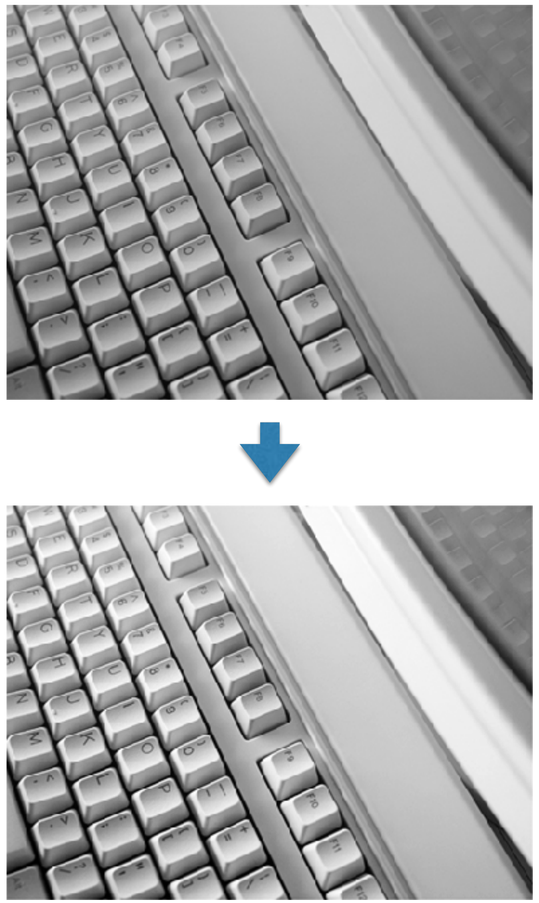
Level (Point) Operations

CS 355: Introduction to Graphics and Image Processing

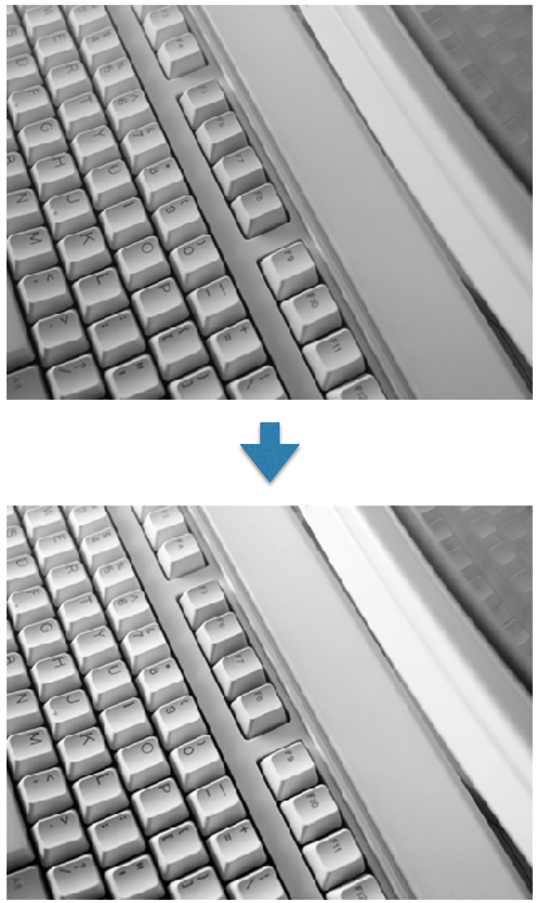
Level Operations

- Simplest enhancement:
  process each point independent of others
- Output value is a function of the input value *only*
- “Point operations” or “level operations”



Level Operations

- Simple idea with lots of applications:
  - Brightness
  - Contrast
  - Scaling
  - Clipping
  - Negatives
  - Thresholding
  - Quantization
  - Logarithmic encoding
  - Gamma correction
  - Windowing
  - Equalization
  - and many more…



