
Image Histogram

Image Histogram

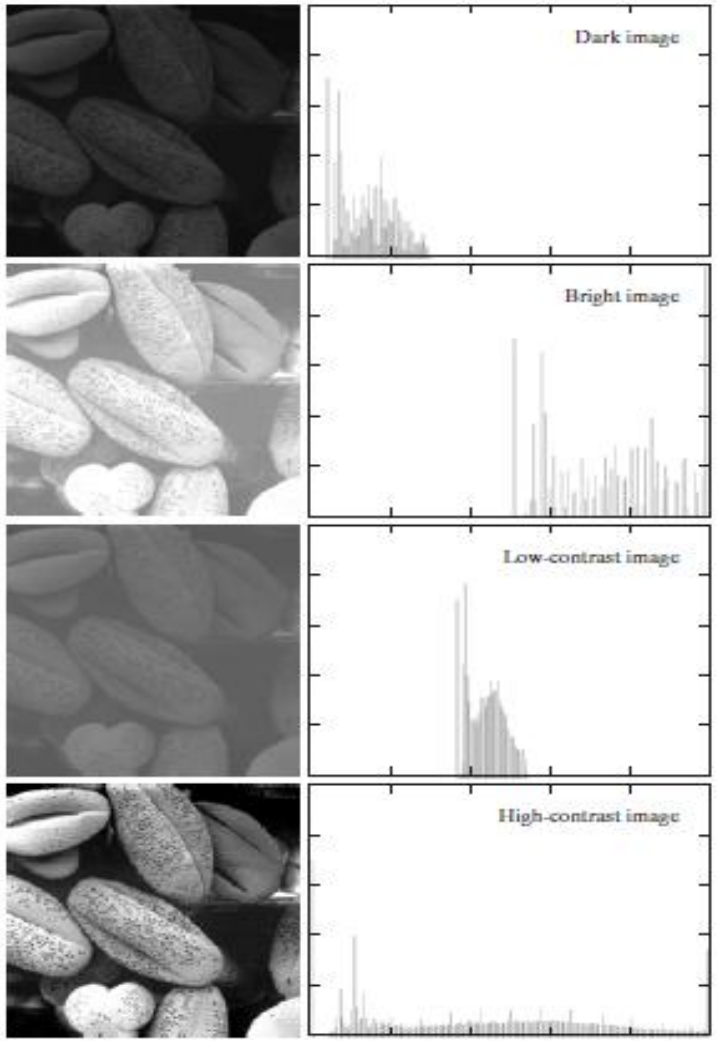
- Histogram

$$h(r_k) = n_k$$

Where r_k is the kth gray level and n_k is the number of pixels in the image having gray level r_k

- Normalized histogram

$$p(r_k) = n_k / n$$



a b

FIGURE 3.15 Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Image Histogram Algo

```
// Initialize the histogram
for (g = 0; g<= 255; g++)
h(g) = 0

// Compute the histogram
for (i = 0; i < MAX_column; i++)
 for (j = 0; j < MAX_row; j++)
  h(f(i,j))++
```

Calculating Histogram in OpenCV

- cv2.calcHist(images, channels, mask, histSize, range)

- hist = cv2.calcHist([img],[0],None,[256],[0,255])

Histogram Equalization

- Histogram equalization can be used to improve the visual appearance of an image.

- Histogram equalization automatically determines a transformation function that produce and output image that has a near uniform histogram.

