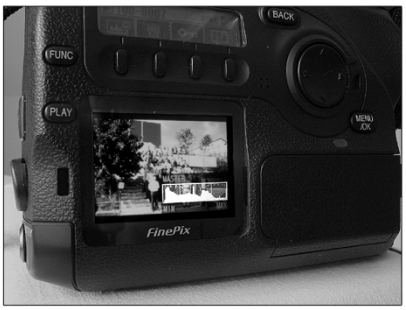
CS334: Digital Imaging and Multimedia

Image Histograms

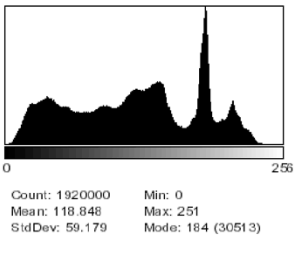
Ahmed Elgammal
Dept. of Computer Science
Rutgers University

Image Histograms

- Histograms are used to depict image statistics in an easily interpreted visual format
- Useful during image capturing: now already in digital cameras
- Used to improve the visual appearance of an image
- Can also be used to determine what type of processing has been applied to an image.

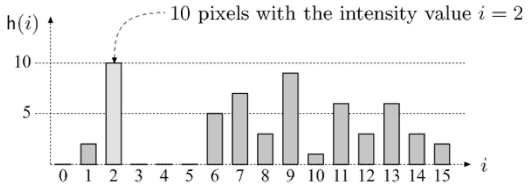


- Image histogram: describes the frequency of the intensity values that occur in an image



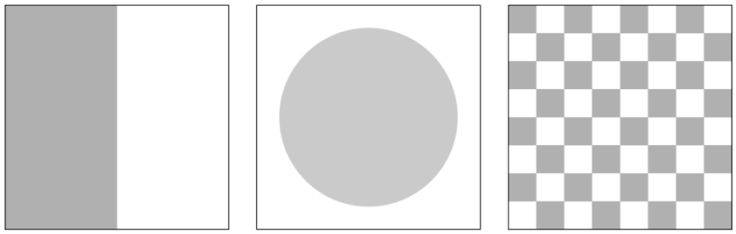
$\mathsf{h}(i) =$ the *number* of pixels in I with the intensity value i

$$\mathsf{h}(i) = \mathrm{card}\{(u,v) \mid I(u,v) = i\}$$



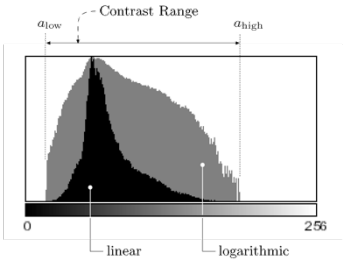
i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$\mathsf{h}(i)$	0	2	10	0	0	0	5	7	3	9	1	6	3	6	3	2

- Histograms don't encode information about the spatial arrangement of pixels in the image
- We cannot reconstruct an image given only it's histogram

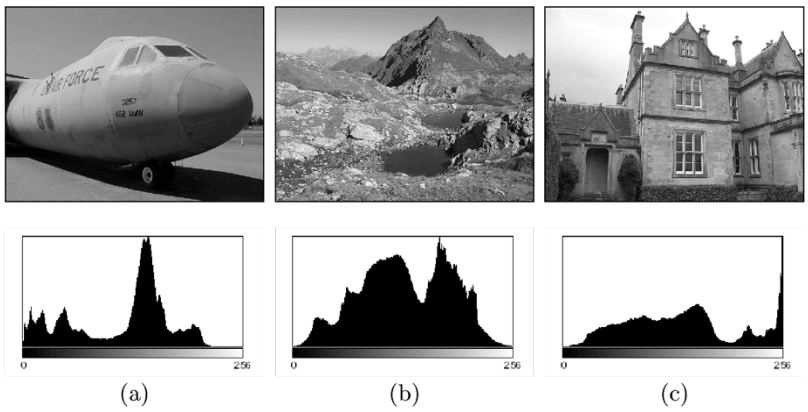


Interpreting Histograms

- Histograms depicts problems that originate during image acquisition
  - Exposure, contrast, dynamic range
- Histograms can be used to detect a wide range of image defects: saturation, spikes and gaps, impact of image compression