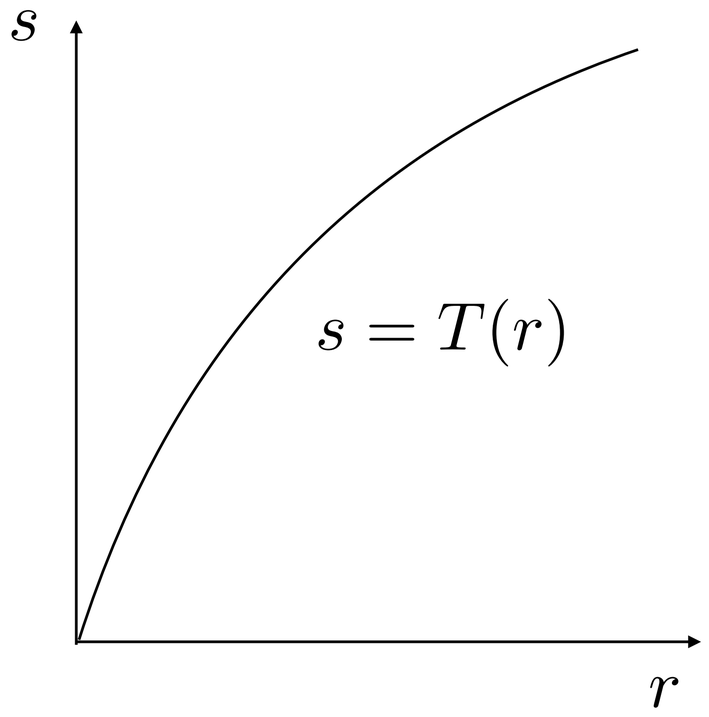
Level Operations

- Output value is a function of the input value

$$r = \text{input value}$$

$$s = \text{output value}$$

$$T = \text{a greylevel transformation}$$

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for all pixel positions x, y:
    out[x,y] = func(in[x,y])
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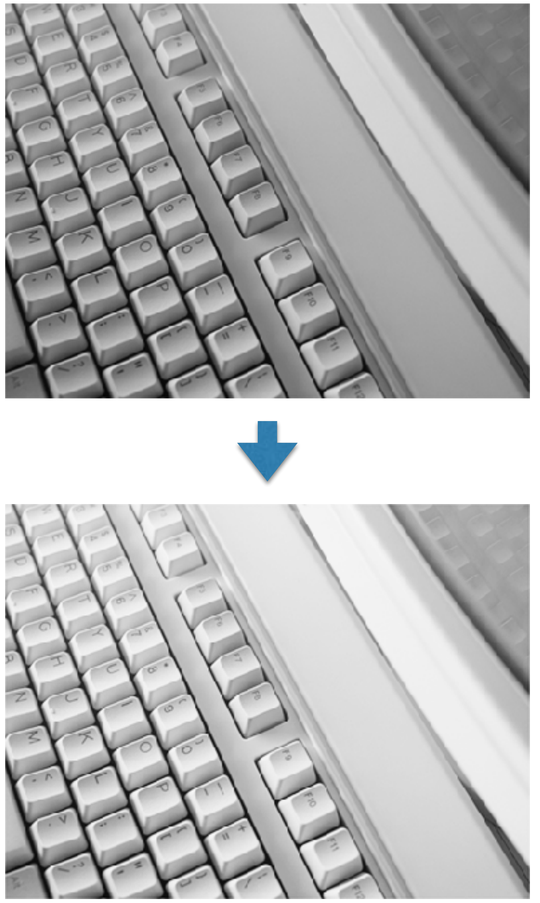
Brightness

