Image Processing

- Image Processing
  - Spatial Domain (دستکاری بیتها به طور مستقیم-میدان مکان)
  - Transform Domain (تبدیل تصویر و انتقال آن به یک فضای دیگر و انجام تغییرات در آن فضا و بازگشت از آن)
Intensity Transformations & Spatial Filtering

A $3 \times 3$ neighborhood about a point $(x, y)$ in an image in the spatial domain. The neighborhood is moved from pixel to pixel in the image to generate an output image.
Chapter 3
Intensity Transformations & Spatial Filtering

Contrast Stretching, Thresholding

\[ s = T(r) \]

**FIGURE 3.2**
Intensity transformation functions.
(a) Contrast-stretching function.
(b) Thresholding function.
FIGURE 3.3 Some basic intensity transformation functions. All curves were scaled to fit in the range shown.
1-Image Negatives

\[ s = L - 1 - r \]

Figure 3.4
(a) Original digital mammogram.
(b) Negative image obtained using the negative transformation in Eq. (3.2-1).
(Courtesy of G.E. Medical Systems.)
2-Log Transformations

\[ s = c \log(1+r) \]
3-Power-Law (Gamma) Transformations

\[ s = c r^\gamma \]

**FIGURE 3.6** Plots of the equation \( s = cr^\gamma \) for various values of \( \gamma \) (\( c = 1 \) in all cases). All curves were scaled to fit in the range shown.

\( \gamma > 1 \) مشابه لگاریتم با انواع مختلف گاما نگاشرت های مختلفی می توان تولید کرد
Chapter 3
Intensity Transformations & Spatial Filtering

تصحيح گاما در مانیتورهای CRT

**FIGURE 3.7**
(a) Intensity ramp image. (b) Image as viewed on a simulated monitor with a gamma of 2.5. (c) Gamma-corrected image. (d) Corrected image as viewed on the same monitor. Compare (d) and (a).
Chapter 3

Intensity Transformations & Spatial Filtering

FIGURE 3.8
(a) Magnetic resonance image (MRI) of a fractured human spine.
(b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and
$\gamma = 0.6, 0.4,$ and $0.3$, respectively.
FIGURE 3.9
(a) Aerial image.
(b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0$, and $5.0$, respectively.
(Original image for this example courtesy of NASA.)
Chapter 3
Intensity Transformations & Spatial Filtering

Piecewise-Linear Transformation Functions

Contrast stretching

FIGURE 3.10
Contrast stretching.
(a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding.
Piecewise-Linear Transformation Functions

Intensity Level Slicing

*FIGURE 3.11* (a) This transformation highlights intensity range \([A, B]\) and reduces all other intensities to a lower level. (b) This transformation highlights range \([A, B]\) and preserves all other intensity levels.
FIGURE 3.12  (a) Aortic angiogram. (b) Result of using a slicing transformation of the type illustrated in Fig. 3.11(a), with the range of intensities of interest selected in the upper end of the gray scale. (c) Result of using the transformation in Fig. 3.11(b), with the selected area set to black, so that grays in the area of the blood vessels and kidneys were preserved. (Original image courtesy of Dr. Thomas R. Gest, University of Michigan Medical School.)
Bit-Plane Slicing

FIGURE 3.13
Bit-plane representation of an 8-bit image.
**Bit-Plane Slicing**

![Bit-Plane Slicing Diagram](image)

**FIGURE 3.14** (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.
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**FIGURE 3.15** Images reconstructed using (a) bit planes 8 and 7; (b) bit planes 8, 7, and 6; and (c) bit planes 8, 7, 6, and 5. Compare (c) with Fig. 3.14(a).
FIGURE 3.16 Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms.

Histogram Processing

\[ h(r_k) = n_k \]

Normalized Histogram

\[ p(r_k) = \frac{n_k}{MN} \]
Histogram Equalization=Histogram Linearization

\[ s = T(r) \]

 csak تصویر با هیستو گرام یکنواخت تمایز (کنترست) بهتری دارد

اعمال تبدیل

گام‌های تعیین هیستوگرام (بافت نگار)

محاسبه هیستوگرام

نرمال سازی هیستوگرام

یافتن تبدیل زیر

\[ s_k = T(r_k) = L - 1 \sum_{j=0}^{MN} \frac{n_j}{MN} \]
Table 3.1
Intensity distribution and histogram values for a 3-bit, $64 \times 64$ digital image.

