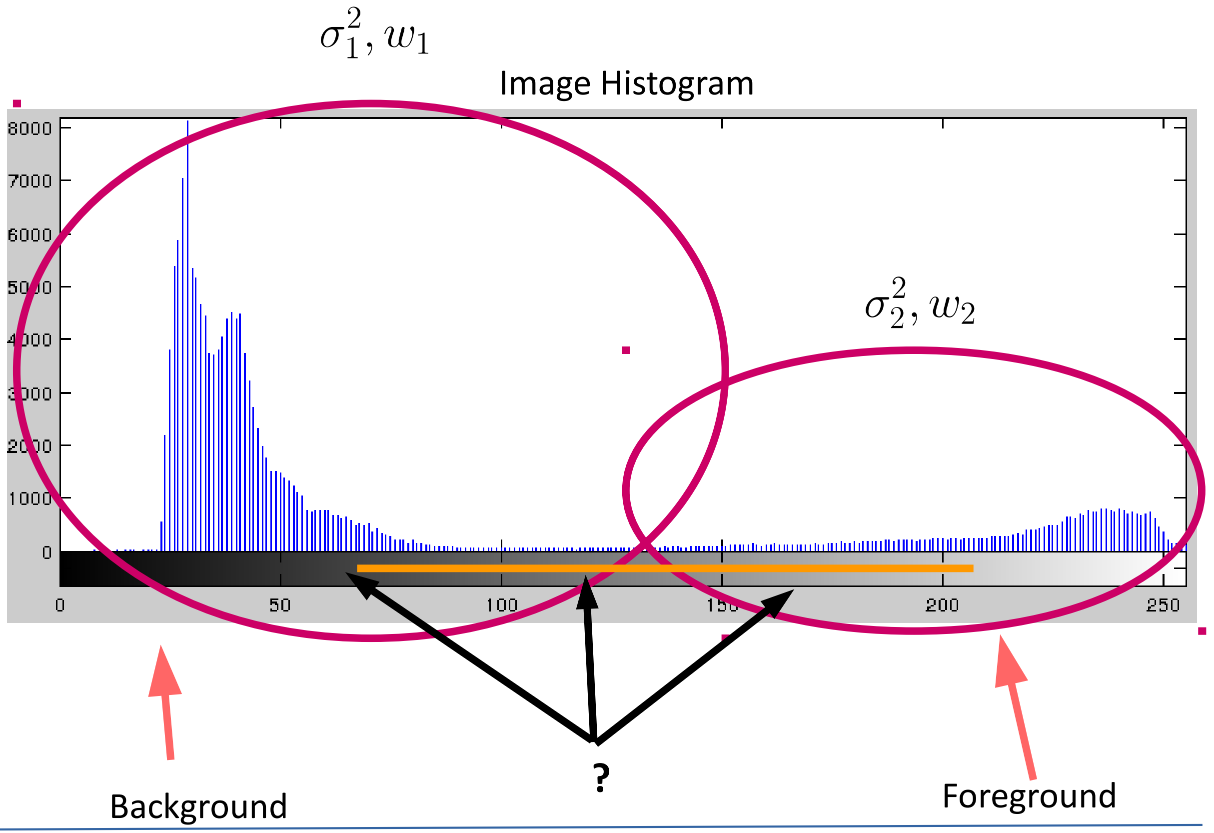


Image Binarization

- What the Best Threshold Value for this image?
  - Intra-class variance (within):

$$\sigma_w^2(t) = w_1(t)\sigma_1^2(t) + w_2(t)\sigma_2^2(t)$$

where:

$$\begin{aligned} \sigma_1^2(t)&: \text{ background variance} \\ \sigma_2^2(t)&: \text{ foreground variance} \\ w_1(t)&: \text{ background weight} \\ w_2(t)&: \text{ foreground weight} \end{aligned}$$

  - Otsu 's Method:

$$\arg\min_t \sigma_w^2(t)$$

Image Histogram

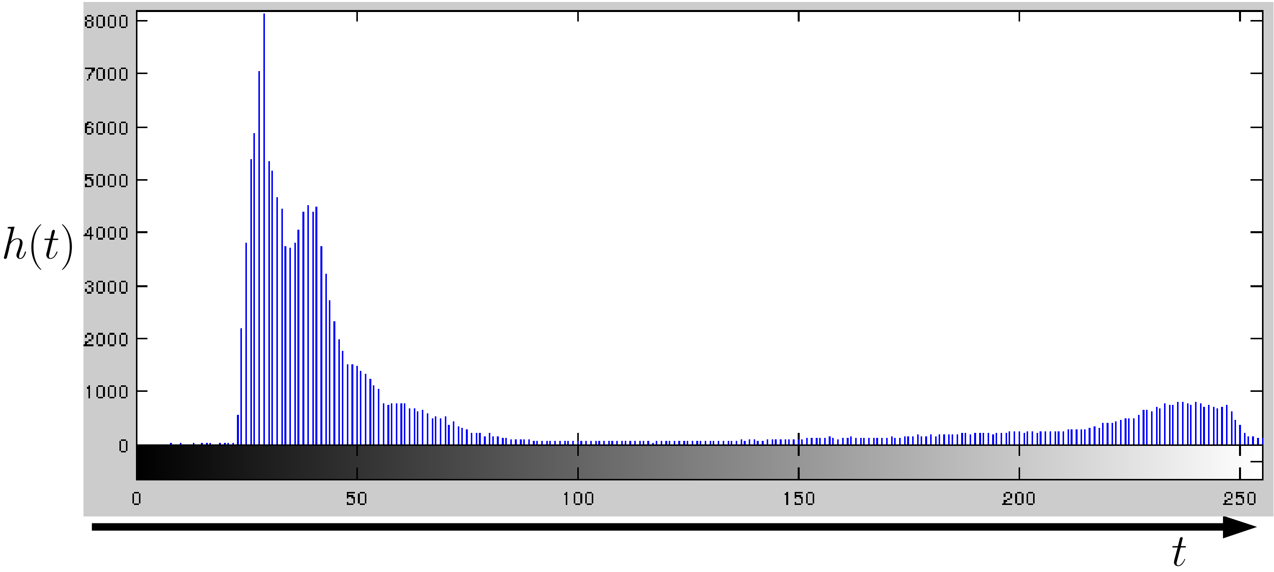


Image Binarization

- What the Best Threshold Value for this image?
  - Intra-class variance (within):

$$\sigma_w^2(t) = w_1(t)\sigma_1^2(t) + w_2(t)\sigma_2^2(t)$$

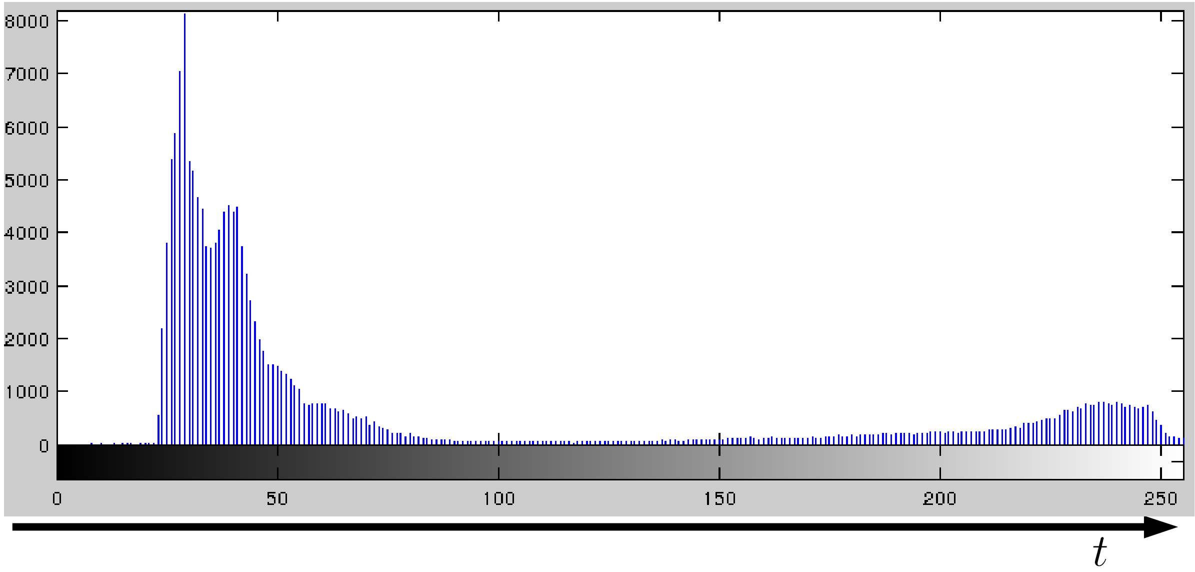
  - Inter-class variance (between):

$$\begin{aligned}\sigma_b^2 &= \sigma^2 - \sigma_w^2 \\ &= w_1(\mu_1 - \mu) + w_2(\mu_2 - \mu) \\ &= w_1 w_2 (\mu_1 - \mu_2)^2 \\ &\text{where } \mu = w_1\mu_1 + w_2\mu_2\end{aligned}$$

  - Otsu 's Method:

$$\arg\min_t \sigma_w^2(t) \Leftrightarrow \arg\max_t \sigma_b^2(t)$$

Image Histogram



- Otsu 's Method:

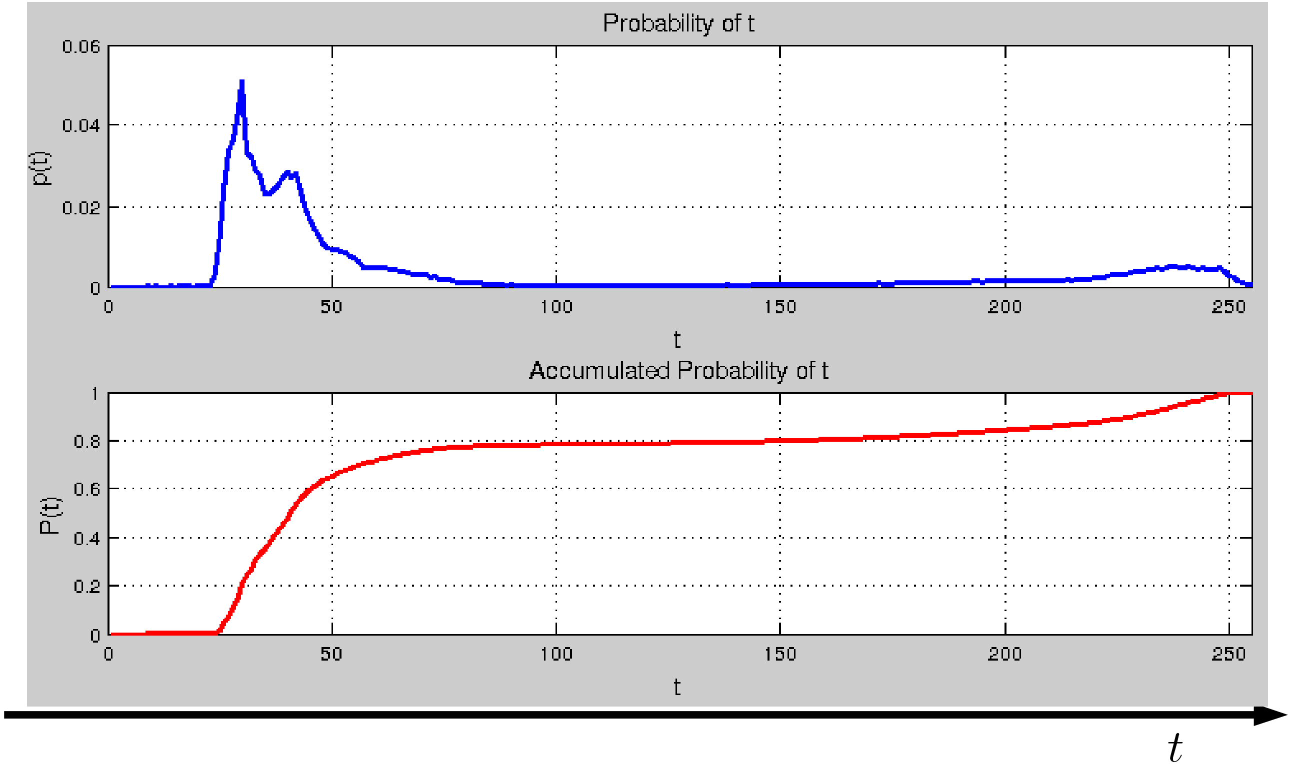


Image Binarization

- What the Best Threshold Value for this image?
  - Otsu's Algorithm $\arg\min_t \sigma_w^2(t) \Leftrightarrow \arg\max_t \sigma_b^2(t)$

$$
\begin{aligned}
\sigma_b^2 &= \sigma^2 - \sigma_w^2 \\
&= w_1(\mu_1 - \mu) + w_2(\mu_2 - \mu) \\
&= w_1 w_2 (\mu_1 - \mu_2)^2 \\
&\text{where } \mu = w_1\mu_1 + w_2\mu_2
\end{aligned}
$$

- Probability of t: $p(t) = \dfrac{h(t)}{WH}$
- Weights:

$$w_1(t) = \sum_{i=0}^{t} p(i) = P(t)$$

$$w_2(t) = \sum_{i=t+1}^{L-1} p(i) = P(L-1) - P(t)$$

- Accumulated Probability

$$P(t) = \sum_{i=0}^{t} p(t)$$

Image Binarization

- Otsu 's Method:

```
// Total number of pixels
int total = W*H;

// Calculate histogram
for (int t=0 ; i< 256 ; t++) hist[t]=0;
for (int i=0 ; i< total ; i++) hist[ data[i] ]++;

// Calculate total sum
float sum = 0;
for (int t=0 ; t<256 ; t++) sum += t * hist[t];

float sumB = 0;
int w1 = 0;
int w2 = 0;

float varMax = 0;
char threshold = 0;
```

```
for (int t=0 ; t<256 ; t++) {
  w1 += histData[t];            // Weight Background
  if (w1 == 0) continue;

  w2 = total - w1;              // Weight Foreground
  if (w2 == 0) break;

  sum1 += (float) (t * histData[t]);

  float m1 = sum1 / w1;         // Mean Background
  float m2 = (sum - sum1) / w2;  // Mean Foreground

  // Calculate Between Class Variance
  float varBetween = (float)w1 * (float)w2 * (m1 - m2) * (m1 - m2);

  // Check if new maximum found
  if (varBetween > varMax) {
    varMax = varBetween;
    threshold = t;
  }
}
```

