Slide 4: Point Operations

LUT:

8 bit image → 256 entries 1111 1111 = 255 ← 8 bit image 256 values
0 to 255 is 256

Threshold:

grayscale image → · if input pixel's grayvl is > some threshold → output pixel = 1
· otherwise → output pixel = 0

0 = black
255 = white

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

anything below a certain threshold is black & above is white

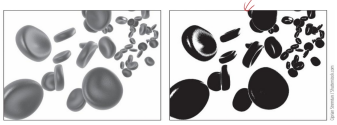


Figure 3.14 An 8-bit grayscale image (left), and the binarized result obtained by thresholding with $\tau = 150$ (right).

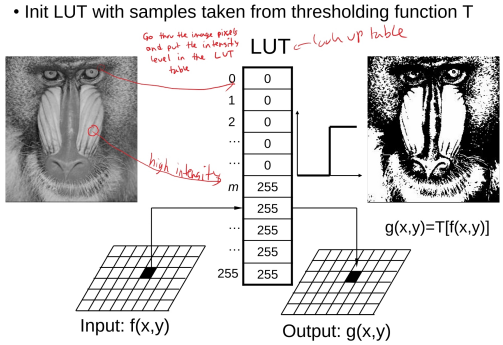
Wolberg: Image Processing Course Notes

Lookup table

go thru input image pxl by pxl → store grayscale level on LUT → use the LUT vale to make output → f(LUT vale of the pixel) → output pixel

thresholding T(f(x,y)) = g(x,y)

• Init LUT with samples taken from thresholding function T



• Better approach: exploit LUT to avoid `total` comparisons:

```
// init lookup tables
for(i=0; i<thr; i++) lut[i] = BLACK;
for(; i<MXGRAY; i++) lut[i] = WHITE;

// iterate over all pixels
for(i=0; i<total; i++) out[i] = lut[in[i]];
```

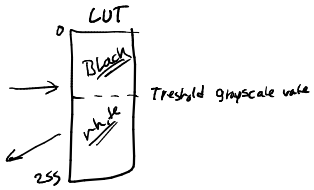
assign black or white to look up table

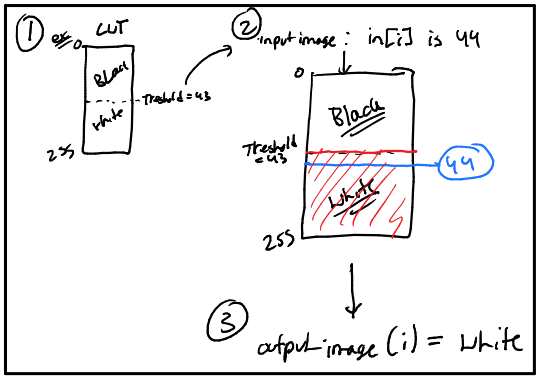
256

Smart way

• If less than treshold → BLACK
If more than treshold → White

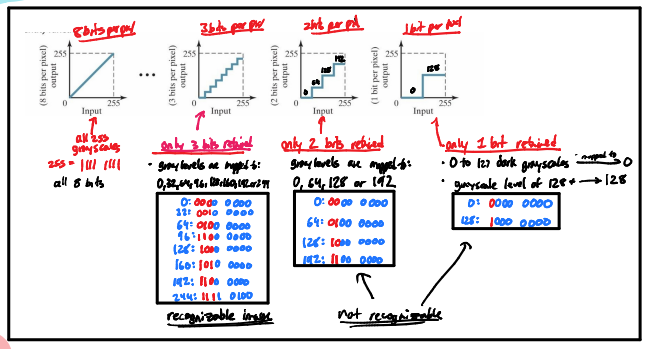
• go over all input pixels and use the value of the input pixel for the LUT



