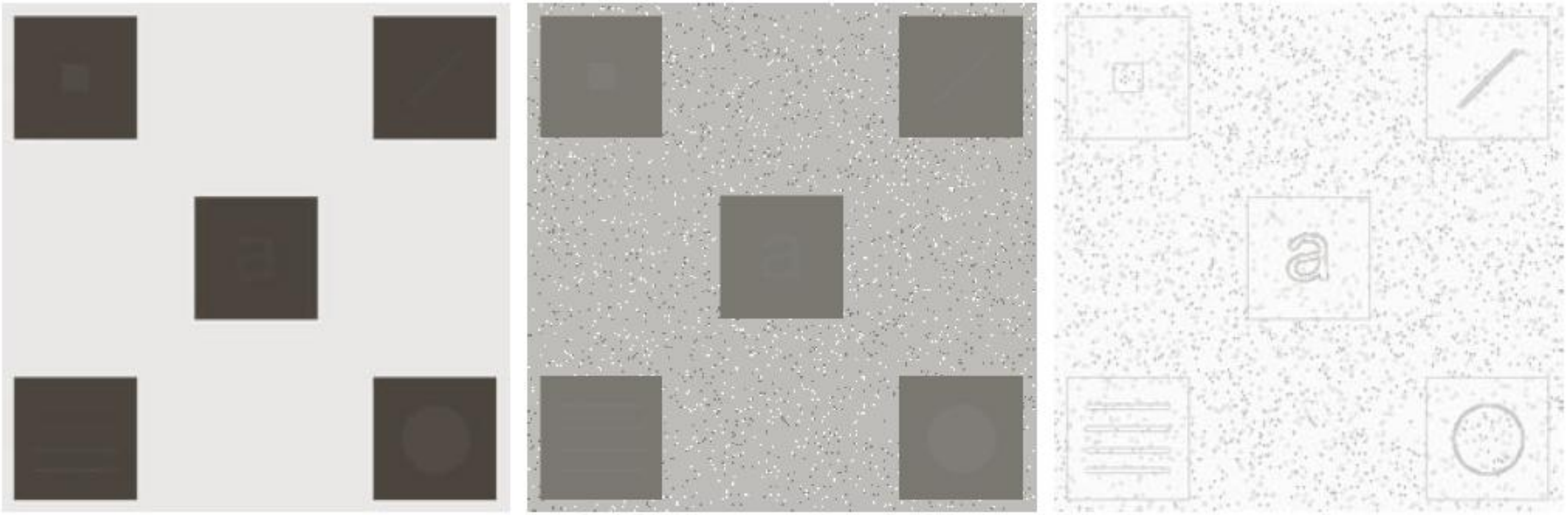
Histogram Processing and Histogram Statistics

Local Histogram Processing



a b c

FIGURE 3.26 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization applied to (a), using a neighborhood of size 3 × 3.