<table>
<thead>
<tr>
<th>$r_k$</th>
<th>$n_k$</th>
<th>$p_r(r_k) = n_k/MN$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r_0 = 0$</td>
<td>790</td>
<td>0.19</td>
</tr>
<tr>
<td>$r_1 = 1$</td>
<td>1023</td>
<td>0.25</td>
</tr>
<tr>
<td>$r_2 = 2$</td>
<td>850</td>
<td>0.21</td>
</tr>
<tr>
<td>$r_3 = 3$</td>
<td>656</td>
<td>0.16</td>
</tr>
<tr>
<td>$r_4 = 4$</td>
<td>329</td>
<td>0.08</td>
</tr>
<tr>
<td>$r_5 = 5$</td>
<td>245</td>
<td>0.06</td>
</tr>
<tr>
<td>$r_6 = 6$</td>
<td>122</td>
<td>0.03</td>
</tr>
<tr>
<td>$r_7 = 7$</td>
<td>81</td>
<td>0.02</td>
</tr>
</tbody>
</table>
FIGURE 3.19 Illustration of histogram equalization of a 3-bit (8 intensity levels) image. (a) Original histogram. (b) Transformation function. (c) Equalized histogram.

\[ s_0 = 1.33 \rightarrow 1 \quad s_4 = 6.23 \rightarrow 6 \]
\[ s_1 = 3.08 \rightarrow 3 \quad s_5 = 6.65 \rightarrow 7 \]
\[ s_2 = 4.55 \rightarrow 5 \quad s_6 = 6.86 \rightarrow 7 \]
\[ s_3 = 5.67 \rightarrow 6 \quad s_7 = 7.00 \rightarrow 7 \]
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.
FIGURE 3.21
Transformation functions for histogram equalization. Transformations (1) through (4) were obtained from the histograms of the images (from top to bottom) in the left column of Fig. 3.20 using Eq. (3.3-8).
Histogram Matching (Specification)

**FIGURE 3.22**
(a) Histogram of a 3-bit image. (b) Specified histogram. (c) Transformation function obtained from the specified histogram. (d) Result of performing histogram specification. Compare (b) and (d).
Histogram Matching (Specification)

$$p(r) \rightarrow p(z)$$

$$s = T(r) \rightarrow z = G^{-1}(T(r))$$
TABLE 3.2
Specified and actual histograms (the values in the third column are from the computations performed in the body of Example 3.8).

<table>
<thead>
<tr>
<th>$z_q$</th>
<th>Specified $p_z(z_q)$</th>
<th>Actual $p_z(z_k)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$z_0 = 0$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>$z_1 = 1$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>$z_2 = 2$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>$z_3 = 3$</td>
<td>0.15</td>
<td>0.19</td>
</tr>
<tr>
<td>$z_4 = 4$</td>
<td>0.20</td>
<td>0.25</td>
</tr>
<tr>
<td>$z_5 = 5$</td>
<td>0.30</td>
<td>0.21</td>
</tr>
<tr>
<td>$z_6 = 6$</td>
<td>0.20</td>
<td>0.24</td>
</tr>
<tr>
<td>$z_7 = 7$</td>
<td>0.15</td>
<td>0.11</td>
</tr>
</tbody>
</table>
انطباق هیستوگرام - مثال

<table>
<thead>
<tr>
<th>$q$</th>
<th>$G(z_q)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>0</td>
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<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
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<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

**TABLE 3.3**
All possible values of the transformation function $G$ scaled, rounded, and ordered with respect to $z$.

<table>
<thead>
<tr>
<th>$s_k$</th>
<th>$z_q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

**TABLE 3.4**
Mappings of all the values of $s_k$ into corresponding values of $z_q$. 
انطباق هیستوگرام - مثال

FIGURE 3.23
(a) Image of the Mars moon Phobos taken by NASA’s Mars Global Surveyor.
(b) Histogram. (Original image courtesy of NASA.)
FIGURE 3.24
(a) Transformation function for histogram equalization.
(b) Histogram-equalized image (note the washed-out appearance).
(c) Histogram of (b).
FIGURE 3.25
(a) Specified histogram.
(b) Transformations.
(c) Enhanced image using mappings from curve (2).
(d) Histogram of (c).
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 $3 \times 3$. 
Local Histogram Processing

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.)
Chapter 3
Intensity Transformations & Spatial Filtering