Image Binarization

- Otsu 's Method:

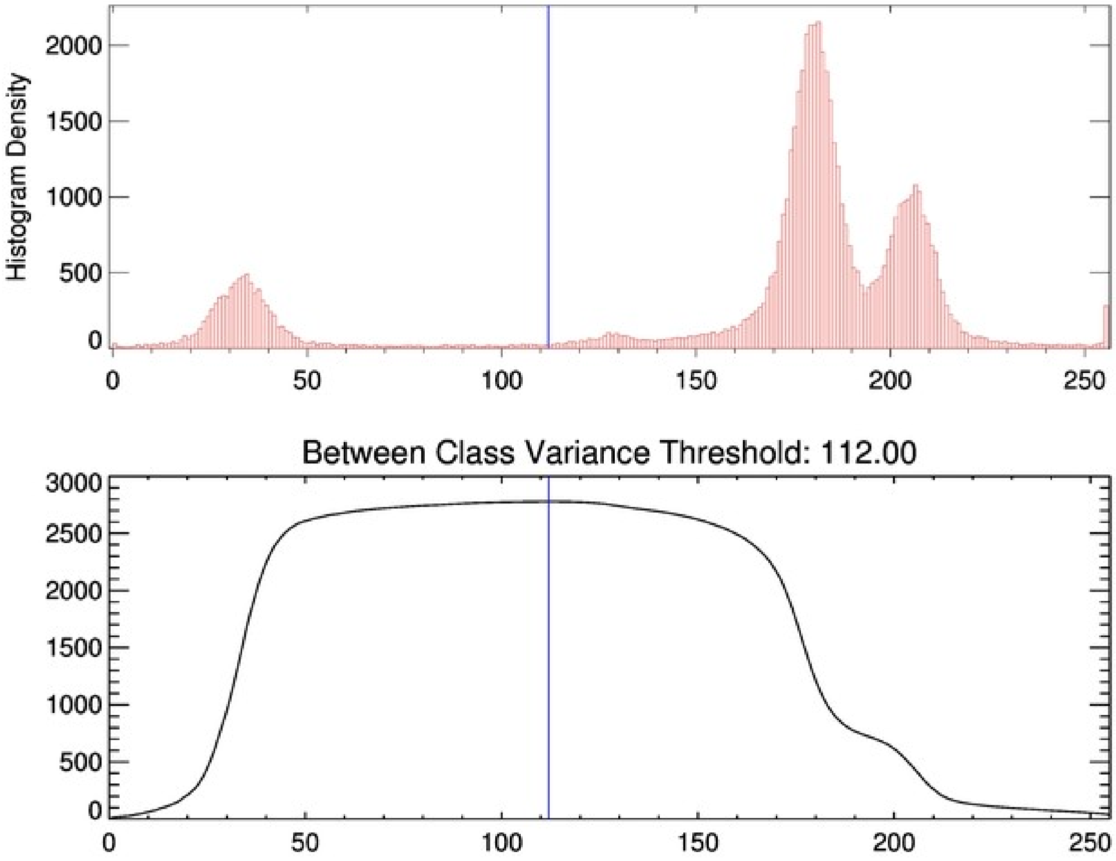
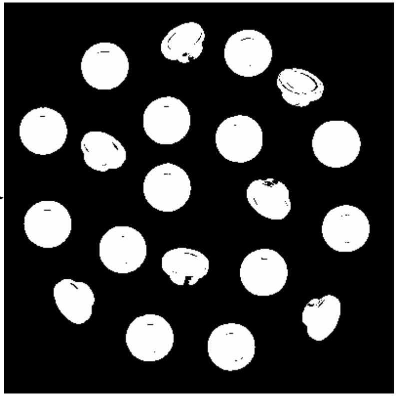
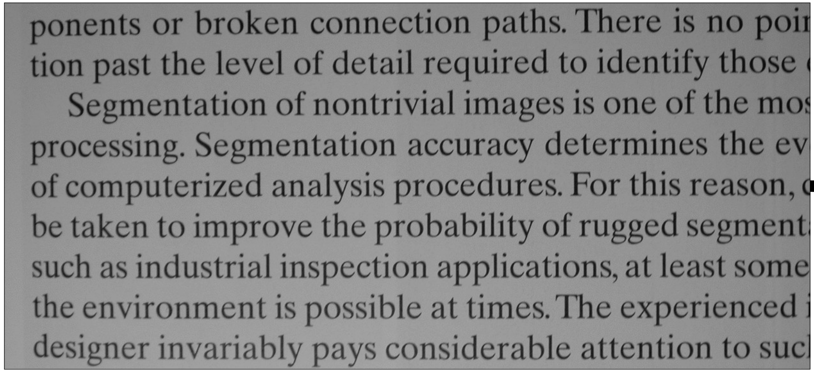