Histograms and Exposure



(a) (b) (c)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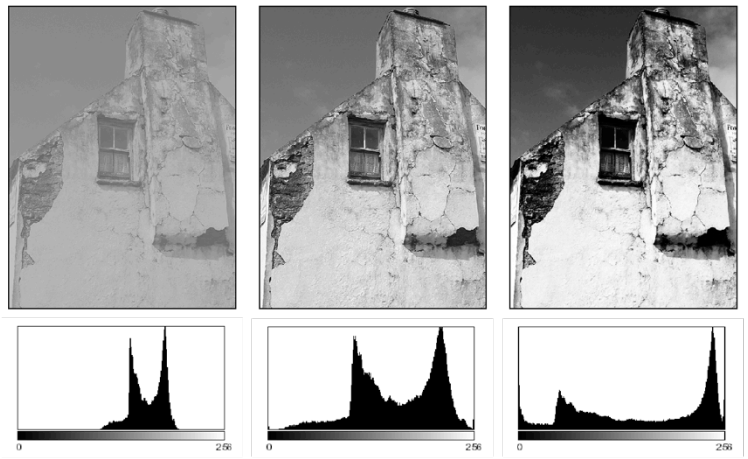
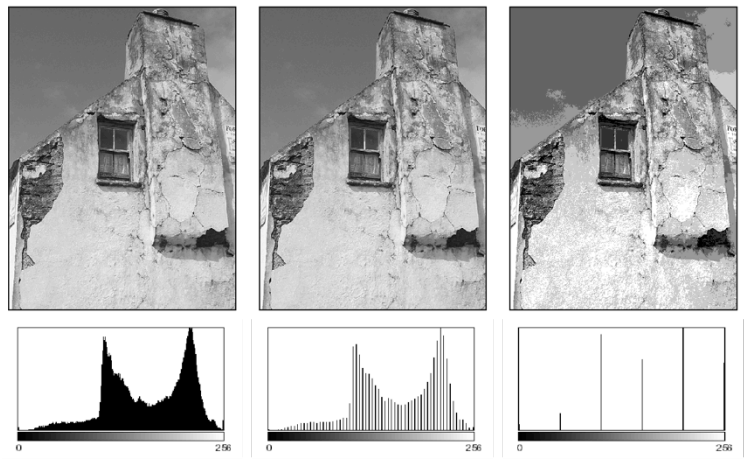
Histogram and Contrast



(a) (b) (c)

Contrast: the range of intensity values effectively used within an image, low contrast, normal contrast, high contrast

Dynamic Range

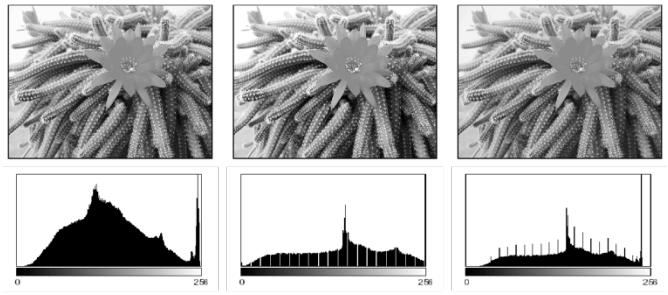


(a) (b) (c)

Dynamic Range: the number of distinct pixel value in an image

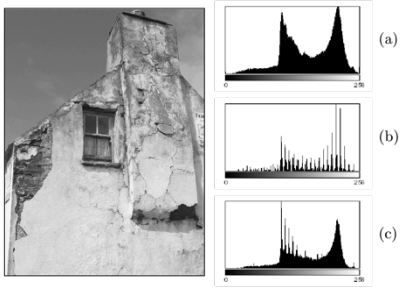
Detecting Image Defects

- There is no ideal or optimal histogram shape. It depends on the image and on the application
- Image Defects:
  - Saturation: the illumination values lying outside of the sensor's range are mapped to its maximum or minimum values: spike at the tails
  - Spikes and Gaps in manipulated images. Why?
  - Impact of image compression

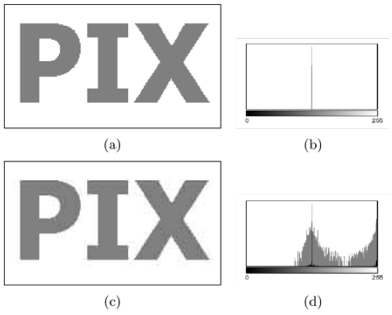


(a) (b) (c)

- Histograms show the impacts of image compression
- Ex: in GIF compression, the dynamic range is reduced to only few intensities (quantization)



- Ex: JPEG compression on a line graphics.