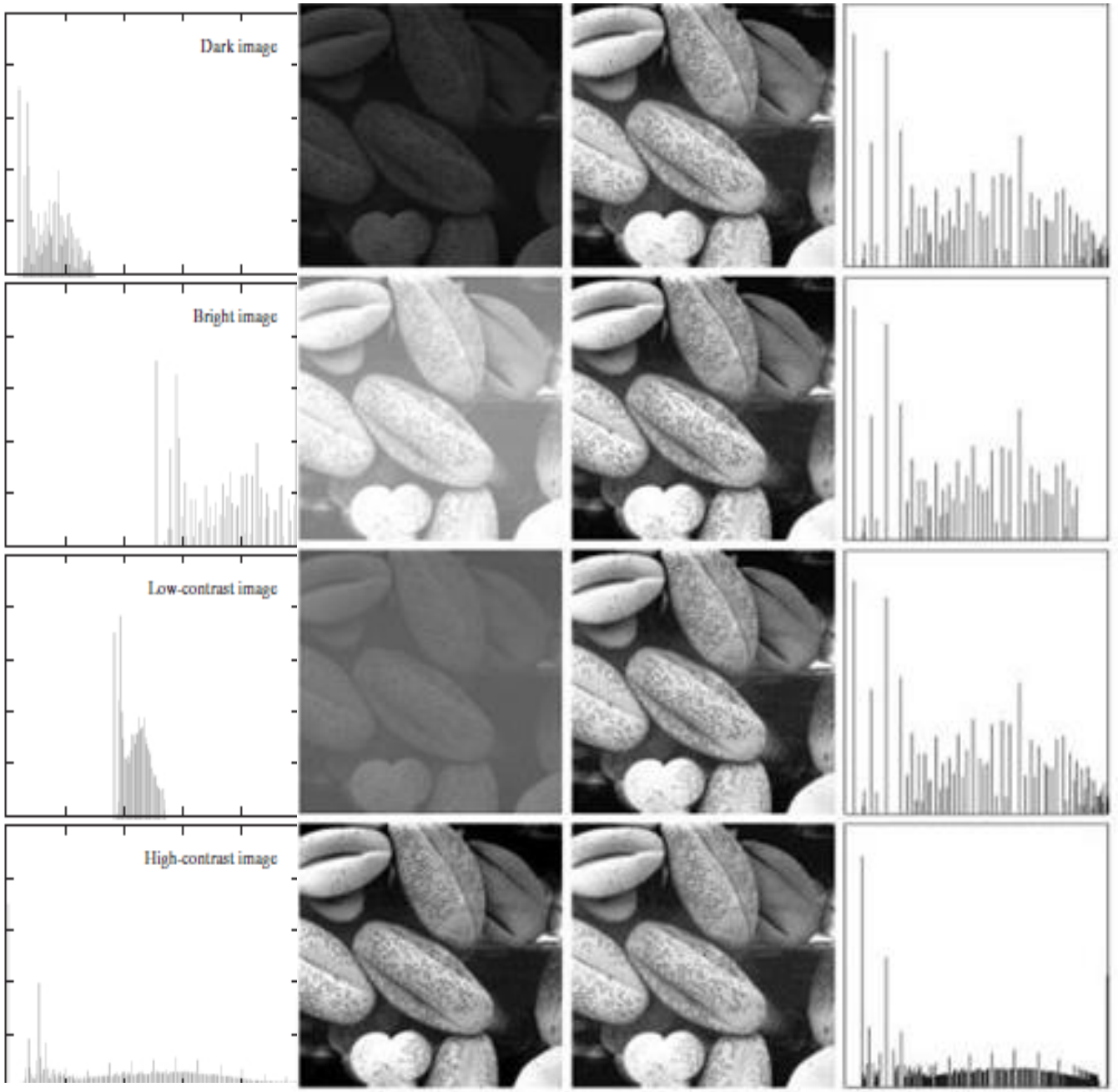


FIGURE 3.20 Left column: images from Fig. 3.16. Center column: corresponding histogram equalized images. Right column: histograms of the images in the center column.

Histogram Equalization

- Let r_k, $k \in [0..L-1]$ be intensity levels and let $p(r_k)$ be its normalized histogram function.
- The intensity transformation function for histogram equalization is

$$s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j)$$

$$= \frac{L-1}{MN}\sum_{j=0}^{k} n_j, k = 0,1,2,...,L-1$$

Histogram Equalization - Example

- Let f be an image with size 64x64 pixels and L=8 and let f has the intensity distribution as shown in the table

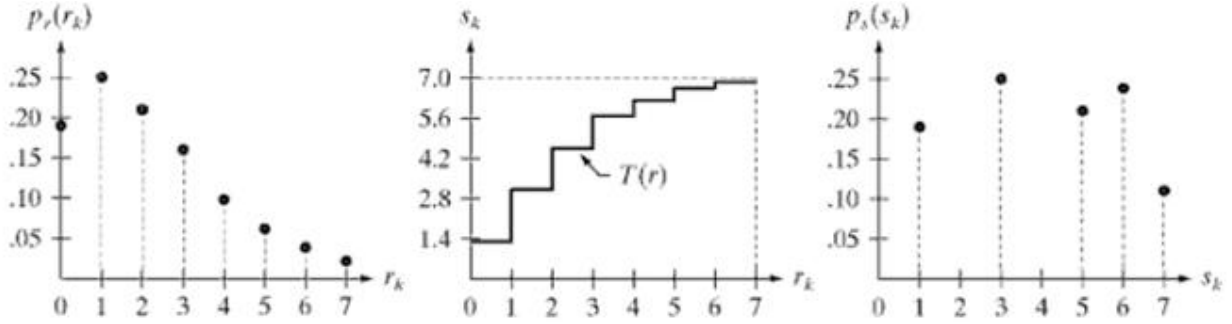
r_k	n_k	$p_r(r_k)=n_k/MN$
0	790	0.19
1	1023	0.25
2	850	0.21
3	656	0.16
4	329	0.08
5	245	0.06
6	122	0.03
7	81	0.02