$$s = r + c$$

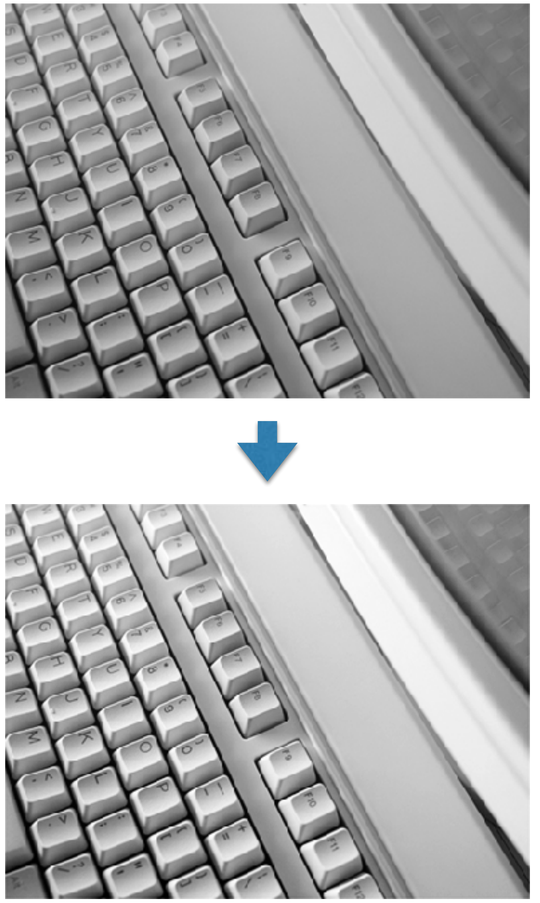


$c > 0$ brighter

$c < 0$ darker

Contrast

$$s = a\ r$$



$a > 1$ more contrast

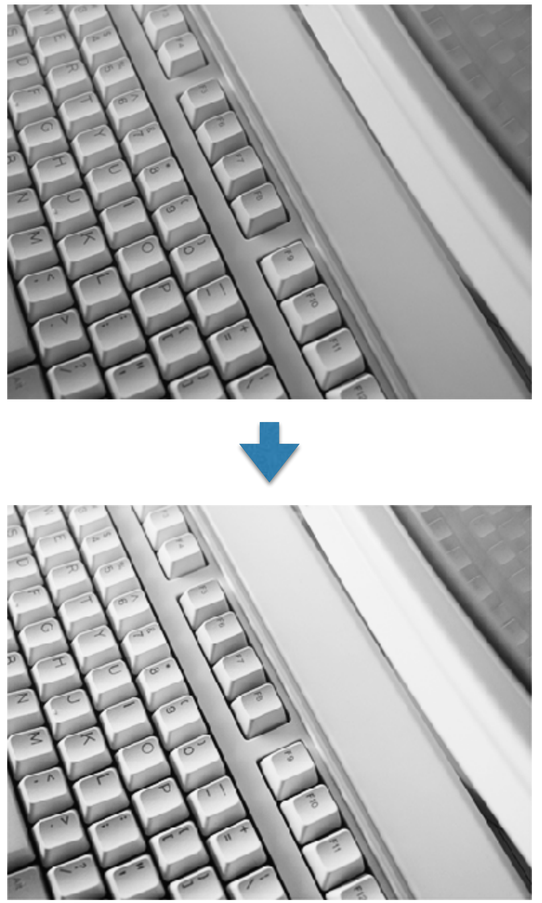
$a < 1$ less contrast

Linear Operations

$$s = a\ r + c$$

a gain

c bias / offset



Clipping

Clipping to a limited range:

$$s = \begin{cases} s_{\min} & \text{if } r < s_{\min} \\ s_{\max} & \text{if } r > s_{\max} \\ r & \text{otherwise} \end{cases}$$

Very common to clip to [min,max] of the range
to avoid unsigned wrap-around

Scaling

Scaling linearly from one range to another:

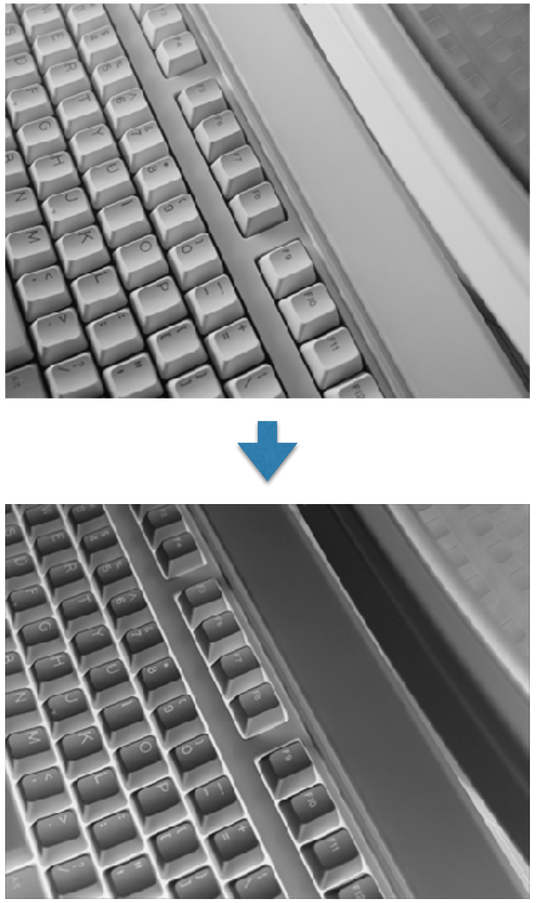
$$s = (r - r_{\min}) \frac{s_{\max} - s_{\min}}{r_{\max} - r_{\min}} + s_{\min}$$