Computing Histograms

```
1  public class Compute_Histogram implements PlugInFilter {
2
3      public int setup(String arg, ImagePlus img) {
4          return DOES_8G + NO_CHANGES;
5      }
6
7      public void run(ImageProcessor ip) {
8          int[] H = new int[256]; // histogram array
9          int w = ip.getWidth();
10         int h = ip.getHeight();
11
12         for (int v = 0; v < h; v++) {
13             for (int u = 0; u < w; u++) {
14                 int i = ip.getPixel(u,v);
15                 H[i] = H[i] + 1;
16             }
17         }
18         ... //histogram H[] can now be used
19     }
20
21 } // end of class Compute_Histogram
```

- Histograms of images with more than 8 bits:
  - Binning

$$\mathsf{h}(j) = \text{card}\,\{(u,v) \mid a_j \le I(u,v) < a_{j+1}\} \quad \text{for } 0 \le j < B$$

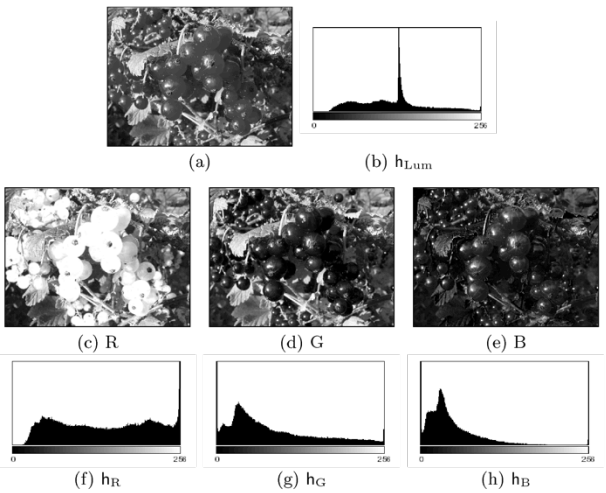
$$a_j = j \cdot \frac{K}{B} = j \cdot k_B$$

  - B: number of bins
- Ex: B=256 for 14 bit image

K=16384, bin width = 64

$$\begin{array}{lcrcr}
\mathsf{h}(0) & \leftarrow & 0 & \le I(u,v) < & 64 \\
\mathsf{h}(1) & \leftarrow & 64 & \le I(u,v) < & 128 \\
\mathsf{h}(2) & \leftarrow & 128 & \le I(u,v) < & 192 \\
\vdots & & \vdots & \vdots & \vdots \\
\mathsf{h}(j) & \leftarrow & a_j & \le I(u,v) < & a_{j+1} \\
\vdots & & \vdots & \vdots & \vdots \\
\mathsf{h}(255) & \leftarrow & 16320 & \le I(u,v) < & 16384
\end{array}$$

Color Image Histograms



(a) (b) h_{Lum}

(c) R (d) G (e) B

(f) h_{R} (g) h_{G} (h) h_{B}

Color Image Histograms

- For color images, two kind of histograms:
  - Intensity histogram
  - Individual Color Channel Histograms
- Both provides useful information about lighting, contrast, dynamic range and saturation effects for individual color components
- They provide no information about the actual color distribution!

Cumulative Histograms

$$\mathsf{H}(i) = \sum_{j=0}^{i} \mathsf{h}(j) \quad \text{for } 0 \le i < K$$

$$\mathsf{H}(i) = \begin{cases} \mathsf{h}(0) & \text{for } i = 0 \\ \mathsf{H}(i-1) + \mathsf{h}(i) & \text{for } 0 < i < K \end{cases}$$

$$\mathsf{H}(K-1) = \sum_{j=0}^{K-1} \mathsf{h}(j) = M \cdot N$$