EEE-6512: Image Processing and Computer Vision

September 6, 2017

Lecture #5: Point and Geometric Transformations

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Chapter Outline

- Different ways to transform an image into another image
- Simple Geometric Transformations
- Graylevel Transformations
- Graylevel Histograms
- Multispectral Transformations
- Multi-Image Transformations
- Change Detection
- Compositing
- Interpolation
- Warping

Linear Contrast Stretching

- **Linear contrast stretch:** A transformation that specifies a line segment that maps gray levels between g_{min} and g_{max} in the input image to the gray levels g'_{min} and g'_{max} in the output image according to a linear function:

$$I'(x, y) = \frac{g'_{\mathrm{max}} - g'_{\mathrm{min}}}{g_{\mathrm{max}} - g_{\mathrm{min}}}(I(x, y) - g_{\mathrm{min}}) + g'_{\mathrm{min}}$$

Linear Contrast Stretching (cont'd)

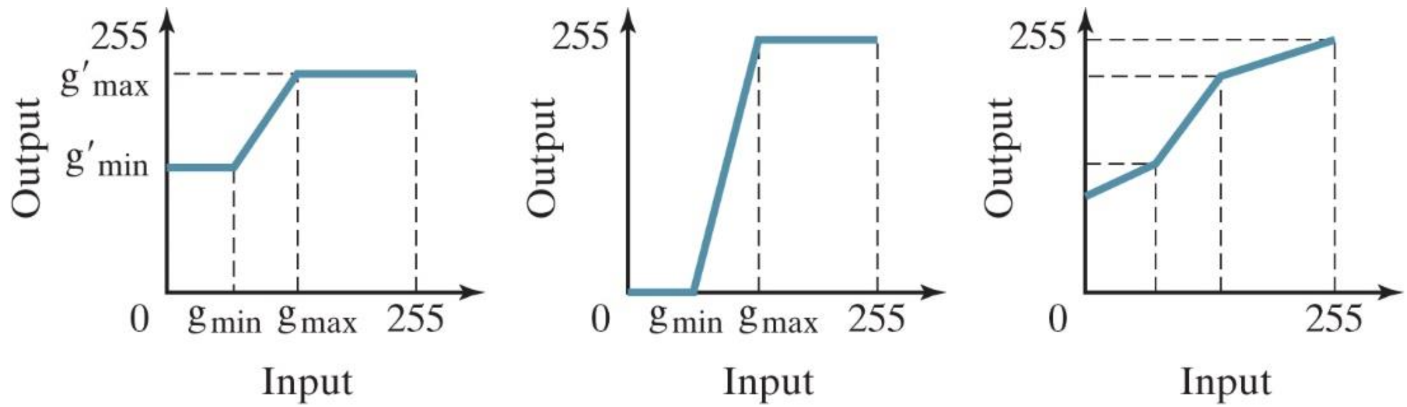


Figure 3.11 Left: Linear contrast stretching maps all the gray levels between g_{min} and g_{max} to the range g'_{min} to g'_{max}. Middle: If $g'_{min} = 0$ and $g'_{max} = 255$, then the full output range is used. RIGHT: A piecewise linear contrast stretch can model any graylevel transformation with arbitrary precision.

Analytic Transformations

- Graylevel transformations can be specified using analytic functions such as the logarithm, exponential, or power functions:

$$I'(x, y) = \log(I(x, y))$$

$$I'(x, y) = \exp(I(x, y))$$

$$I'(x, y) = (I(x, y))^{\gamma}$$

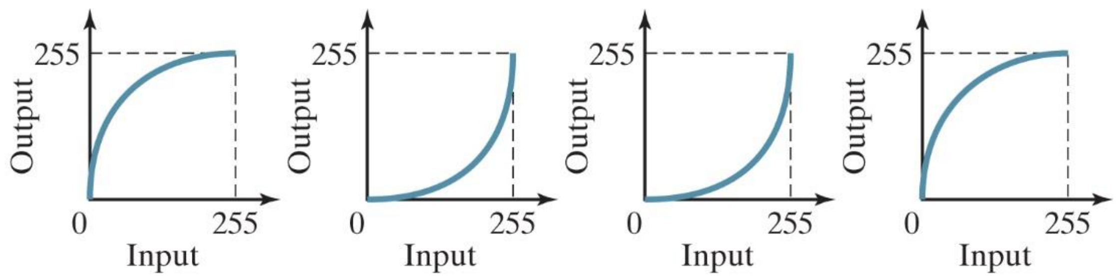


Figure 3.13 Analytic graylevel mapping. From left to right: logarithm, exponential, gamma expansion ($\gamma = 2$), and gamma compression ($\gamma = 0.5$). All transformations are monotonically nondecreasing.

