Reading Instructions

Chapters for this lecture

- Chapter 2.6 – 2.6.4 and 3.1 – 3.3 in Gonzales-Woods.
Digitization

- Sampling in space \((x, y)\).
- Sampling in amplitude (intensity).

Sampling

Sample in space twice as often as the smallest detail you want to see.

Image Processing

We want to create an image which is “better” in some sense.

For example,

- Image restoration (reduce noise),
- Image enhancement (enhance edges, lines, etc.),
- Make the image more suitable for visual interpretation.

Image enhancement does NOT increase image information!
Image Processing
Spatial domain transformations

The operator \( T \) is applied to each position \((x, y)\) in the input image \( f \) yielding a value \( g(x, y) \) as output.

\[
g(x, y) = T[f(x, y)]
\]

In point processing \( T \) the neighborhood is of size \( 1 \times 1 \).

\[
S = T(r)
\]

Larger neighborhoods are referred to as masks (or filters, kernel windows, templates).

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Image Processing

Processing domains

- Spatial domain (lectures 2, and 3)
  - Brightness transforms, works per pixel \( \rightarrow \) point processing,
  - Spatial filters, local transforms, works on small neighborhoods,
  - Geometric transforms, interpolation,
- Frequency domain (lectures 4, 11, and 12).
Gray Level Transform

Pixel-wise transform
- Change the gray level for each individual pixel.
- Compare to television: Brightness and contrast
  - brightness: addition
  - contrast: multiplication

\[ r = T(s) = \text{gray level out} \]

\[
\begin{align*}
> 45^\circ & \rightarrow \text{increased contrast} \\
< 45^\circ & \rightarrow \text{decreased contrast} \\
\text{up} & \rightarrow \text{increased brightness} \\
\text{down} & \rightarrow \text{decreased brightness}
\end{align*}
\]

Image Processing

Brightness

Subtract.

Add.
Image Histograms

A gray level histogram shows how many pixels there are at each intensity level.
Gray Level Transformations
Some basic gray level transformation functions used for image enhancement.

![Graph showing various gray level transformations](image-url)
Gray Level Transformations

Negative or positive

- Original digital mammogram (left).
- Image negative to enhance white or gray details embedded in dark regions (right).

Gray Level Transformations

Log transformations

- Visualize patterns in the dark region of an image
  - Fourier spectrum (left).
  - Result of applying the log transform (right).
Histogram Equalization

Idea: Create an image with evenly distributed gray levels, for visual contrast enhancement

- The normalized gray level histogram gives the probability for a pixel to have a certain gray level,
- Transform the image using the cumulative normalized histogram,
- The histogram for the output image is uniform (theoretically in the continuous case), why not in the with our digital images?

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

Histogram Equalization Example

<table>
<thead>
<tr>
<th>Intensity</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pixels</td>
<td>10</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\[ p(0) = 10/50 = 0.2 \]
\[ p(1) = 20/50 = 0.4 \]
\[ p(2) = 12/50 = 0.24 \]
\[ p(3) = 8/50 = 0.16 \]
\[ p(r) = 0/50 = 0, \ r = 4, 5, 6, 7 \]
Histogram Equalization Example (cont.)

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

\[ T(0) = 7 \times p(0) = 1 \]
\[ T(1) = 7 \times (p(0) + p(1)) = 4 \]
\[ T(2) = 7 \times (p(0) + p(1) + p(2)) = 6 \]
\[ T(3) = 7 \times (p(0) + p(1) + p(2) + p(3)) = 7 \]
\[ T(r) = 7, r = 4, 5, 6, 7 \]

Intesity | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7
--- | --- | --- | --- | --- | --- | --- | --- | ---
Number of pixels | 0 | 10 | 0 | 0 | 20 | 0 | 12 | 8

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Histogram Equalization

Original image.

Result of histogram equalization.
Histogram Equalization

Transformations for image 1 – 4. Note that the transform for figure 4 (dashed line) is close to the neutral transform (dotted line).

Histogram Equalization
Not always “optimal” for visual quality
Histogram Equalization

Example: Original image $f(x, y)$

Histogram Equalization

Example: Histogram
Histogram Equalization
Example: Normalized histogram

Histogram Equalization
Example: Cumulative histogram
Histogram Equalization
Example: Normalized cumulative histogram

Histogram Equalization
Example: Histogram equalization transform
Histogram Equalization

Example: Histogram equalization

Histogram Equalization

Example: Equalized histograms
Histogram Equalization
Local histogram equalization

- Original image.
- Result of global histogram equalization.
- Result of local histogram equalization using a $7 \times 7$ neighborhood about each pixel.

Arithmetic/Logical Operations

- Information from two different images with the same size can be combined by adding, subtracting, multiplying or comparing the pixel values, pixel by pixel.
- For enhancement, segmentation, change detection.
Arithmetic/Logical Operations

Enhancement by image subtraction

(a) Mask image.
(b) Image (after injection of dye into the bloodstream) with mask subtracted out.
Arithmetic/Logical Operations
Reduction of noise by averaging

Noise can be reduced by observing the same scene over a long period of time, and averaging the images. Image averaged 8, 16, 64 and 128 times.

Reading Instructions
Chapters for tomorrow's lecture

• Chapter 2.5.1 – 2.5.2, and 3.4 – 3.7 in Gonzales-Woods.