$$s_0 = T(r_0) = 7\sum_{j=0}^{0} p_r(r_j) = 7\,p_r(r_0) = 1.33$$

$$s_1 = T(r_1) = 7\sum_{j=0}^{1} p_r(r_j) = 7(p_r(r_0) + p_r(r_1)) = 3.08$$

$$s_2 = 4.55, s_3 = 5.67, s_4 = 6.23, s_5 = 6.65, s_6 = 6.86, s_7 = 7.00.$$

$s_0 = 1.33 \rightarrow 1$
$s_1 = 3.08 \rightarrow 3$
$s_2 = 4.55 \rightarrow 5$
$s_3 = 5.67 \rightarrow 6$
$s_4 = 6.23 \rightarrow 6$
$s_5 = 6.65 \rightarrow 7$
$s_6 = 6.86 \rightarrow 7$
$s_7 = 7.00 \rightarrow 7$



a b c

FIGURE 3.19 Illustration of histogram equalization of a 3-bit (8 intensity levels) image. (a) Original histogram. (b) Transformation function. (c) Equalized histogram.

Food for thought!

1. What is an image histogram?
2. What is meant by a normalized histogram?
3. How is an image histogram computed?
4. What is histogram equalization and why is it used?
5. What effect does histogram equalization have on image appearance?

Programming assignment

- Implement image histogram computation and histogram equalization to analyze and enhance the contrast of grayscale images.
- **Concepts Used**
  - Image histogram
  - Normalized histogram
  - Histogram computation algorithm
  - Histogram equalization
  - Intensity transformation
- **Tasks**
  - Read a grayscale image.
  - Compute and display the image histogram (gray level vs number of pixels).
  - Compute the normalized histogram of the image.
  - Implement histogram equalization using the normalized histogram and transformation function.
  - Generate and display the histogram-equalized image.
  - Compare the original and equalized images along with their histograms and briefly comment on contrast improvement.

AI supported self-learning (Prompts compatible with ChatGPT)

Active Learners (Learning by Doing)

1. Give me a small grayscale image matrix and ask me to manually compute its histogram. Let me try first, then explain the solution.
2. Create a numerical example where I perform histogram equalization step by step and explain how pixel values change.

Reflective Learners (Learning by Thinking)

1. Explain image histogram and normalized histogram step by step and summarize their importance in image analysis.
2. Explain histogram equalization conceptually and why it improves the visual appearance of images.

Sensing Learners (Concrete & Practical)

1. Explain histogram computation using actual pixel values and a small grayscale image example.
2. Show practical examples where histogram equalization improves contrast in low-contrast images.

Intuitive Learners (Concepts & Patterns)

1. Explain the concept of histogram equalization as an intensity transformation based on probability distributions.
2. Explain how reshaping the histogram affects image contrast and information distribution.

Visual Learners (Diagrams & Structure)

1. Explain image histogram and normalized histogram using bar graphs and visual illustrations.
2. Visually compare an image and its histogram before and after histogram equalization.

Verbal Learners (Words & Explanation)

1. Explain image histograms in simple language using everyday analogies like counting brightness levels.
2. Explain histogram equalization as if teaching it to someone new to image processing.

Sequential Learners (Step-by-Step Logic)

1. Explain the algorithm for computing an image histogram step by step, including initialization and counting.
2. Explain step by step how the histogram equalization transformation function is computed from the normalized histogram.

Global Learners (Big Picture First)

1. First explain the overall role of image histograms in image enhancement and analysis, then explain histogram computation and equalization.
2. Explain where histogram equalization fits in the overall digital image processing pipeline.