Thresholding

- **Thresholding:** takes a grayscale image and sets every output pixel to 1 if its input gray level is above a certain threshold, or to 0 otherwise:

$$I'(x,y) = \begin{cases} 1 & \text{if } I(x,y) > \tau \\ 0 & \text{otherwise} \end{cases}$$

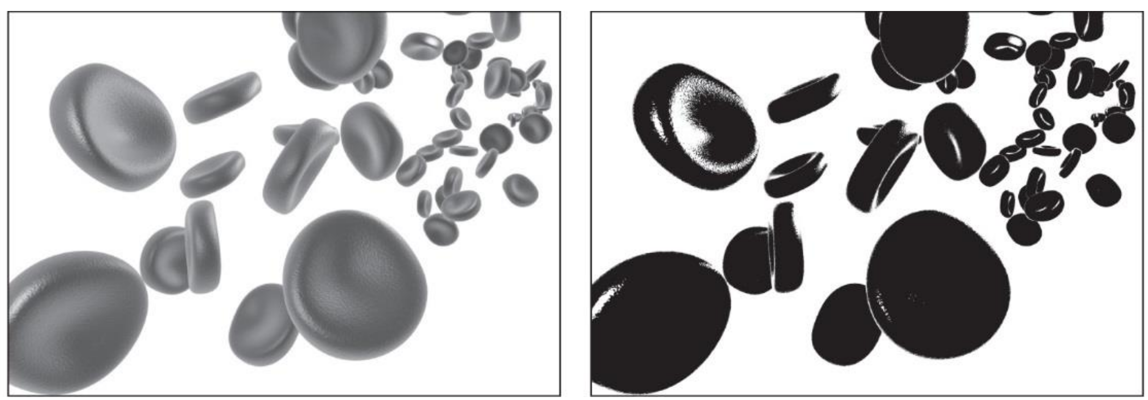


Figure 3.14 An 8-bit grayscale image (left), and the binarized result obtained by thresholding with $\tau = 150$ (right).

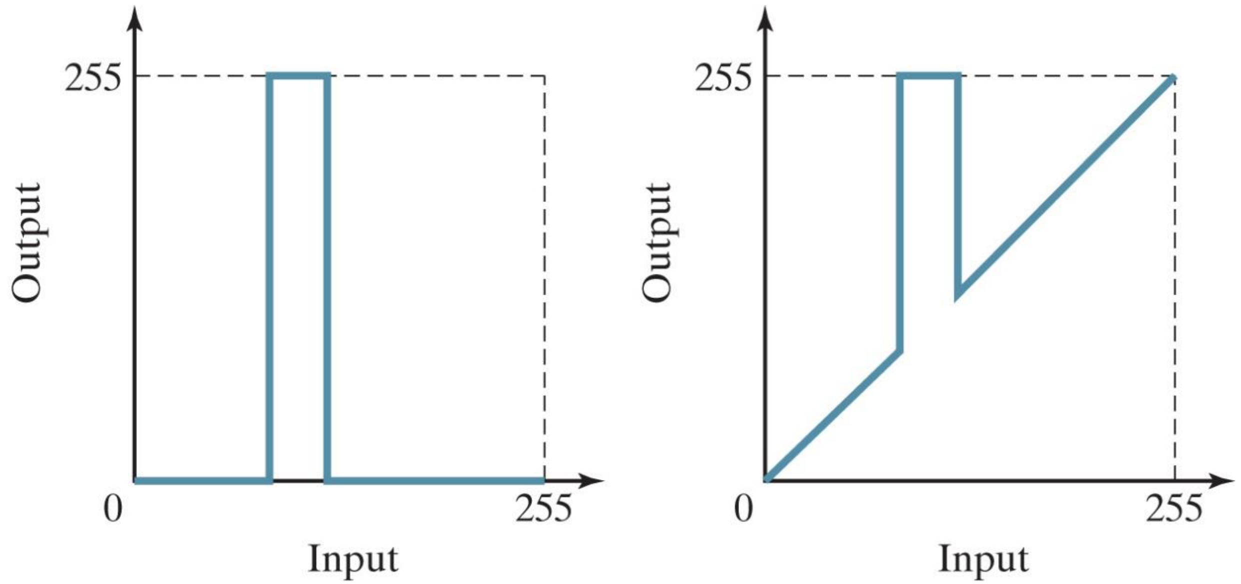
Ciprian Stremtan / Shutterstock.com

Other Transformations

- **Density slicing:** assigns all gray levels within a certain range to a certain value.
- **Quantization:** discards one or more of the lower-order bits.
- **Bit-plane slicing:** another transformation that is sometimes mentioned in the context of graylevel transformations.
  - A *bit plane* is a binary image whose value at each pixel is the same as the appropriate bit in the corresponding pixel of the original image.