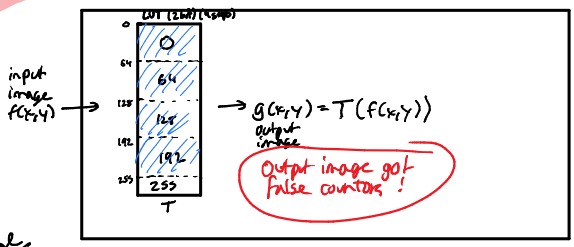


Quantization:

8 bit images takes up space
quantization gets rid of the lower order bits via a staircase func
∴ # of steps ↑ = # of bits retained ↑

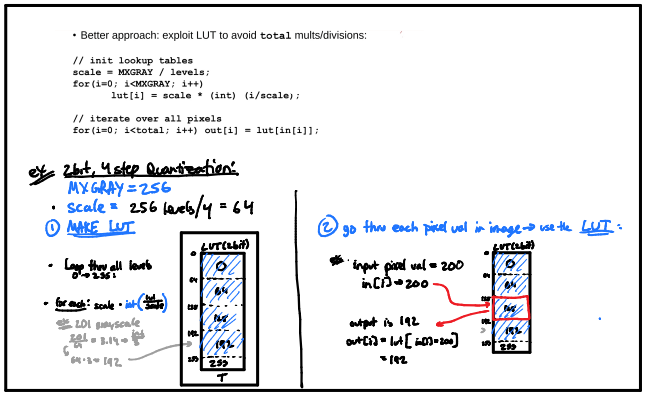


Issue: image → LUT created using 2 bit quantization (4 steps)



With Quantization info will obviously be lost bec we are grouping a lot of values and setting them as one value to save space
↓
so will get false contours

code



• Better approach: exploit LUT to avoid `total` mults/divisions:

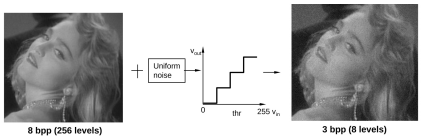
```
// init lookup tables
scale = MXGRAY / levels;
for(i=0; i<MXGRAY; i++)
      lut[i] = scale * (int) (i/scale);

// iterate over all pixels
for(i=0; i<total; i++) out[i] = lut[in[i]];
```


Fix to false contours when quantizing

FIX: • add dither (uniformly distributed white noise)
to the input image BEFORE quantization → LUT not affected

• dither = some random # from [-m to m]
m = MXGRAY / quantization-levels = 256 / q-levs



Clipping

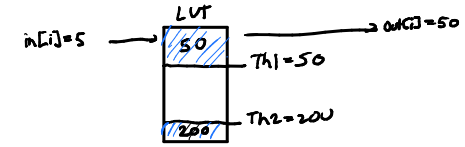
- th1 = 0
- th2 = 255

default

range of grayscale values

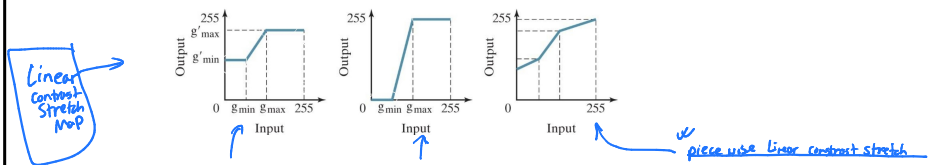
Say I made th1 = 50 and th2 = 200
∴ any grayscale <50 becomes 50
∴ any grayscale >200 becomes 200

if in[i] ≤ th1 → out[i] = th1
if in[i] ≥ th2 → out[i] = th2



Linear Contrast Stretching using Piecewise functions

- Advantage: The form of piecewise functions can be arbitrarily complex
- Disadvantage: Their specification requires considerably more user input