Negative

$$s = r_{\max} - r$$

or

$$s = r_{\max} - r + r_{\min}$$

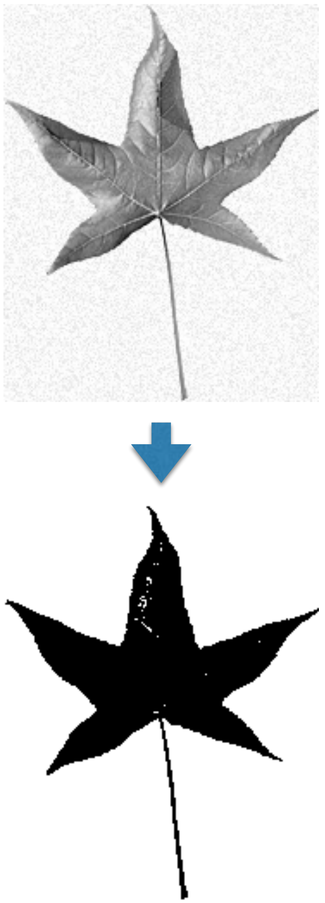


Thresholding

Binarization based on a threshold

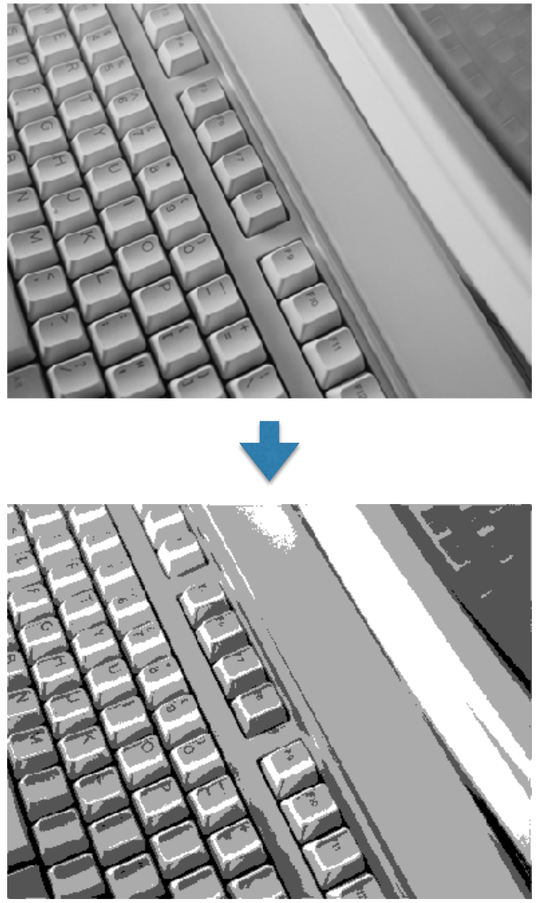
$$s = \begin{cases} 1 & \text{if } r > r_0 \\ 0 & \text{otherwise} \end{cases}$$

$r_0 = \text{selected threshold}$



Quantization

$$s = \begin{cases} s_0 & \text{if } r_{\min} \leq r_< r_0 \\ s_1 & \text{if } r_1 \leq r_< r_2 \\ s_2 & \text{if } r_2 \leq r < r_3 \\ \vdots & \\ s_n & \text{if } r_n \leq r \leq r_{\max} \end{cases}$$