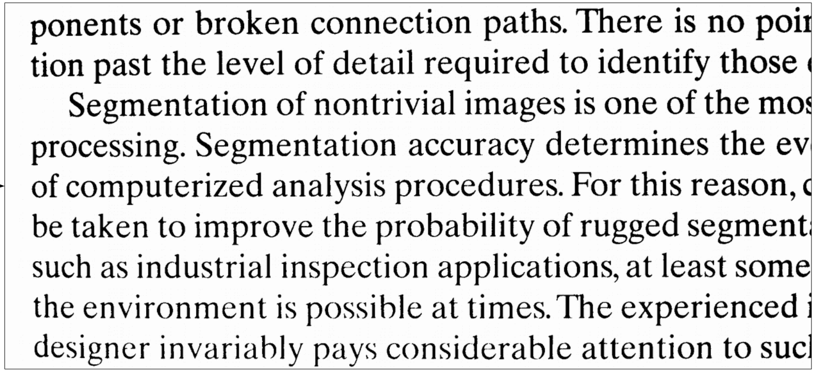
Image Binarization

- Otsu's Method:





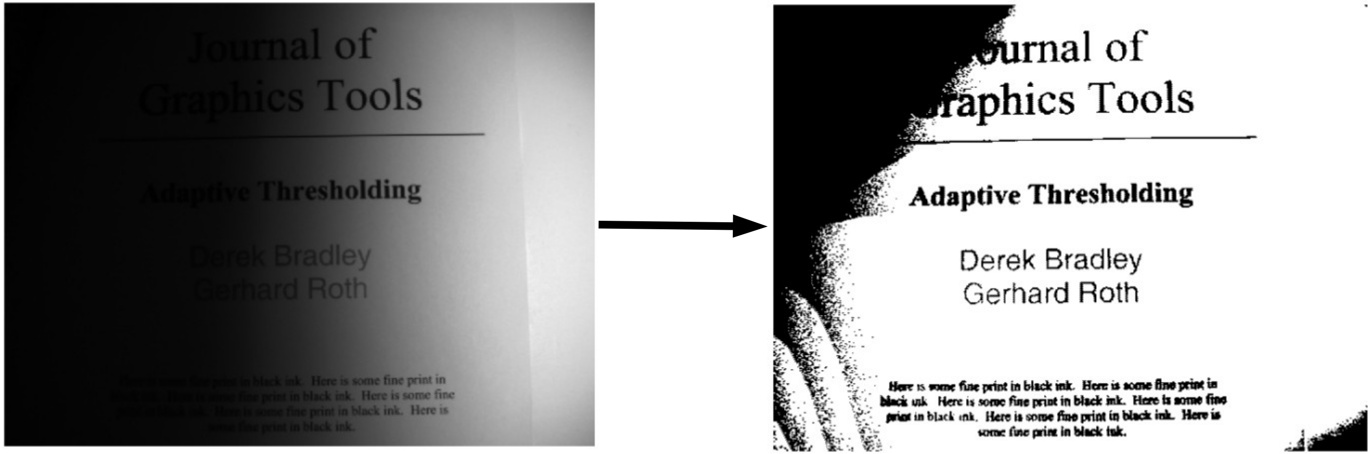
ponents or broken connection paths. There is no poi
tion past the level of detail required to identify those
Segmentation of nontrivial images is one of the mos
processing. Segmentation accuracy determines the ev
of computerized analysis procedures. For this reason,
be taken to improve the probability of rugged segment
such as industrial inspection applications, at least some
the environment is possible at times. The experienced
designer invariably pays considerable attention to suc



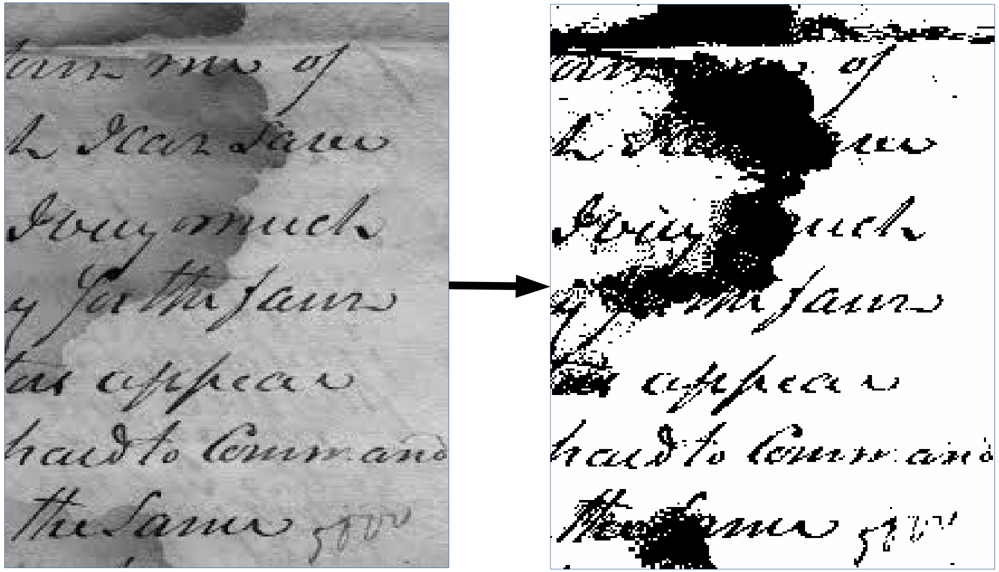
ponents or broken connection paths. There is no poi
tion past the level of detail required to identify those
Segmentation of nontrivial images is one of the mos
processing. Segmentation accuracy determines the ev
of computerized analysis procedures. For this reason,
be taken to improve the probability of rugged segment
such as industrial inspection applications, at least some
the environment is possible at times. The experienced
designer invariably pays considerable attention to suc

