Image Thresholding (Week 5)

Image Histogram Binary Thresholding

- In digital image processing, thresholding is the simplest method of segmenting images.
  - For a grayscale image, thresholding can be used to create binary images.
- The simplest thresholding methods replace each pixel in an image with a black/white pixels depending upon pixel intensity.
- Challenges in image thresholding which leads to imperfect binary image with false positive and false negative regions. Some challenges are as follows:
  - High level of noise,
  - Lower variance between background and foreground groups,
  - Non-homogeneous lighting, etc.

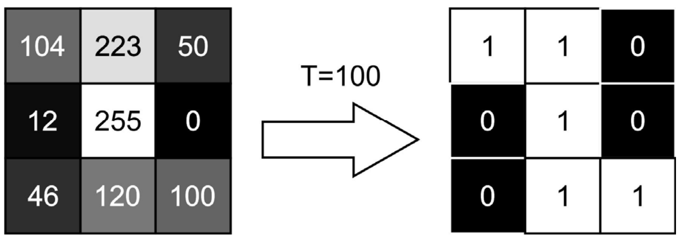
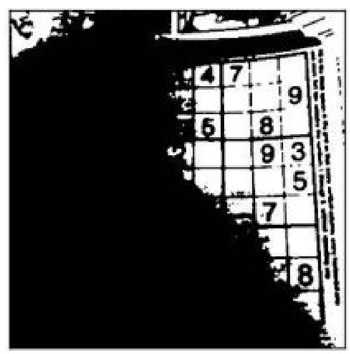


Image Histogram Binary Thresholding (Within-Class variance)

Adaptive Thresholding

- Both simple thresholding (like mean/median/mode) and within-class variance thresholding are global thresholding techniques using a single threshold value in image thresholding.
- But a single threshold value may not be sufficient because it may work well in a certain part of the image but may fail in another part.
- To resolve these limitations, adaptive thresholding can be used.

Image

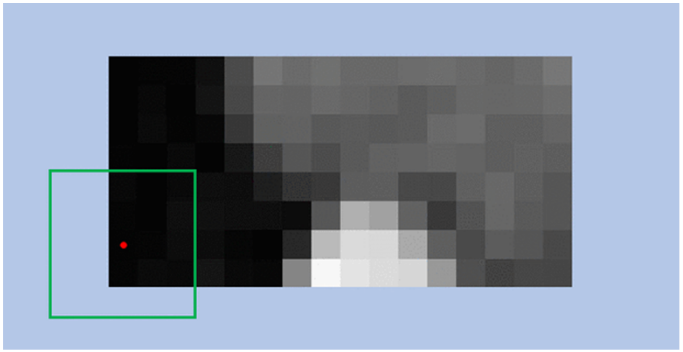


Global

Adaptive

Adaptive Thresholding

- Adaptive thresholding is a local thresholding technique.
  - This technique considers each pixel and its neighborhood.
- The arithmetic mean of pixels intensity is commonly used to calculate the threshold of the neighborhood; then the threshold value is used to classify the pixel.



Entropy Based Thresholding

- In this method, two probability distributions are derived for a matrix through threshold t. For example, one defined for discrete values $[1, t]$ and the other for values $[t+1, L]$.
- The total entropy $\psi(t)$ is the sum of the entropies associated with each distribution.

$$\psi(t) = \ln p_t(1 - p_t) + \frac{e_t}{p_t} + \frac{e_T - e_t}{1 - p_t}$$

where, $e_t = -\sum_{i=1}^{t} p(i) \ln p(i)$, $e_T = -\sum_{i=1}^{L} p(i) \ln p(i)$, $p_t = \sum_{i=1}^{t} p(i)$

- It is required to obtain the maximum information between the object and background distributions in the matrix.
- The discrete value t which $\max_{\psi(t)}$ is to be opted as the threshold value.

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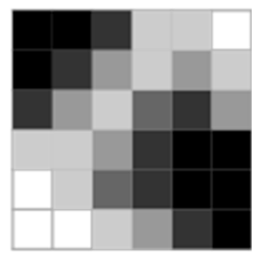
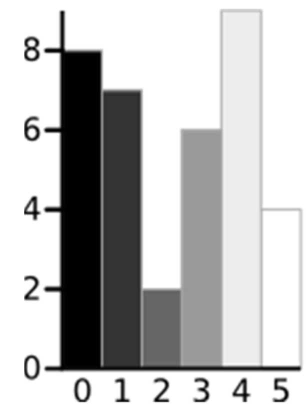
Entropy Based Thresholding: DIY

- Assume a 6-level matrix.

