Chapter 4
Image Processing
Point Processing
Lecture Digital Image Processing, Oct. 18th, 2010

© Kenneth Kwan

Dr. Volker Krüger
Institute for Production
Copenhagen Inst. Of Technology
Topics: Point Processing

1. What is point processing?
2. Grey level mapping
3. Histograms
4. Segmentation using thresholding
What is Point Processing

Under the term **Point Processing** we summarize all processing that can be done based on a single image pixel. The output of the process is a single value. Usually, this output value replaces the input pixel in the image. The process is carried out *pixel-wise*.

Examples: A number of examples are given in this lecture. Grey level mapping, histograms, segmentation using thresholding.
Images can be Added

• Image computation, like the mapping, is pixel-wise.
• Also possible: -, , , AND, OR

\[
\begin{array}{cccc}
a_1 & a_2 & \ldots & \\
a_3 & a_4 & \ldots & \\
\ldots & \ldots & \ldots & \\
\end{array}
\quad +
\begin{array}{cccc}
b_1 & b_2 & \ldots & \\
b_3 & b_4 & \ldots & \\
\ldots & \ldots & \ldots & \\
\end{array}
= 
\begin{array}{cccc}
a_1 + b_1 & a_2 + b_2 & \\
a_3 + b_3 & a_4 + b_4 & \\
\ldots & \ldots & \ldots & \\
\end{array}
\times \div
\]
AND-, OR-Operations

<table>
<thead>
<tr>
<th>AND</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OR</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

AND =

OR =
Example: Image Subtraction, Background Subtraction
Caution!!

• Undesired effects may happen, when computing with images:
  Overflow / Underflow

Example: Two Gray value images $I_1, I_2$, Pixel range: 0..255! Their Pixel sum (multipl.) may be larger than 255!! Subtraction results may be smaller than 0!!
Gray Level Enhancement?

- Process one pixel at a time independent of all other pixels
- For example used to correct Brightness and Contrast (remote control)
Brightness

• The brightness is the intensity
• Change brightness:
• To each pixel is added the value $b$
  \[ g(x,y) = f(x,y) + b \]
• $f(x,y)$ is the input image
• $g(x,y)$ is the (enhanced) output image
• If $b>0$ => brighter image
• If $b<0$ => less bright image
Example Program Code for Brightness Change

Int x,y,helpVal;
int a=10;
for (y=1; y<height; y++) %run the loop. To run the y-loop
  for (x=1; x<width; x++) %first is faster!!
    helpVal=pixel(x,y)+a; %compute the new val
    if (helpVal>255) %check for overflow
      pixel(x,y)=255 %if overflow, save max value 255
    else %if not overflow, save helpVal
      pixel(x,y)=helpVal;
  end
end
end
10
Contrast

• The contrast describes the level of details we can see
• Change contrast: \( g(x,y) = a \times f(x,y) \)
• Each pixel is multiplied by \( a \)
• \( f(x,y) \) is the input image
• \( g(x,y) \) is the (enhanced) output image
• If \( a > 1 \) => more contrast
• If \( a < 1 \) => less contrast
Combining brightness and contrast

- Both: \( g(x,y) = a \times f(x,y) + b \)
- Greylevel mapping
- X-Axis: Input Value
- Y-Axis: Output Value
- This plot: **Identity**
  - Output equals Input
- Apply to each pixel!
- To save time the greylevel mapping can be written as a **Lookup-Table**:

<table>
<thead>
<tr>
<th>Input</th>
<th>0</th>
<th>2</th>
<th>...</th>
<th>255</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>0</td>
<td>2</td>
<td>...</td>
<td>255</td>
</tr>
</tbody>
</table>

\[ g(x,y) = a \times f(x,y) + b \]
Histogram
How to set the greylevel mapping

A Histogram is a discrete function \( p(k) = \frac{n_k}{n} \),

- \( n_k \) is the number of pixels with the \( k \)-th gray level
- \( n \) is the total number of pixels
- Histogram entry \( p(k) \) gives the probability of gray value \( k \) of appearing in the image.

• Histogram processing – a powerfull tool!
Histogram Types

- **Dark Image**
- **Bright Image**
- **Low Contrast**
- **High Contrast**
Histogram processing

- Different types of mapping
- Piecewise linear
Histogram processing

- Non-linear, e.g., Logarithmic
- Arbitrary
Histogram Equalization
In Statistical Terms

- The Histogram is given by the probabilistic density function (pdf) of the pixel gray values $p(x)$.
- The mapping $g$ for a gray value $k$ is defined by the probability distribution of the pdf $p(x)$:

$$g(k) = 255 \cdot \sum_{i=1}^{k} p(i)$$
Improving contrast

- Humans cannot tell the difference between greylevel values that are too close to each other
- So: spread out the greylevel values
- This is called histogram stretching
Histogram stretching

- Algorithm:
  1. Find maximum:
  2. Find minimum…
  3. **Shift** values so that minimum is 0:
  4. **Scale** values so that maximum is 255 and write into output image \( g(x,y) \):

```plaintext
max=0;
//Check each pixel:
if f(x,y)>max
  max=f(x,y);

//For each pixel:
g(x,y)=f(x,y)-min;

c=255/(max-min);
//For each pixel:
g(x,y)=round(g(x,y)*c);
```
Something really different...
Segmentation

• Until now: Image processing (manipulation)
• Image analysis: segmentation
• The task:
  – Information versus noise
  – Foreground (object) versus background
Segmentation

• Use greylevel mapping and the histogram
• When two peaks (modes) of a histogram correspond to object and noise
• Find a **THRESHOLD** value, $T$, that separates the two peaks. This process is called **THRESHOLDING**
• Algorithm:
  – If $f(x,y) > T$ then $g(x,y) = 1$, else $g(x,y) = 0$
  – If $f(x,y) < T$ then $g(x,y) = 1$, else $g(x,y) = 0$
• Result: a binary image where object pixels = 1 and noise = 0
What to remember

- Point processing
- Brightness and contrast
- Greylevel mapping
- Histogram
- Thresholding (segmentation)
Amazing Computer Vision

Play Automatic Movie Summary
Exercises

• Questions to the lecture?
• What was good about the lecture and what could have been better?
• Discuss the questions
• Generate a simple C-program for changing the image contrast and/or the image brightness. For this: Load “Lenna” into the memory and show her on the screen. Then, apply today's techniques and generate a new image.
• Write a program to Histogram-Equalize the image!!
• Finish the exercises from last time

Questions
• What does Point Processing mean?
• Describe Brightness and Contrast
• Describe greylevel mapping and how it relates to Brightness and Contrast
• What is a histogram?
• How can a histogram be used to choose the greylevel mapping?
• What is histogram stretching?
• What is thresholding and how is it related to a histogram and to segmentation?