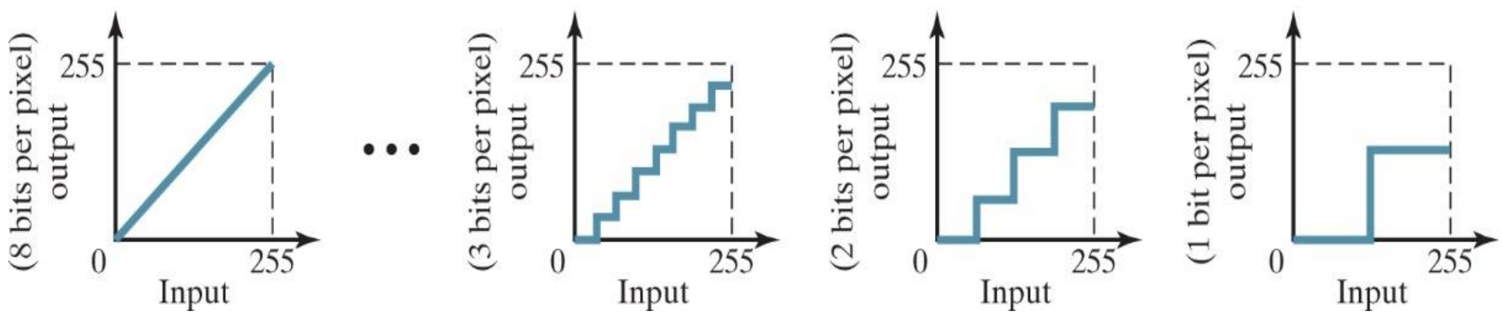
Other Transformations (cont.): Density Slicing

Figure 3.15 Density slicing maps a range of input gray levels to a specific output gray level. All other input gray levels are either mapped to zero (left) or remain unchanged (right).



Other Transformations (cont.): Quantization

Figure 3.16 Quantization discards the lower-order bits via a staircase function, with the number of stairs determined by the number of bits retained. From right to left: Only 1 bit is retained, so the gray levels in the dark half (less than 128) map to 0, while the gray levels in the bright half (above 127) map to 128 (binary: 10000000); 2 bits are retained, so gray levels are mapped to either 0, 64, 128, or 192; 3 bits are retained, so all gray levels are mapped to either 0, 32, 64, 96, 128, 160, 192, or 224; all 8 bits are retained (no quantization, the identity function).



Other Transformations (cont.): Bit Slicing

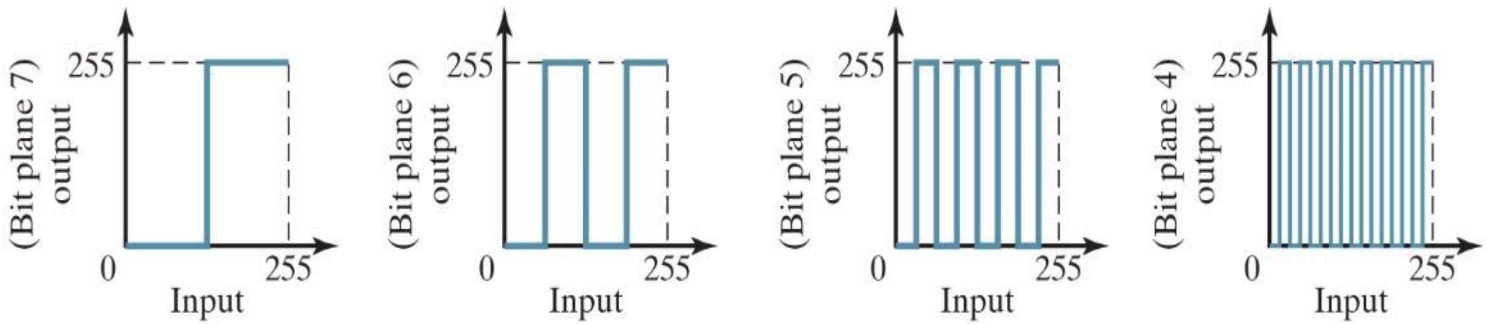


Figure 3.18 Bit-plane slicing transformations for the four highest-order bit planes. The transformation for bit plane 7 is identical, apart from scaling, to thresholding with a value of 127.