Logarithm / Exponent

- Sometimes care more about *relative changes* than absolute ones

- Lots of things use logarithmic scales
  - Decibel (dB) units
  - Apparent brightness
  - Richter scale
  - Human Vision

- Can “undo” with exponentiation

$$s = \log(r)$$

$$s = e^r$$

Power Functions

Can also raise to a desired power:

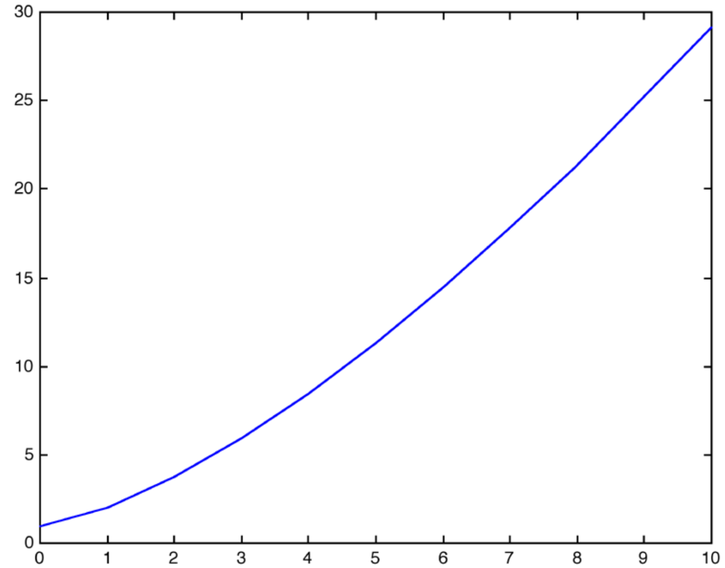
$$s = r^p$$

Gamma Responses

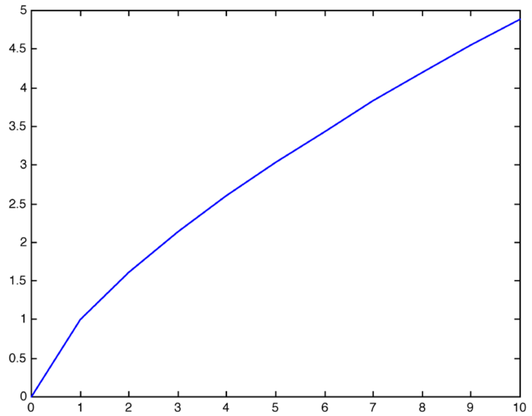
- Many devices have a nonlinear response:
- For a CRT, the intensity is related to the voltage by