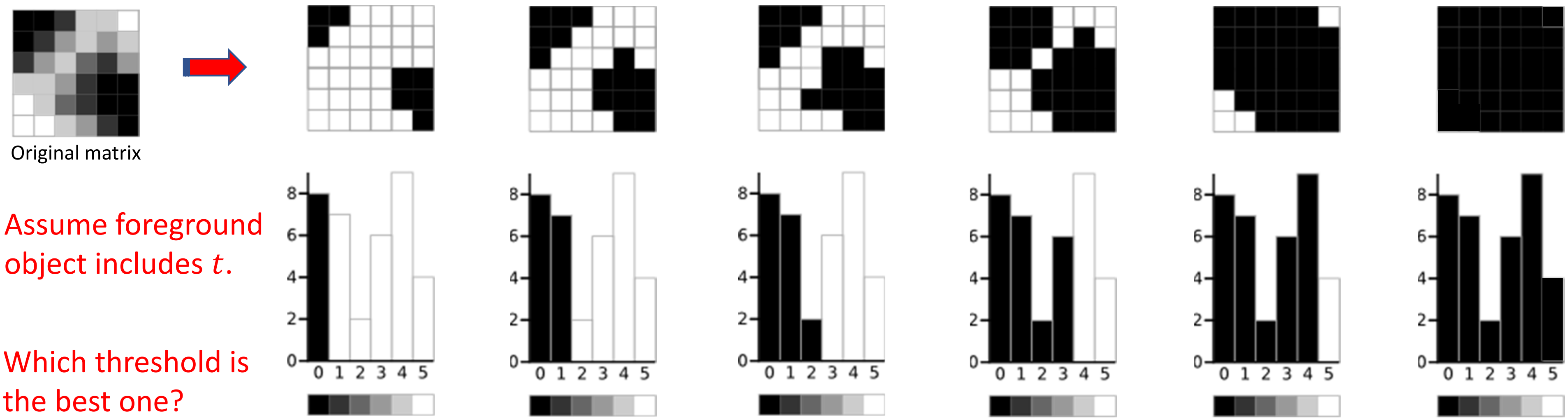
0	0	1	4	4	5
0	1	3	4	3	4
1	3	4	2	1	3
4	4	3	1	0	0
5	4	2	1	0	0
5	5	4	3	1	0





- Form a group, and assume threshold t as 0, 1, 2, 3, 4 or 5.

Entropy Based Thresholding: DIY



Assume foreground object includes t.

Which threshold is the best one?

Total entropy, $\psi(t)$	1.5080	1.9518	2.0178	1.9095	1.5230	NaN

Minimum Cross-Entropy Thresholding

- Minimum cross-entropy-based thresholding describes the threshold by minimizing the variance between two class entropies.
- Consider an image $I(x, y)$ is given with its corresponding histogram. The threshold t divides L-level matrix into two parts:

$$D(t) = \sum_{i=1}^{L} i * p(i) * \log(i) - \sum_{i=1}^{t} i * p(i) * \log(\mu_1(t)) - \sum_{i=t+1}^{L} i * p(i) * \log(\mu_2(t))$$

- The result of optimal threshold can be estimated using $\min_t(D(t))$.

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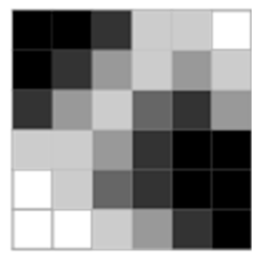
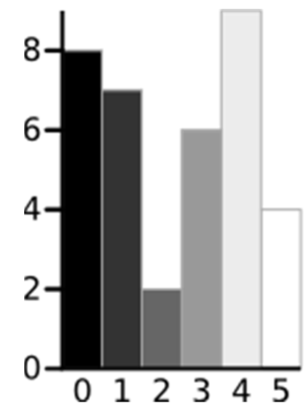
Minimum Cross-Entropy Thresholding: DIY

- Assume a 6-level matrix.

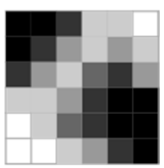
0	0	1	4	4	5
0	1	3	4	3	4
1	3	4	2	1	3
4	4	3	1	0	0
5	4	2	1	0	0
5	5	4	3	1	0