Image Binarization

- Otsu's Method:



- Otsu's Method:



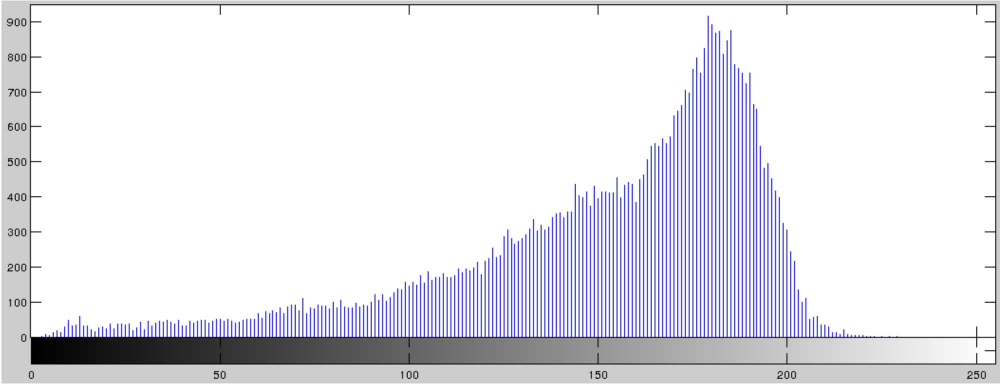


