University of Idaho
Department of Computer Science
Coeur d'Alene

Lecture #9

Histograms

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Lecture #9

2024-09-09

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Review

- Variation in Pixel Intensity → Image Topography
- Changes in topography reveal information
  1. edges
  2. groups of pixels at same value (isophotes)
- Image Gradients
  1. color → grayscale
  2. blur
  3. calculate gradients

Review

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Review

Important Workflows...

Workflows

1. Camera Calibration
2. Image Gradients

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└Review

└Review

Review
Important Workflows...
Workflows
1. Camera Calibration
2. Image Gradients

Review

Analyzing information at the pixel level...

- Instead of analyzing the changes in pixel values...

Review
Analyzing information at the pixel level...
► Instead of analyzing the changes in pixel values...

Review

Analyzing information at the pixel level...

- What can we learn by counting pixels by value?

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Histograms

How should we count?

1. Divide range of pixel values ($[0, 256]$) into smaller sets ($[0, 20]$, $[21, 30]$, $\ldots$)
    1.1 if set too small, more sensitive to lighting
    1.2 too large → not useful
2. Count how many pixels fall into each subset
3. Finally, counts can be graphed in histogram

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Image Histogram

B&W…

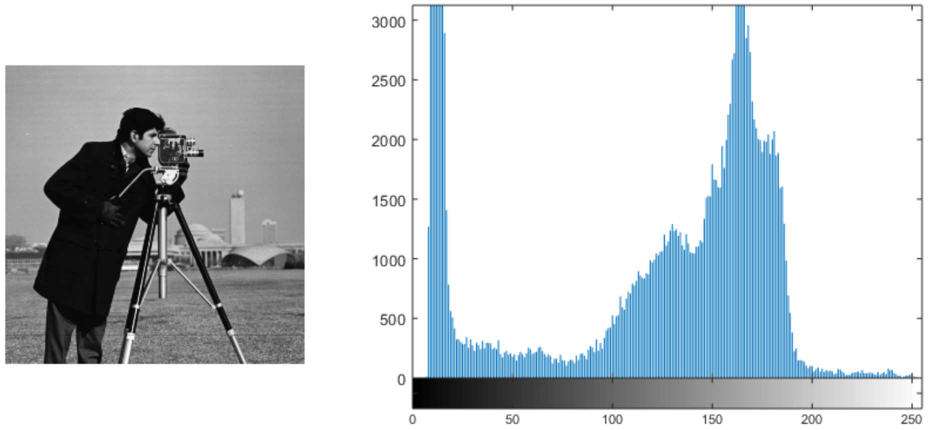

Figure: Histogram Example

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Lecture #9
└Review
└Image Histogram

Image Histogram
B&W…

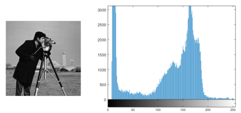
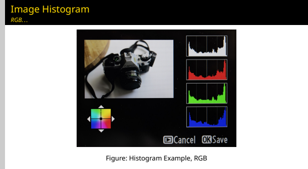


Figure: Histogram Example

Image Histogram

RGB...

Figure: Histogram Example, RGB



Histograms

Other things we might put in a histogram. . .

- Pixel intensity
- Gradient
- Color hue value

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- Pixel intensity
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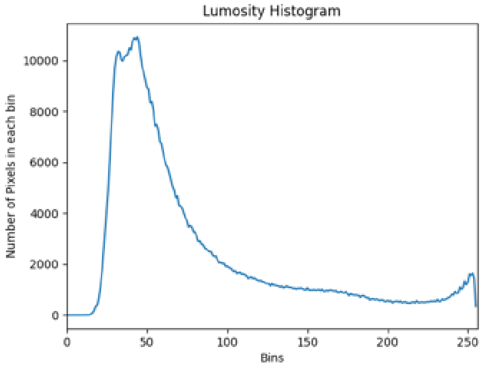
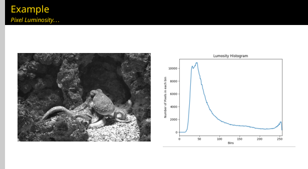
Example

Pixel Luminosity. . .





Histogram Information

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Histogram Code Example

```python
src_img = cv.imread('img_path')
# optional: convert to grayscale
hist = cv.calcHist(
    images=[src_img], # source images
    channels=[0],     # channels to calculate for
    mask=None,        # if not none, count only marks in mask
    histSize=[256],   # number of "bins" to put values in
    ranges=[0, 256]   # range of values in input
)
```


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Visualization

Matplotlib. . .

```python
plt.figure()
plt.title("Histogram")
plt.xlabel("Bins")
plt.ylabel("Pixels")
plt.plot(hist)
plt.xlim([0,256])
plt.show()
```


Visualization
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1. More examples of histogram visualizations at **rosebrockCleverGirlGuide2014**

Histogram Uses

1. Histogram Equalization
2. Comparison
3. Back Projection

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Histogram Equalization

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Modifies the distribution of pixel values in an image to provide a more uniform distribution over the range of pixel values.