Other Transformations (cont.): Bit Slicing

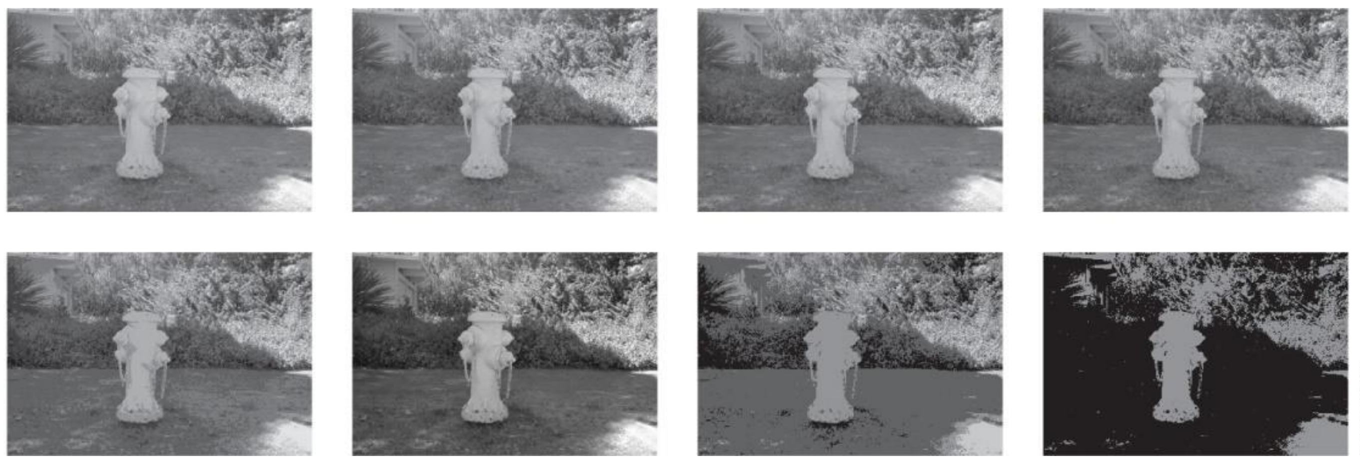


Figure 3.17 From left-to-right and top-to-bottom: An original 8-bit-per-pixel image of a fire hydrant and its quantized versions with 7, 6, 5, 4, 3, 2, and 1 bit per pixel. Note that the image is quite recognizable with as few as 3 bits per pixel.