Local Histogram Processing

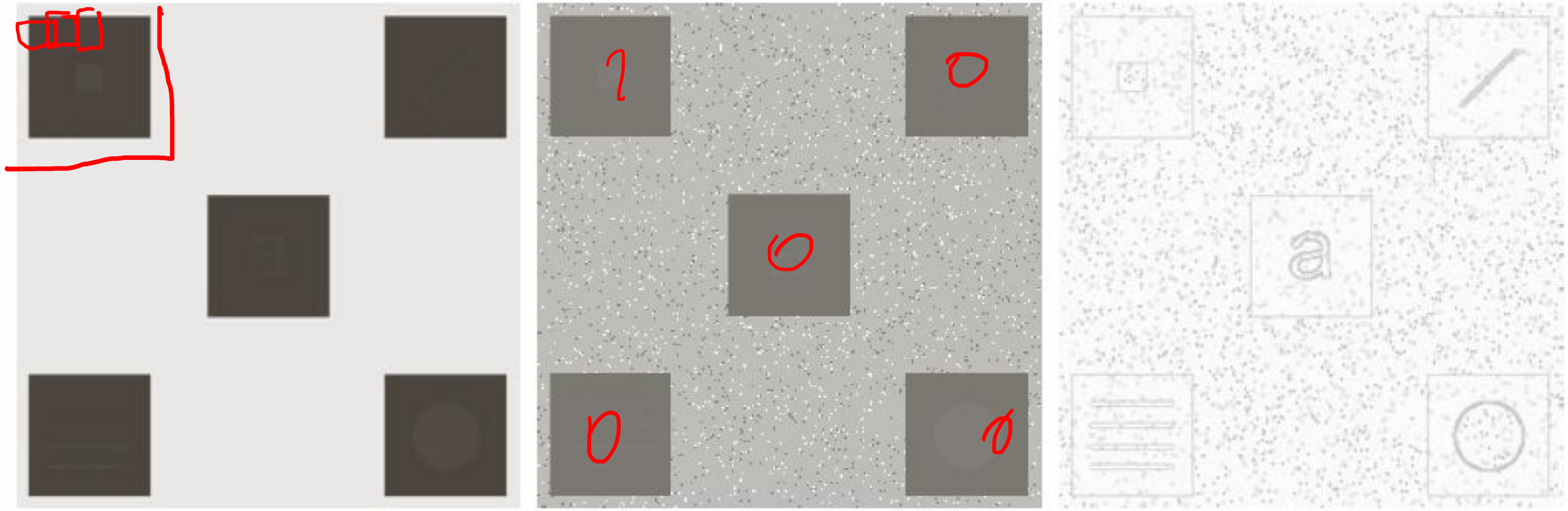


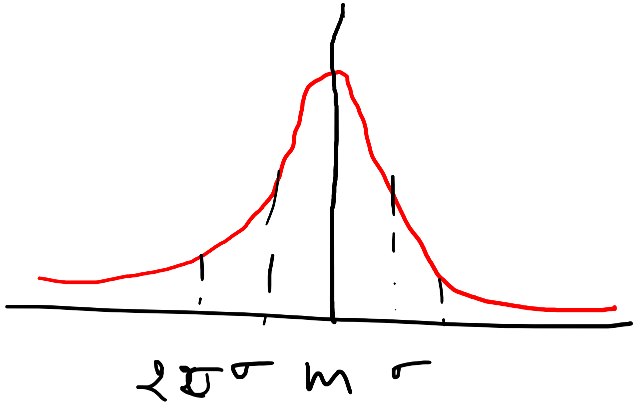
FIGURE 3.26 (a) Original image. (b) Result of global histogram equalization. (c) Result of local histogram equalization applied to (a), using a neighborhood of size 3 × 3.

Mean

$$m = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y)$$

Variance

$$\sigma^2 = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left[f(x, y) - m \right]^2$$



Mean

(Avg. Intensity) $m = \sum_{i=0}^{L-1} r_i P(r_i)$

$$\boxed{P(r_i) = \frac{n_i}{MN}}$$

Variance

(Intensity Contrast) $\mu_2(r) = \sum_{i=0}^{L-1} (r_i - m)^2 P(r_i)$

2-bit $\Rightarrow$ (0, 1, 2, 3)