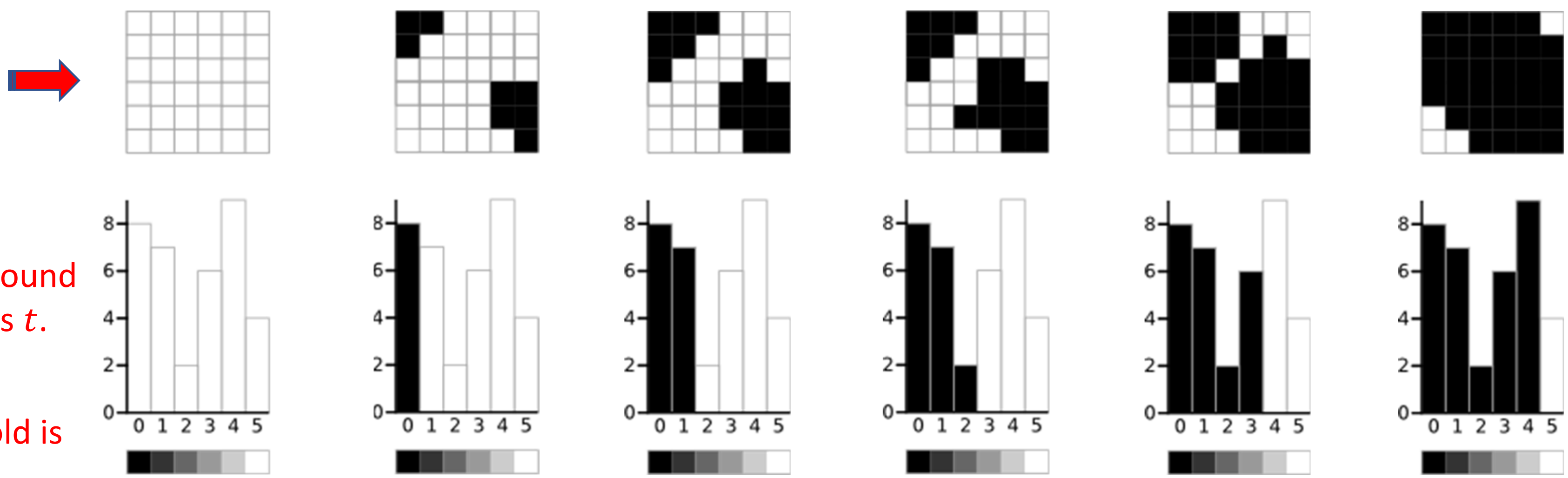


- Form a group, and assume threshold t as 0, 1, 2, 3, 4 or 5.

Minimum Cross-Entropy Thresholding: DIY



Original matrix



Assume foreground object excludes t.

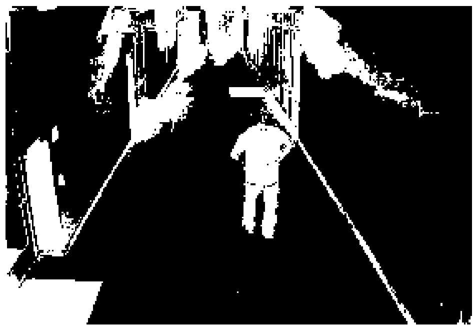
Which threshold is the best one?

Cross entropy, $D(t)$	10.7888	10.7248	10.6112	10.5985	10.6629	10.6823

Noise & Thresholding: Surveillance

Input image

Binary image

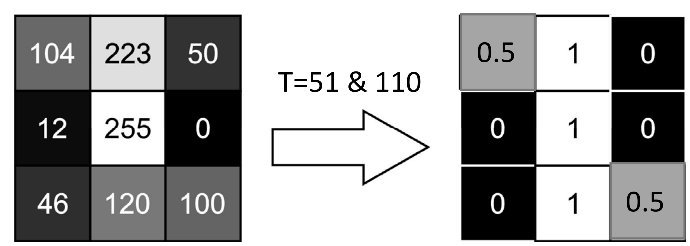


Noise & Thresholding: Surveillance

Input image Improved image Binary image Extracted information

Multi Level Histogram Thresholding

- In digital image processing, MLHT is a technique to segment images into more than 2 segments.
- Similar to Binary thresholding, the MLHT methods replace each pixel in an image with gray pixels depending upon pixel intensity.
- Challenges associated with MLHT are as follows:
  - High level of noise,
  - Lower variance between backgrounds and foregrounds,
  - Non-homogeneous lighting, etc.



Minimum Cross-Entropy Thresholding: MLHT scenario

- First threshold:
  - Consider an image $I(x, y)$. Let threshold t divides L-level matrix into two parts, defined as $L_{lower} \cup L_{upper} = L$.

$$D(t_1) = \sum_{i=1}^{L} i * p(i) * \log(i) - \sum_{i=1}^{t_1} i * p(i) * \log(\mu_1(t_1)) - \sum_{i=t_1+1}^{L} i * p(i) * \log(\mu_2(t_1))$$

  The optimal threshold is $\min_t(D_1(t))$.