Image Binarization

- Local Methods

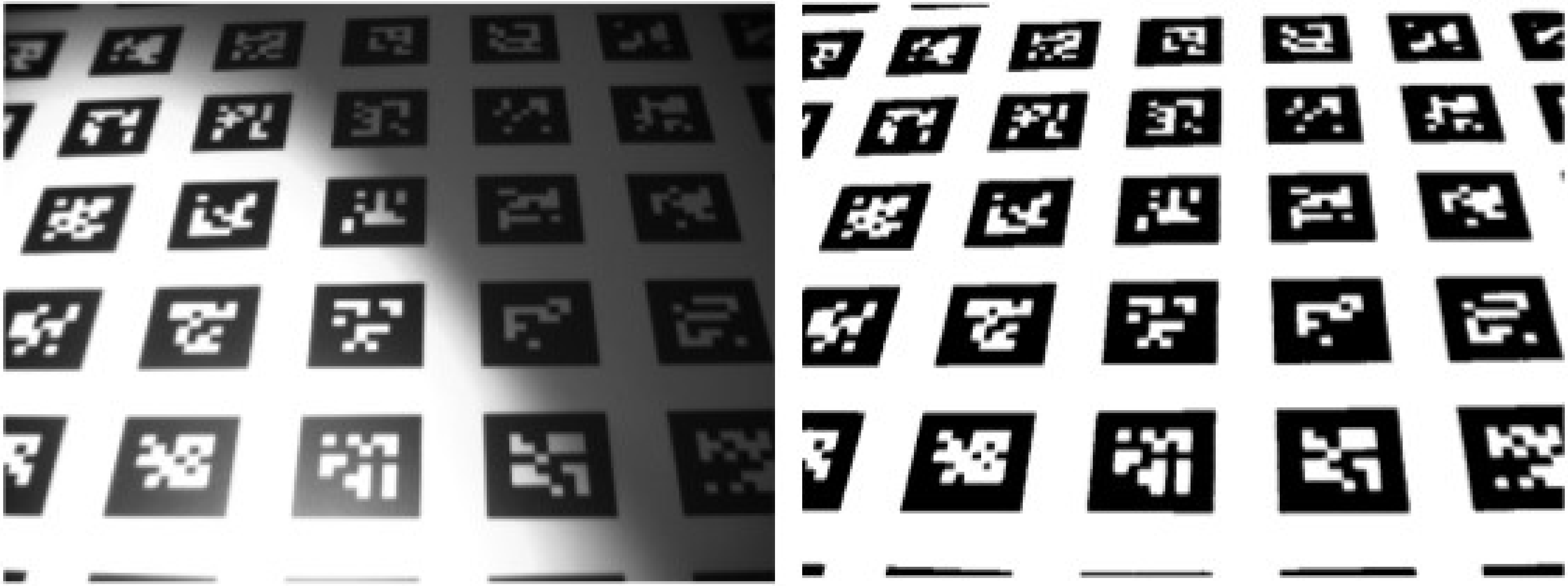
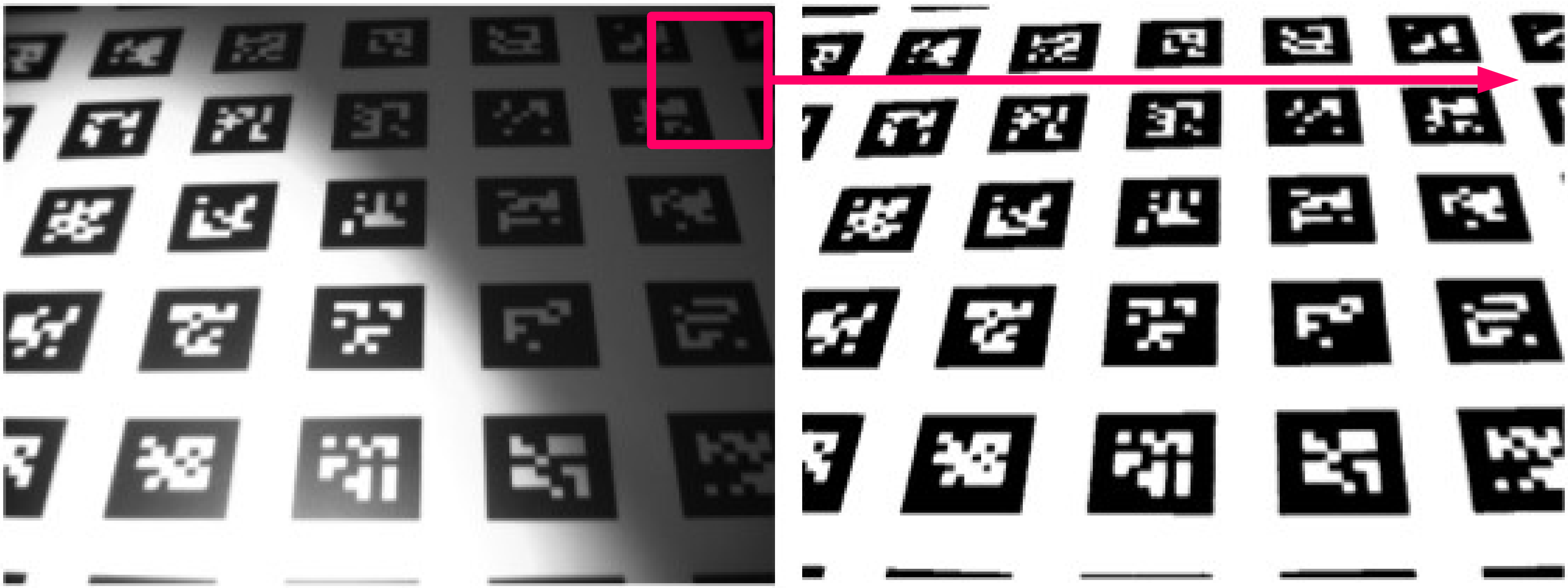


