Lecture 2, Point Processing
GW 2.6-2.6.4, & 3.1-3.4, Ida-Maria
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Last Lecture

Digitization
- sampling in space (x,y)
- sampling in amplitude (intensity)

How often should you sample in space to see details of a certain size?

How do you avoid aliasing when sampling?

RGB Image
3 channels, two dimensional image.

Which image is which channel?
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

Problem solving using image analysis: fundamental steps

- Knowledge about the application
- Feature extraction, description
- Classification, interpretation, recognition
- Result

Image histograms

- A grey scale histogram shows how many pixels there are at each intensity level.

Image processing can be performed in the
- Spatial domain (lectures 2 and 3)
  - Brightness transforms, works per pixel=>point processing
  - Spatial filters, local transforms, works on small neighborhood
  - Geometric transforms, interpolation
- Frequency domain (lecture 4)
Gray-level histogram shows intensity distribution

Intensity histogram says nothing about the spatial distribution of the pixel intensities

Match the histograms & images

greylevel transform

- change the greylevel for each individual pixel
- compare to TV: brightness & contrast
  - brightness: addition
  - contrast: multiplication

>45° → increased contrast
<45° → decreased contrast
up → increased brightness
down → decreased brightness

\[ s = \text{greylevel in} \]

\[ T(s) = \text{greylevel out} \]
Gray level histogram and contrast and brightness

Contrast: multiply

Brightness: subtract
Add

Gray-level transformations

Figure 3.3 shows basic gray-level transformation functions used for image enhancement.
Log transformation to visualize patterns in the dark regions of an image

Figure 3.5
(a) Fourier spectrum.
(b) Result of applying the log transformation given in Eq. (3.2-2) with c=1.

Negative or inverse
original digital mammogram
image negative to enhance white or grey details embedded in dark regions

Histogram stretching/image normalization
Min-max stretching
Histogram equalization

Useful when much information is in a narrow part of the histogram.

Drawbacks:
- Amplifies noise in large homogenous areas
- Can produce unrealistic transformations
- Information might be lost, no new information is gained

histogram equalization

idea: create an image with evenly distributed greylevels, for visual contrast enhancement

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

Hist eq: small example

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

- p(0) = 10/50 = 0.2, cdf(0)=0.2
- p(1) = 20/50 = 0.4, cdf(1)=0.6
- p(2) = 12/50 = 0.24, cdf(2)=0.84
- p(3) = 8/50 = 0.16, cdf(3)=1
- p(r) = 0/50 = 0, r = 4, 5, 6, 7 cdf(r)=1
• $T(0) = 7 \times (p(0)) \approx 1$
• $T(1) = 7 \times (p(0) + p(1)) \approx 4$
• $T(2) = 7 \times (p(0) + p(1) + p(2)) \approx 6$
• $T(3) = 7 \times (p(0) + p(1) + p(2) + p(3)) \approx 7$
• $T(r) = 7, r = 4, 5, 6, 7$

Intensity

<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>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>12</td>
<td>8</td>
</tr>
</tbody>
</table>

**Local histogram equalization**

![Local histogram equalization](image)

**More examples of histogram equalization**

![More examples of histogram equalization](image)

**Histogram equalization is not always "optimal" for visual quality**

![Histogram equalization is not always "optimal" for visual quality](image)
Histogram eq: the result depends on the amount of different intensities

Histogram matching

- In histogram equalization, a flat distribution is what is strived for.
- In histogram matching, the distribution of another image is the goal.

Image 2 histogram matched to image 1

Image 1 histogram matched to image 2
Arithmetic operators (pixel wise)

- addition, subtraction, multiplication, division
- noise reduction
  - mean value of image 1 and image 2 (addition)
- background removal
  - image – background image (subtraction)

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

\[\text{image 1} + \text{image 2} = \text{result} \]

Reduction of noise by averaging

Noise can be reduced by observing the same scene over a period of time, and averaging the images. (1, 2, 10, 20, 50 times)
Image sharpening

Creating a background image

Max or median of the pixel intensities at all positions.

Other ways of getting/creating a background image?
Give some situations when this is suitable/not suitable

Correction by subtracting the bg image

Example 2: Subtracting a background image/correcting for uneven illumination

How shall the “black” parts = no signal transmitted be treated?
Suggested problems

• 2.22, 2.18, 2.9
• 3.1, 3.6