Fundamentals of Spatial Filtering

اصول فیلترهای مکانی
Spatial Filtering

\[ g(x, y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s, t) f(x + s, y + t) \]

**FIGURE 3.28** The mechanics of linear spatial filtering using a 3 x 3 filter mask. The form chosen to denote the coordinates of the filter mask coefficients simplifies writing expressions for linear filtering.
Chapter 3
Intensity Transformations & Spatial Filtering

Correlation and Convolution

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Convolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td></td>
</tr>
<tr>
<td>0 0 0 1 0 0 0 0</td>
<td>0 0 0 1 0 0 0 0</td>
</tr>
<tr>
<td>(b)</td>
<td></td>
</tr>
<tr>
<td>0 0 0 1 0 0 0</td>
<td>0 0 0 1 0 0 0</td>
</tr>
<tr>
<td>Starting position alignment</td>
<td></td>
</tr>
<tr>
<td>(c)</td>
<td></td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 1</td>
<td>0 0 0 0 0 0 1</td>
</tr>
<tr>
<td>Zero padding</td>
<td></td>
</tr>
<tr>
<td>(d)</td>
<td></td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 1</td>
<td>0 0 0 0 0 0 1</td>
</tr>
<tr>
<td></td>
<td>Position after one shift</td>
</tr>
<tr>
<td>(e)</td>
<td></td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 1</td>
<td>0 0 0 0 0 0 1</td>
</tr>
<tr>
<td></td>
<td>Position after four shifts</td>
</tr>
<tr>
<td>(f)</td>
<td></td>
</tr>
<tr>
<td>0 0 0 0 0 0 0 1</td>
<td>0 0 0 0 0 0 1</td>
</tr>
<tr>
<td></td>
<td>Final position</td>
</tr>
<tr>
<td>(g)</td>
<td></td>
</tr>
<tr>
<td>0 0 0 8 2 3 2 1</td>
<td>0 0 0 1 2 3 2 8</td>
</tr>
<tr>
<td>Full correlation result</td>
<td></td>
</tr>
<tr>
<td>(h)</td>
<td></td>
</tr>
<tr>
<td>0 8 2 3 2 1 0</td>
<td>0 1 2 3 2 8 0</td>
</tr>
<tr>
<td>Cropped correlation result</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 3.29** Illustration of 1-D correlation and convolution of a filter with a discrete unit impulse. Note that correlation and convolution are functions of displacement.
Correlation and Convolution

FIGURE 3.30
Correlation (middle row) and convolution (last row) of a 2-D filter with a 2-D discrete, unit impulse. The 0s are shown in gray to simplify visual analysis.
Correlation and Convolution

Correlation of filter $w$ with image $m$: 

$$
= \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s, t)f(x + s, y + t)
$$

Convolution of filter $w$ with image $m$: 

$$
= \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s, t)f(x - s, y - t)
$$
Smoothing Spatial Filters

Averaging Filters

\[ \frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \]

\[ \frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \]

**FIGURE 3.32** Two 3 × 3 smoothing (averaging) filter masks. The constant multiplier in front of each mask is equal to 1 divided by the sum of the values of its coefficients, as is required to compute an average.
Chapter 3
Intensity Transformations & Spatial Filtering

خواص فیلتر میانگین گیر

• حذف نویز
• تار نمودن تصویر و هموار نمودن لبه‌ها
FIGURE 3.33 (a) Original image, of size 500 × 500 pixels. (b)–(f) Results of smoothing with square averaging filter masks of sizes \( m = 3, 5, 9, 15, \) and 35, respectively. The black squares at the top are of sizes 3, 5, 9, 15, 25, 35, 45, and 55 pixels, respectively; their borders are 25 pixels apart. The letters at the bottom range in size from 10 to 24 points, in increments of 2 points; the large letter at the top is 60 points. The vertical bars are 5 pixels wide and 100 pixels high; their separation is 20 pixels. The diameter of the circles is 25 pixels, and their borders are 15 pixels apart; their intensity levels range from 0% to 100% black in increments of 20%. The background of the image is 10% black. The noisy rectangles are of size 50 × 120 pixels.
Фільтр міангін گیر

FIGURE 3.34  (a) Image of size 528 × 485 pixels from the Hubble Space Telescope. (b) Image filtered with a 15 × 15 averaging mask. (c) Result of thresholding (b). (Original image courtesy of NASA.)
Order-statistic (Nonlinear) Smoothing Filters