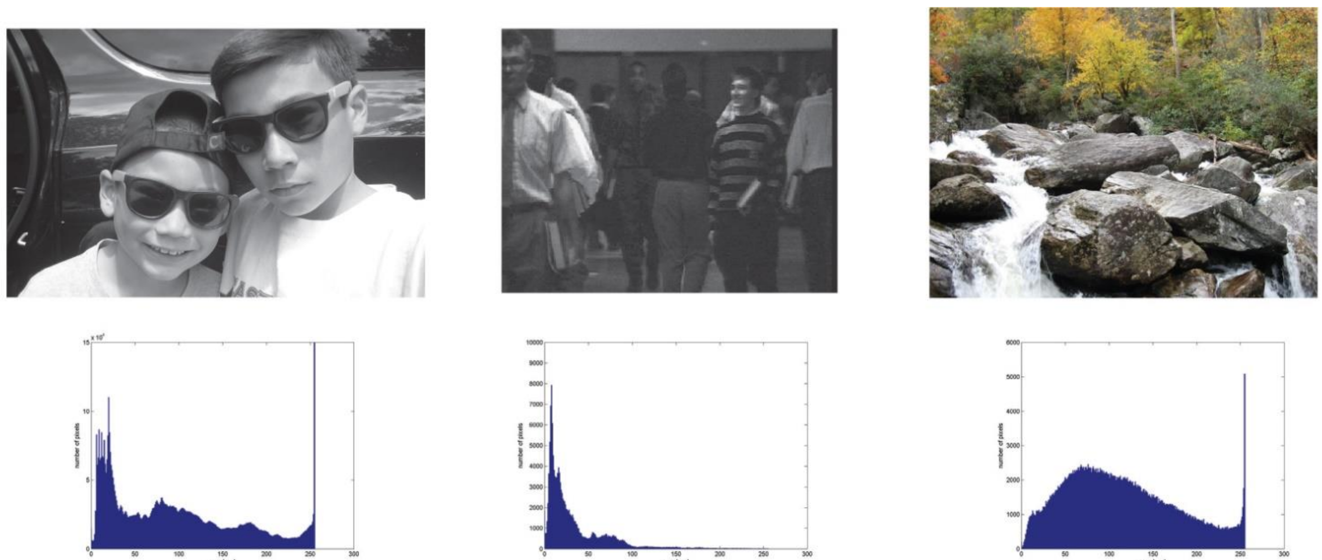
Graylevel Histograms

Graylevel Histograms

- **Histogram:** a simple but powerful technique for capturing the statistics of any type of data.
  - The space in which the data reside is divided into bins, and the histogram records the number of occurrences in each bin.
    - **Graylevel histogram:** a histogram of image gray levels
    - **Normalized histogram:** computed from the histogram by simply dividing each value by the total number of pixels in the image
    - **Probability density function (PDF):** the normalized histogram

Graylevel Histograms (cont.)

Figure 3.20 Images and their histograms. From left to right: an image with high contrast and many dark or bright pixels, a dark image with low contrast, and another high contrast image with good exposure. Note the spikes at 255 in the first and last images, indicating pixel saturation.



Stan Birchfield, Source: Movie *Hoop Dreams*, Jessica Birchfield

Histogram Equalization

- **Histogram Equalization:** converts the PDF (captured by the normalized histogram) to a **cumulative distribution function (CDF)** by computing the running sum of the histogram:

$$\bar{c}[\ell] = \sum_{k=0}^{\ell} \bar{h}[k], \quad \ell = 0, \ \ldots, 255$$

Histogram Equalization (cont'd)

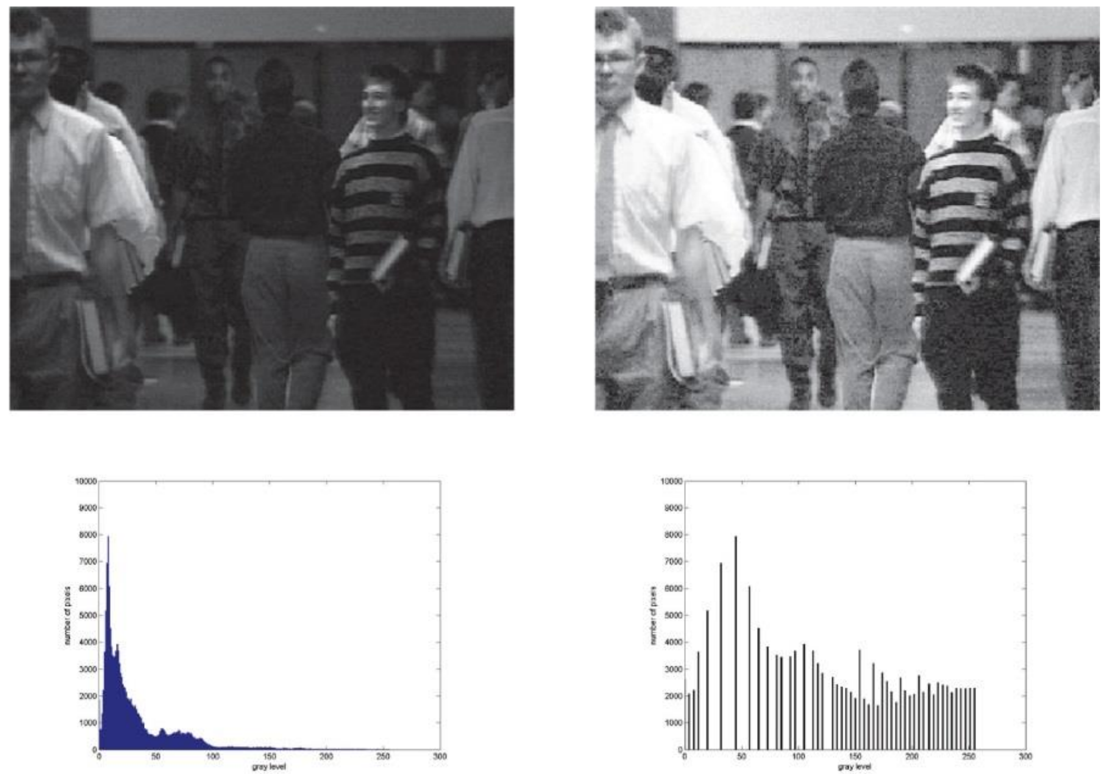


Figure 3.21 The result of histogram equalization applied to an image. The increase in contrast is noticeable. The normalized histogram of the result is much flatter than the original histogram, but it is not completely flat due to discretization effects. Source: Movie *Hoop Dreams*.

Questions?