$$I = V^{\gamma} + c$$

- The exponent is often called the “gamma” of the device

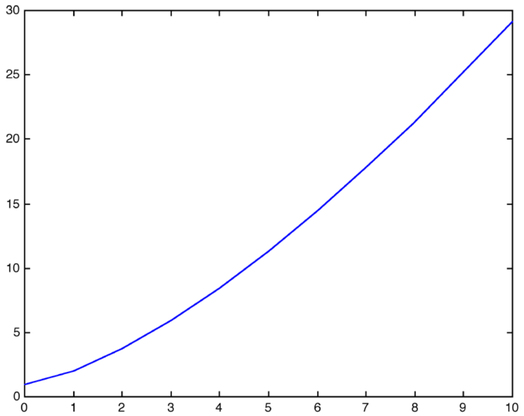


Gamma Correction



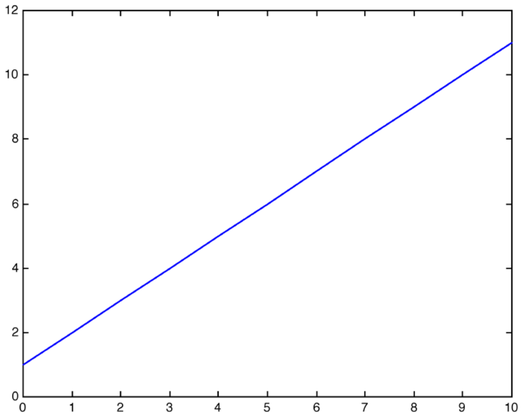
Preprocess

$$s = r^{1/\gamma}$$



Device

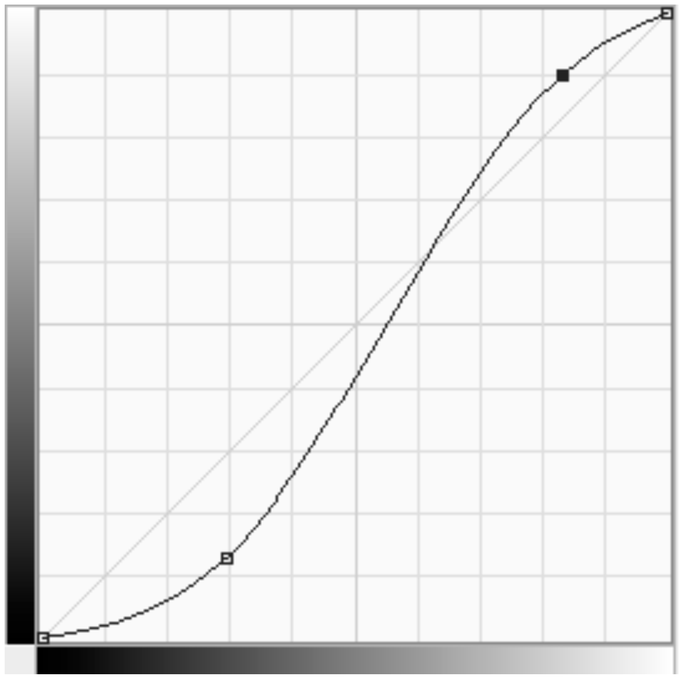
$$I = V^{\gamma} + c$$



Result

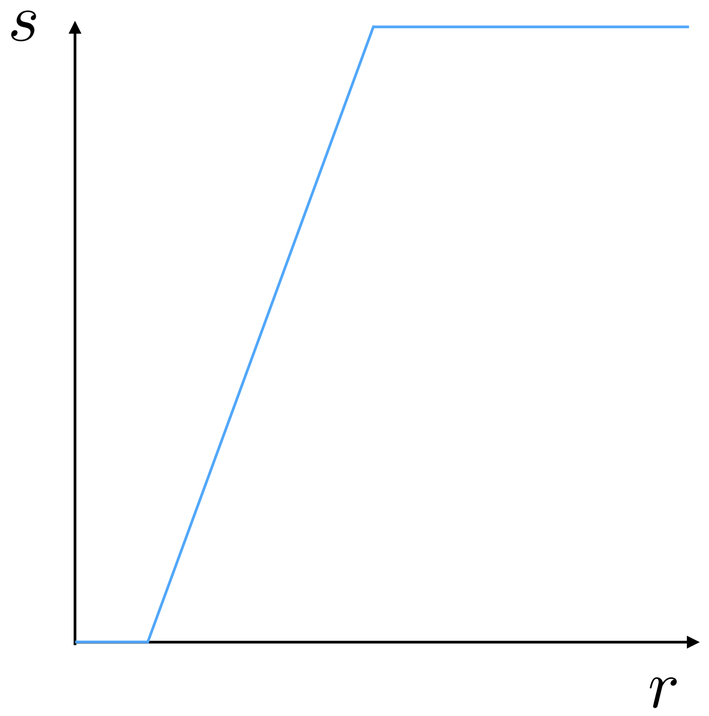
Contrast Enhancement

- *Contrast enhancement* makes differences more distinguishable
- Trades off *decreased contrast* in some part(s) of the range for *increased contrast* in the range we're interested in
- If we plot the function,
  - Slope > 1 means enhancement
  - Slope < 1 means reduction



