IMAGE PROCESSING: POINT PROCESSES

N. C. State University

CSC557 ♦ Multimedia Computing and Networking

Fall 2001

Lecture # 11
Announcements, Questions, ...

- ???
“Point” Operations

- Pixels are processed independently, one by one
- **Examples:**
  1. Change brightness and/or contrast of all pixels
  2. Convert color to grayscale (monochrome)
Example of Pixel Values

- Typically, pixel values range from $0...2^n-1$, where $n$ is the number of bits allocated
  - Most common: $n=8$, total number of colors = 256 ($0...255$)
Another Example

<table>
<thead>
<tr>
<th>R=0</th>
<th>255</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>G=0</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td>B=0</td>
<td>255</td>
<td>255</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>255</th>
<th>255</th>
<th>0</th>
<th>255</th>
</tr>
</thead>
<tbody>
<tr>
<td>255</td>
<td>0</td>
<td>0</td>
<td>255</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>255</th>
<th>0</th>
<th>128</th>
<th>128</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>255</td>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td>255</td>
<td>255</td>
<td>128</td>
<td>128</td>
</tr>
</tbody>
</table>
**Histograms**

- A *histogram* = a graph of brightness vs. the frequency of pixels with that brightness
Brightness Change

- Adding or subtracting a constant to all pixels
  - "Shifts" the histogram to left or right

- Must “saturate” (or “clip”) at the maximum or minimum allowed values
  - Cannot exceed 255 or be less than 0

Old pixel value = 160
Add 40 to 160 to “brighten” pixel
result = 200 = new pixel value

Old pixel value = 220
220 + 40 = 260, but maximum possible value is 255
result = 255 = new pixel value
Contrast Sensitivity

- Our eyes are sensitive to intensity differences
- Higher contrast seems to improve image detail
- $Contrast =$ difference between pixel value and average pixel value

Which middle square below is the brightest?
Changing Contrast

- Equivalent to multiplying the difference to the median by a constant value
- \( \rightarrow \) "Compression" or "expansion" of the histogram

Example (increasing, or doubling the contrast):
Median = 60
Old pixel value = 40
Difference to median = old pixel value - median = 40 - 60 = -20
New pixel value
\[
= \text{median} + 2 \times \text{difference to median}
= 60 + 2 \times (-20)
= 20
\]

Doubling the contrast!
Intensity: Other

- Posterize = reduce # of possible pixel values
  - → coarser quantization scheme, fewer number of bits

  Example (4 posterize levels):
  new pixel values must be one of 0, 85 (=255/3), 170 (=2*255/3), 255
  old pixel value = 60, convert to nearest of (0,85,170,255)
  new pixel value = 85

- Threshold = convert to black or white

  Example (threshold = 110):
  old pixel value = 80 (less than threshold), new value = 0
  old pixel value = 160 (greater than threshold), new value = 255
Other (cont.)

• Invert
  – Grayscale: Swap black for white, dark gray for light gray, etc.
  – Color: swap color for *opposite* color

• Looks like photographic negative

Example:

old pixel value = 60, new value = 255 - 60 = 195
"Dynamics"

- Graphical way to express intensity transformations

**Graph A:**
- New pixel value vs Old pixel value
- **a. What is it?**

**Graph B:**
- Old pixel value vs New pixel value
- **b. What is it?**

**Questions:**

a. Add 75 to all pixel values
b. Threshold (below 100 = 0, above 99 = 255)
"Dynamics" (cont.)

c. What is it?

New pixel value

Old pixel value

255

255

d. What is it?

New pixel value

Old pixel value

255

255
Another Example of Dynamics

- Solarize

![Diagram showing pixel value change](image)

- What does it look like?
Histogram Specification

- **Specification** = “spreading” the original histogram to approximate some desired histogram

- **Equalization** = specification, where the desired histogram is the uniform distribution

Original histogram looks like...

<table>
<thead>
<tr>
<th>Pixel value</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>10%</td>
</tr>
</tbody>
</table>

Desired histogram looks like...

<table>
<thead>
<tr>
<th>Pixel value</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>25%</td>
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<tr>
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</tr>
<tr>
<td></td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>10%</td>
</tr>
</tbody>
</table>
SPECIFICATION (Cont.)

For $j = 0$ to $255$

OrignFrac[$j$] = Fraction of pixels in input image with value $\leq j$

DesiredFrac[$j$] = Fraction of pixels in desired histogram With value $\leq j$

EndFor

NewValue = 0

For $j = 0$ to $255$

While ((DesiredFrac[NewValue] < OrignFrac[$j$]) && (NewValue < 255))

NewValue = NewValue + 1

OutValue[$j$] = NewValue

Endfor
Example:

3-bit grayscale, range of possible values = 0..7

4 pixels; old values = (0, 1, 2, 1)

Desired: uniform distribution

(spread these values as uniformly as possible)

old values =

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

Origfrac = (.25, .75, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0)

DesFrac = (.125, .25, .375, .5, .625, .75, .875, 1.0)

new values =

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

New values = (1, 5, 7, 5)
Arithmetic Combination Of Images

• To combine two images, they must be the same size (same width and height)
  – Combine pixel in position \([i,j]\) in image1 with pixel in position \([i,j]\) of image2 to produce pixel in position \([i,j]\) of image3 (the output)

• Addition (→ “mixing”)

Example:

Image1 pixel = 80, image2 pixel = 40, image3 pixel = 80 + 40 = 120

Image1 pixel = 220, image2 pixel = 160, image3 = min(220+160,255) = 255
Arithmetic on Images: Examples

- Combine fruit image with mask image, using several operations
Example (cont’d)

Operation = ????
Boolean Combination Of Images

- Minimum possible pixel value is black
  = 0 (decimal)
  = 00000000 (8-bit binary)

- Maximum possible pixel value is white
  = 255 (decimal)
  = 11111111 (8-bit binary)

- OR image1 with image2
  - Result = white where image2 = white ("x OR 1 = 1")
  - Result = no change where image2 = black ("x OR 0 = x")

- AND image1 with image2
  - Result = black where image2 = black ("x AND 0 = 0")
  - Result = no change where image2 = white ("x AND 1 = x")
Example (cont’d)

Operation = ????

gray value
masking
demo

Operation = ????

gray value
demo
Sources Of Info

- [Crane97] *A Simplified Approach to Image Processing*
  - Chapter 2