**Figure 3.35** (a) X-ray image of circuit board corrupted by salt-and-pepper noise. (b) Noise reduction with a $3 \times 3$ averaging mask. (c) Noise reduction with a $3 \times 3$ median filter. (Original image courtesy of Mr. Joseph E. Pascente, Lixi, Inc.)
Median Filter

• عناصر داخل پنجره مرتب می‌شوند و عنصر میانی به عنوان مقدار پیکسل در نظر گرفته می‌شود.
• غیرخطی
• حذف نویز بدون تارشندگی
• مقاوم در برابر نویز فلفل نمکی

Salt-and-pepper noise
Sharpening Spatial Filters

مشتق بهترین راه برای نمایش تیزی است

\[ \frac{\partial f}{\partial x} = f(x + 1) - f(x) \]

\[ \frac{\partial^2 f}{\partial x^2} = f(x + 1) - 2f(x) + f(x - 1) \]
### The Second Derivative for Image Sharpening: Laplacian

**FIGURE 3.37**
(a) Filter mask used to implement Eq. (3.6-6).
(b) Mask used to implement an extension of this equation that includes the diagonal terms.
(c) and (d) Two other implementations of the Laplacian found frequently in practice.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>-4</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>-1</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>0</td>
<td>-1</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c</th>
<th>d</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
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<td>1</td>
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</tr>
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<td>1</td>
<td>1</td>
<td>1</td>
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<td>-1</td>
<td>-1</td>
<td>-1</td>
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<tr>
<td>-1</td>
<td>8</td>
<td>-1</td>
</tr>
<tr>
<td>-1</td>
<td>-1</td>
<td>-1</td>
</tr>
</tbody>
</table>
Intensity Transformations & Spatial Filtering

\[ g(x, y) = f(x, y) + c[\nabla^2 f(x, y)] \]

**Figure 3.38**
(a) Blurred image of the North Pole of the moon.
(b) Laplacian without scaling.
(c) Laplacian with scaling. (d) Image sharpened using the mask in Fig. 3.37(a).
(e) Result of using the mask in Fig. 3.37(b).
Highboost filtering

• نوعی روش تیزکردن که تا مدت‌ها در چاپگرها مورد استفاده بوده است.

• مراحل:
  – ایجاد تصویر تار از تصویر اصلی
  – تفريق تصویر تار شده از تصویر اصلی و تولید ماسک
  – اضافه نمودن ماسک به تصویر اصلی
Highboost Filtering

Original signal

Blurred signal

Unsharp mask

Sharpened signal

**FIGURE 3.39** 1-D illustration of the mechanics of unsharp masking. (a) Original signal. (b) Blurred signal with original shown dashed for reference. (c) Unsharp mask. (d) Sharpened signal, obtained by adding (c) to (a).
Highboost Filtering

**FIGURE 3.40**
(a) Original image.
(b) Result of blurring with a Gaussian filter.
(c) Unsharp mask. (d) Result of using unsharp masking.
(e) Result of using highboost filtering.
First Order Derivatives for Image Sharpening - The Gradient

**FIGURE 3.41**
A $3 \times 3$ region of an image (the $z$s are intensity values).
(b)–(c) Roberts cross gradient operators.
(d)–(e) Sobel operators. All the mask coefficients sum to zero, as expected of a derivative operator.
The Gradient (Sobel)

\[ \nabla f = \text{grad}(f) = \begin{pmatrix} g_x \\ g_y \end{pmatrix} \]

\[ M(f) = \text{mag}(f) = \sqrt{g_x^2 + g_y^2} \]
Figure 3.42
(a) Optical image of contact lens (note defects on the boundary at 4 and 5 o’clock).
(b) Sobel gradient.
(Original image courtesy of Pete Sites, Perceptics Corporation.)
Combining Spatial Enhancement Methods

FIGURE 3.43
(a) Image of whole body bone scan.
(b) Laplacian of (a).
(c) Sharpened image obtained by adding (a) and (b).
(d) Sobel gradient of (a).
FIGURE 3.43 (Continued)
(e) Sobel image smoothed with a $5 \times 5$ averaging filter. (f) Mask image formed by the product of (c) and (e).
(g) Sharpened image obtained by the sum of (a) and (f). (h) Final result obtained by applying a power-law transformation to (g). Compare (g) and (h) with (a). (Original image courtesy of G.E. Medical Systems.)