Windowing

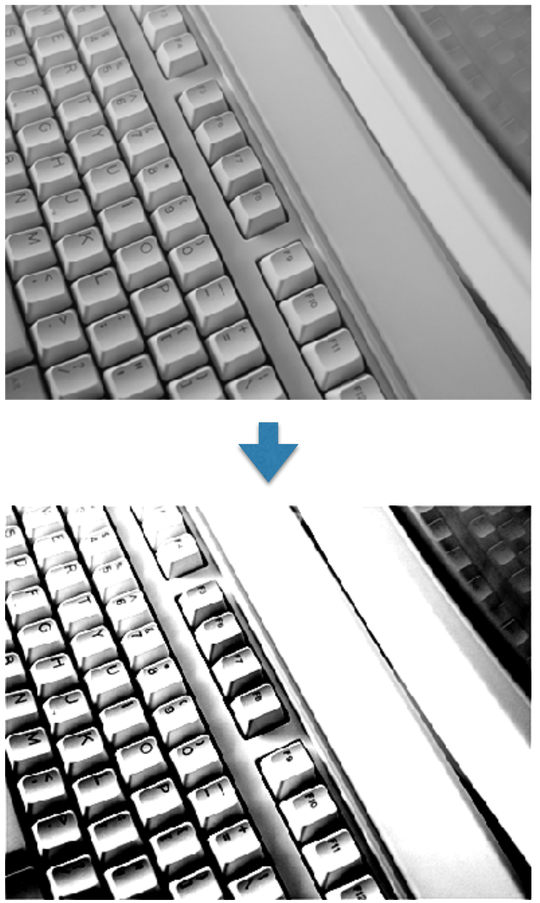
- *Windowing* is enhancement of *one part* of the image range
- Example:
  Displaying 12-bit X-rays on an 8-bit screen
  - Simple: scale [0,4095] to [0,255] by dividing by 16
  - Better: if you know that what you're interested in is in the range [500,2000], *enhance that part of the range*



$$s = \begin{cases} 0 & \text{if } r < 500 \\ 255(r - 500)/(2000 - 500) & \text{if } 500 \leq r < 2000 \\ 255 & \text{if } r \geq 2000 \end{cases}$$

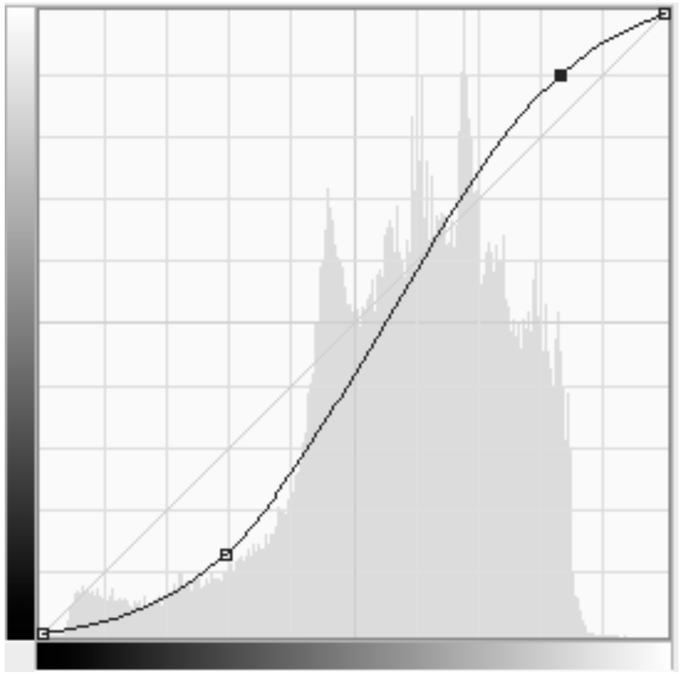
Windowing

- Another example:
  - Want to better see the reflection of the keys
  - Enhance this range at expense of contrast in brighter or darker areas
- If the full range is already used, contrast enhancement is a *zero-sum game*



Histogram Equalization

- Can try to automatically optimize contrast by allocating according to brightness distribution (histogram)
- This is called *histogram equalization* because it tries to spread contrast evenly
- Strong discrimination of detail, but not always good “real looking” result



Histogram Equalization

Coming up...

- Color image processing
- Interimage: blending, masking, differencing, compositing
- Neighborhood operations:
  - noise reduction
  - sharpening
  - edge detection