- Second threshold:

$$D(t_2) = \sum_{i=1}^{L_{lower}} i * p(i) * \log(i) - \sum_{i=1}^{t_2} i * p(i) * \log(\mu_1(t_2)) - \sum_{i=t_2+1}^{L_{lower}} i * p(i) * \log(\mu_2(t_2))$$

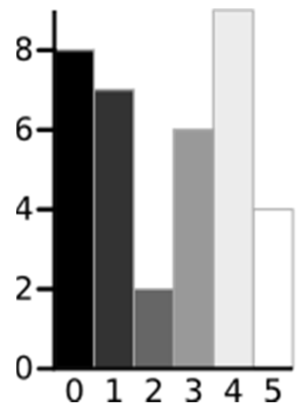
$$D(t_3) = \sum_{i=L_{lower}+1}^{L} i * p(i) * \log(i) - \sum_{i=Llower+1}^{t_3} i * p(i) * \log(\mu_1(t_3)) - \sum_{i=t_3+1}^{L} i * p(i) * \log(\mu_2(t_3))$$

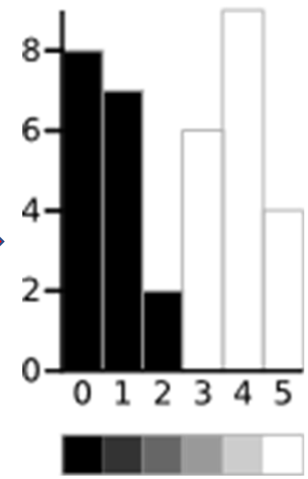
Write possible expressions of 2nd level threshold.

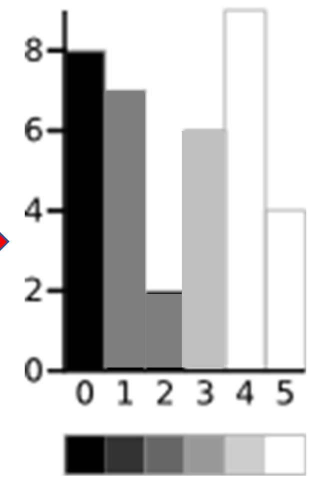
Minimum Cross-Entropy Thresholding: DIY

- Assume a 6-level matrix.

0	0	1	4	4	5
0	1	3	4	3	4
1	3	4	2	1	3
4	4	3	1	0	0
5	4	2	1	0	0
5	5	4	3	1	0

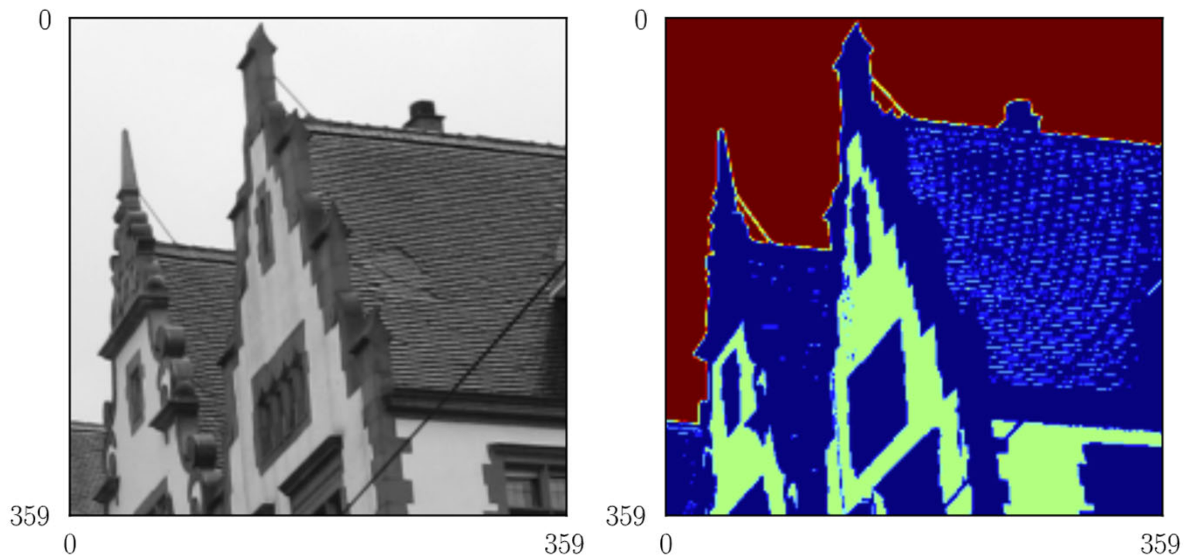






- Form a group, and assume 1st level of threshold t=3. Estimate 2nd level in lower and upper thresholds.

Multi Level Histogram Thresholding



Multi Level vs Binary Histogram Thresholding