5 × 5

0	0	1	1	2
1	2	3	0	1
3	3	2	2	0
2	3	1	0	0
1	1	3	2	2

$m_S = 1.44$

$m_I = 1.44$

$P(r_0) = \frac{6}{25}$

$P(r_1) = 7/25$

$P(r_2) = 7/25$

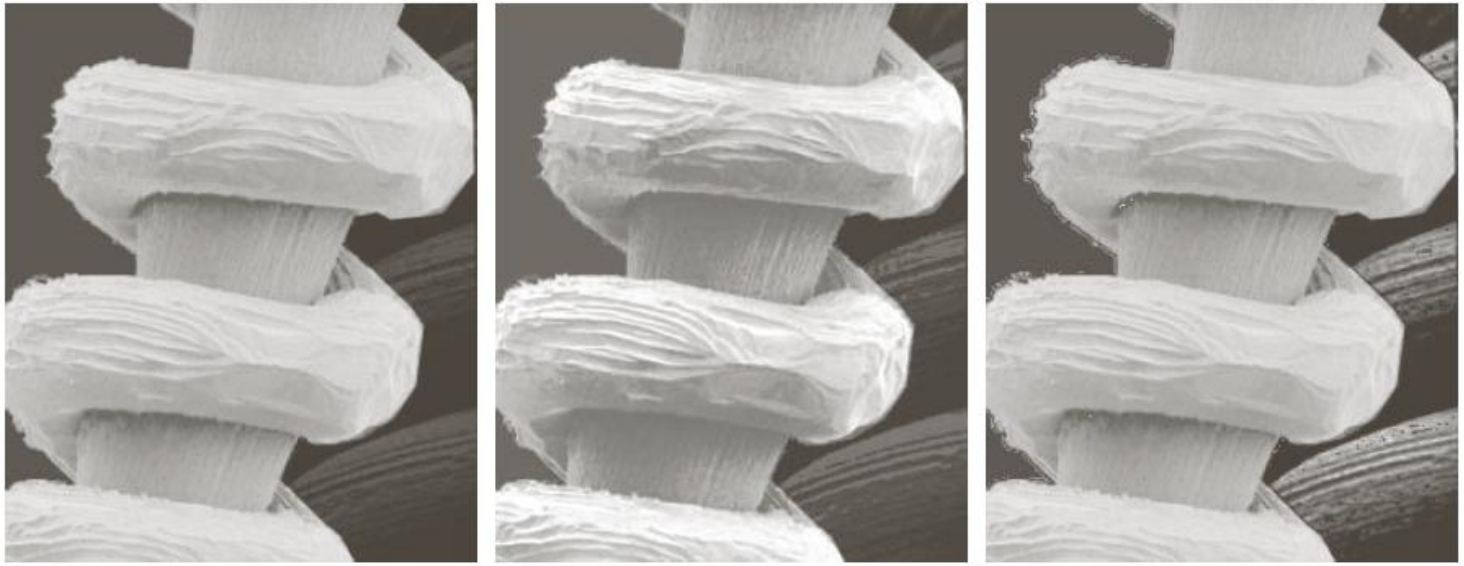
$P(r_3) = 5/25$

Local Processing

$$m_{s_{xy}} = \sum_{i=0}^{L-1} r_i \, p_{s_{xy}}(r_i)$$

$$\sigma^2_{s_{xy}} = \sum_{i=0}^{L-1} (r_i - m_{s_{xy}})^2 \, p_{s_{xy}}(r_i)$$

Using Histogram Statistics for Image Enhancement



a b c

FIGURE 3.27 (a) SEM image of a tungsten filament magnified approximately 130×. (b) Result of global histogram equalization. (c) Image enhanced using local histogram statistics. (Original image courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene.)

Using Histogram Statistics for Image Enhancement

$$g(x, y) = \begin{cases} E \cdot f(x, y) & \text{if } m_{S_{xy}} \le k_0 m_G \text{ AND } k_1 \sigma_G \le \sigma_{S_{xy}} \le k_2 \sigma_G \\ f(x, y) & \text{otherwise} \end{cases}$$

Food for thought!

1. What is histogram processing in digital image processing?
2. What is local histogram processing?
3. Why is local histogram processing often preferred over global histogram methods?
4. What are histogram statistics and how are they useful?
5. How can histogram statistics be used for image enhancement?

Programming assignment

- Implement histogram statistics and local histogram processing techniques to enhance image contrast and analyze how regional intensity variations affect image quality.
- **Concepts Used**
  - Image histogram
  - Histogram statistics (mean, variance)
  - Global vs local histogram processing
  - Sliding window technique
  - Image enhancement
- **Tasks**
  - Read a grayscale image.
  - Compute the global histogram and calculate basic statistics such as mean and variance.
  - Divide the image into small windows (e.g., 3×3 or 7×7) and compute local histogram statistics.
  - Enhance the image using a local contrast enhancement method (e.g., local histogram equalization or intensity adjustment based on local mean).
  - Display the original and enhanced images.
  - Compare global and local enhancement results and briefly comment on improvements in detail visibility.

AI supported self-learning (Prompts compatible with ChatGPT)

Active Learners (Learning by Doing)

1. Provide a grayscale image matrix and guide me to compute global mean and variance first, then compute local statistics using a 3×3 window.
2. Walk me through implementing local histogram processing in Python using NumPy and explain how regional contrast improves.

Reflective Learners (Learning by Thinking)

1. Explain why local histogram processing often produces better enhancement than global methods, and summarize the reasoning.
2. How do mean and variance describe image intensity distribution? Explain conceptually.

Sensing Learners (Concrete & Practical)

1. Demonstrate histogram statistics using actual pixel values and show how they indicate whether an image has low or high contrast.
2. Provide a real-world example where local histogram enhancement reveals details that global enhancement misses.

Intuitive Learners (Concepts & Patterns)

1. Explain local histogram processing as a neighborhood-based statistical transformation rather than a global intensity mapping.
2. How does variance relate mathematically to contrast? Explain the underlying pattern.

Visual Learners (Diagrams & Structure)

1. Show an image enhanced using global histogram equalization and another using local processing, and visually explain the difference.
2. Illustrate how a sliding window moves across an image to compute local statistics.

Verbal Learners (Words & Explanation)

1. Explain local histogram processing in simple language using an analogy such as adjusting brightness in different parts of a photograph.
2. Describe histogram statistics and their role in enhancement as if teaching a beginner.

Sequential Learners (Step-by-Step Logic)

1. Explain step by step how to compute local mean and variance using a sliding window.
2. Break down the algorithm for performing local contrast enhancement into ordered steps.

Global Learners (Big Picture First)

1. Explain how histogram statistics support automated image enhancement systems before diving into calculations.
2. Provide a big-picture comparison of global vs local histogram methods and when each should be used.