Image Binarization

- Local Methods

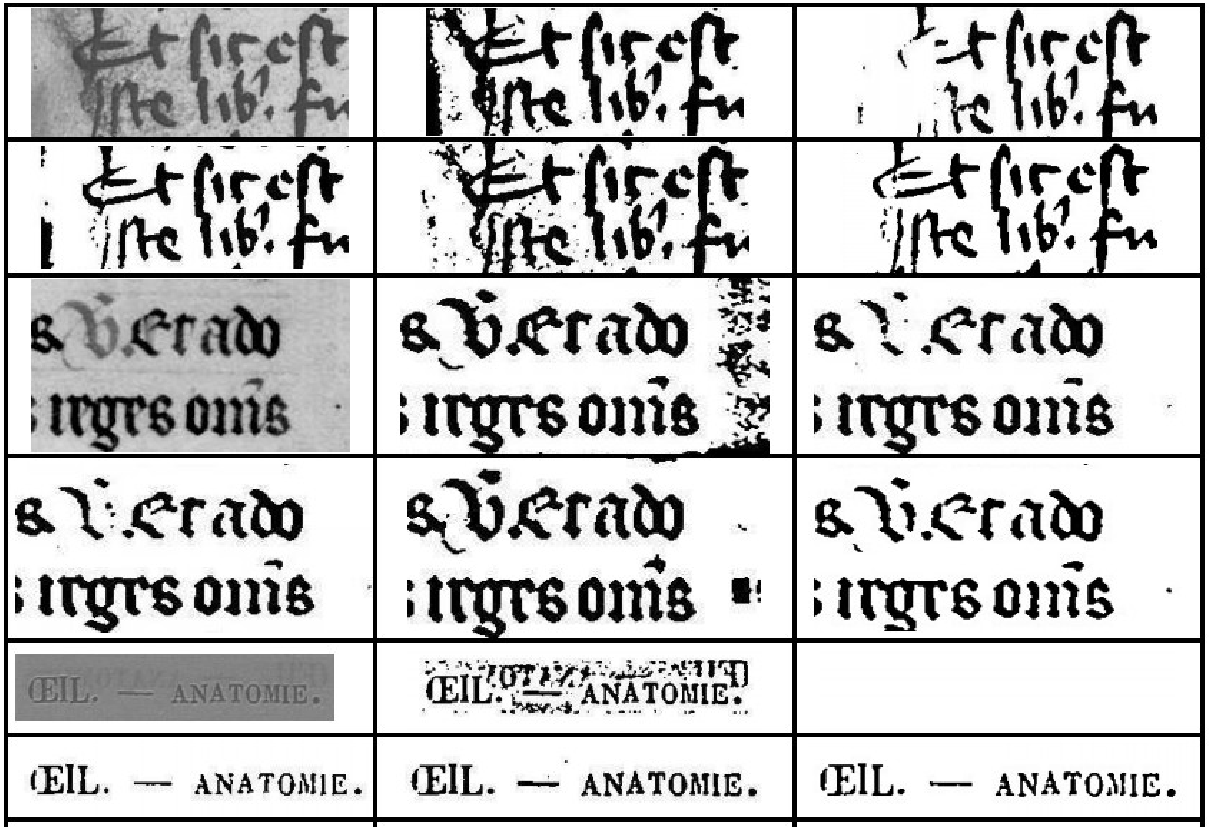


- Local Methods
  - Local Otsu
  - Niblack's Algorithm $T_{Niblack} = \mu + k\sigma$
  - Sauvola's Algorithm $T_{Sauvola} = \mu(1 - k(1 - \frac{\sigma}{R}))$

Image Binarization

- How to measure accuracy of thresholding methods?

- How to measure accuracy of thresholding methods?
  - Visual



- How to measure accuracy of thresholding methods?
  - Influence in final results

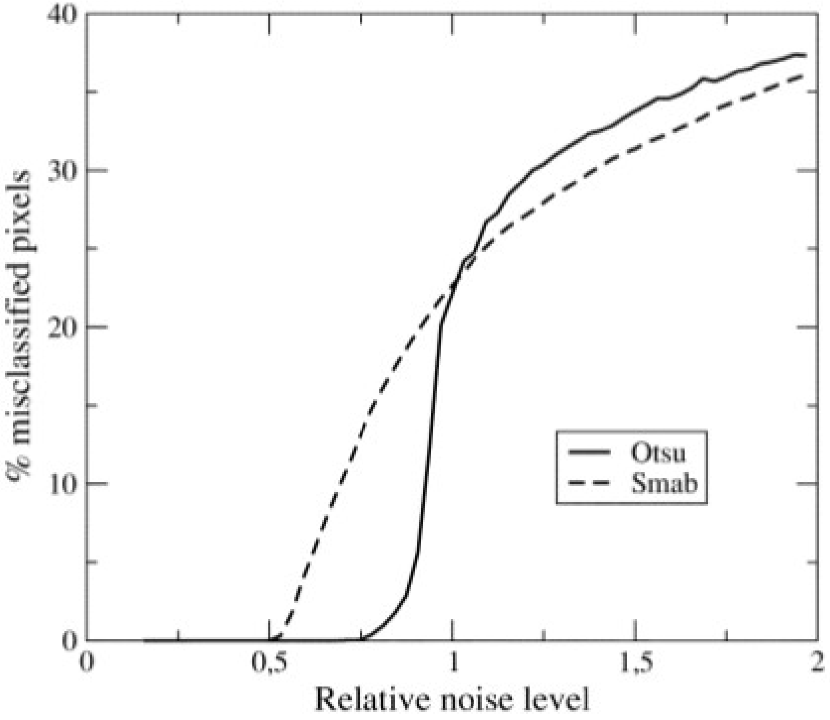
Image	Total Characters	Number of characters correctly recognized				
		Niblack	Sauvola	Wolf	Feng	NICK
Image 1	2012	0	1907	2003	1932	2002
Image 2	944	887	0	821	938	940
Image 3	241	239	233	233	230	238
Image 4	364	0	356	354	344	363
Other 21 images	5446	2687	3783	4828	5364	5411
Total	9007	3813	6279	8239	8808	8954
RECG RATE		**42.33**	**69.71**	**91.47**	**97.79**	**99.41**

Image Binarization

- How to measure accuracy of thresholding methods?
  - Using a ground truth image

Image Binarization

- How to measure accuracy of thresholding methods?
  - Counting misclassified points after inject noise



Torbjørn Sund and Karsten Eilertsen (2003).
An Algorithm for Fast Adaptive Image Binarization With Applications in Radiotherapy Imaging

Hough Transform