- Essentially “stretches” values to cover range of input values
- Improves contrast in an image

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► Improves contrast in an image

Code Example

1. Calculate histogram H
2. Normalize histogram so that sum of bin contents is 255
3. Compute integral, H'
4. Transform image using H' as lookup table

```
hist = cv.equalizeHist(
            src # input image
        )
```


Code Example

1. Calculate histogram H
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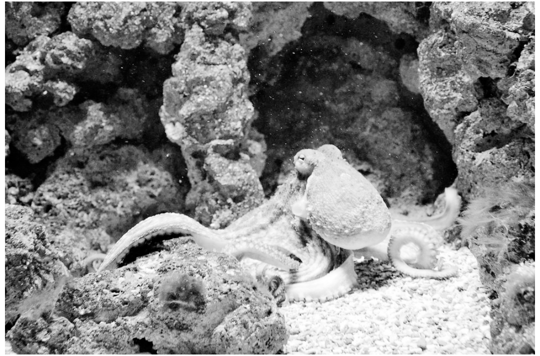
Example Output



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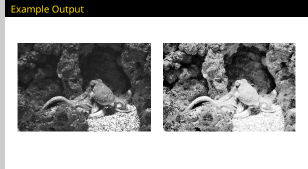
└Histogram Uses
  └Histogram Equalization
    └Example Output



Histogram Comparison

Histogram Comparison Methods

1. Correlation
2. Chi-Square
3. Intersection
4. Bhattacharyya Distance

Histogram Comparison[1]

```
cv.compareHist(
    H1, # first histogram
    H2,  # second histogram
    method, # comparison method enum value
)
```

[1]OpenCV Histogram Methods [1]

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[1]OpenCV Histogram Methods [1]

Correlation

Given histograms H_1, H_2 then $d(H_1, H_2)$ expresses how well they match[2].

$$d(H_1, H_2) = \frac{\sum_I (H_1(I) - \bar{H}_1)(H_2(I) - \bar{H}_2)}{\sqrt{\sum_I (H_1(I) - \bar{H}_1)^2 \sum_I (H_2(I) - \bar{H}_2)^2}} \tag{1}$$

where

$$\bar{H}_k = \frac{1}{N} \sum_J H_k(J) \tag{2}$$

and N is the total number of histogram bins.

[1]See OpenCV documentation [2]

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[1]See OpenCV documentation [2]

Code

```
cv.HISTCMP_CORREL
```


Code

cv.HISTCMP_CORREL

Chi-Square

$$d(H_1, H_2) = \sum_I \frac{(H_1(I) - H_2(I))^2}{H_1(I)} \tag{3}$$

[2] OpenCV documentation [2]

Chi-Square

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Code

```
cv.HISTCMP_CHISQR
```


Code

cv.HISTCMP_CHISQR

Intersection

$$d(H_1, H_2) = \sum_I \min(H_1(I), H_2(I)) \tag{4}$$

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$$d(H_1, H_2) = \sum_I \min(H_1(I), H_2(I)) \tag{4}$$

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cv.HISTCMP_INTERSECT
```


Code

cv.HISTCMP_INTERSECT

Bhattacharyya Distance

$$d(H_1, H_2) = \sqrt{1 - \frac{1}{\sqrt{\bar{H}_1 \bar{H}_2 N^2}} \sum \sqrt{H_1(I) \cdot H_2(I)}} \tag{5}$$

[2] OpenCV documentation [2]

Bhattacharyya Distance

$$d(H_1, H_2) = \sqrt{1 - \frac{1}{\sqrt{\bar{H}_1 \bar{H}_2 N^2}} \sum \sqrt{H_1(I) \cdot H_2(I)}} \tag{5}$$

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Code

`cv.HISTCMP_BHATTACHARYYA`

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cv.HISTCMP_BHATTACHARYYA

Final Notes on Histogram Comparison

1. Not very powerful
2. Heavily constrained
3. Need very consistent environment
4. May not work on similar objects

The Simplest Classifier: Histogram Comparison [3]

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Back Projection

A method of searching for a feature in an image.[3]

1. Calculate histogram of feature (a subsection of a source image)
2. Search an input image for a section that matches the histogram of our feature

Example Uses

- searching for objects that are made of a single material

[3] See OpenCV tutorial [4]

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[2] "OpenCV: Histogram Comparison," (), [Online]. Available: https://docs.opencv.org/4.x/d8/dc8/tutorial_histogram_comparison.html (visited on 09/07/2024).

[3] M. Patacchiola, "The Simplest Classifier: Histogram Comparison," mpatacchiola's blog. (Nov. 12, 2016), [Online]. Available: https://mpatacchiola.github.io/blog/2016/11/12/the-simplest-classifier-histogram-intersection.html (visited on 09/07/2024).

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