Linear Contrast Stretch Map

stretches it a bit
maps gray lvls from g_{min} to g_{max} to g'_{min} to g'_{max}

crazy contrast stretch
below g_{min} gray lvl → output gray = 0
above g_{max} gray lvl → output gray = 255
from g_{min} to g_{max} → FULL RANGE 0 to 255
∴ if gray lvl not putting g_{min} to g_{max} → its 0 or 255

piece wise linear contrast stretch

low contrast image

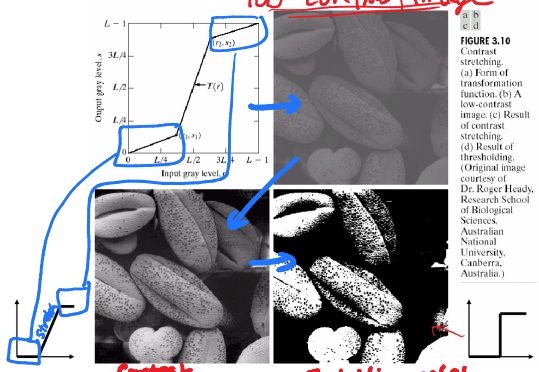


FIGURE 3.10 Contrast stretching. (a) Form of transformation function. (b) A low-contrast image. (c) Result of contrast stretching. (d) Result of thresholding. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Contrast stretching

Thresholding applied

This is the brightness
You actually move the histogram to the left or right. add or subtract to each pixel

Linear Contrast Stretch:

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

contrast value

input image

take out g_{min}

$g'_{max} = 255$ = white
$g'_{min} = 0$ = black

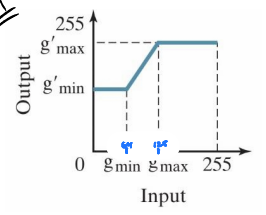
- g_{min} to g_{max} is input image's range

This will basically map the image's low values to black & g_{min}

output_pixel = middle_of_range + (in[i] − middle_of_range) * contrast + brightness

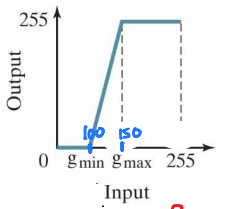
128 128

ex1



- mapping 0 − g_{min} to g'_{min}
- mapping g_{min} − g_{max} to STRETCH FUNC
- mapping g_{max} − 255 to g'_{max} = 255

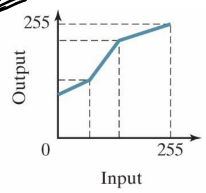
ex2



- mapping 0 − 100 to g'_{min} = 0
- mapping 100 − 150 to STRETCH FUNC
- mapping 150 − 255 to g'_{max} = 255

$\frac{255-0}{150-100} = 5.1$

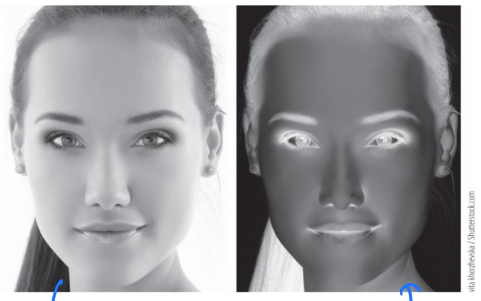
ex3



arbitrary

Figure 3.9 An 8-bit grayscale image (left), and the inverted image obtained by subtracting each pixel from 255 (right).

8 bit grayscale pic



each output pixel = 255 − in[i]

Contrast Code

DONE

Linear Contrast Stretch:

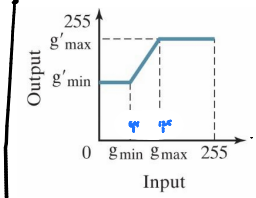
$$I(x,y) = \frac{g'_{max} - g'_{min}}{g_{max} - g_{min}} \cdot (I(x,y) - g_{min}) + g'_{min}$$

contrast | brightness

- $g'_{max} = 255$ = white
- $g'_{min} = 0$ = black

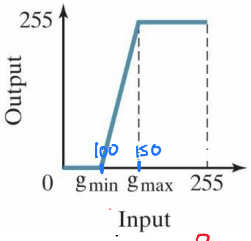
input image | take out gain

This will basically map the image's low values to BLACK = g'_{min}



- mapping $0 - \frac{64}{g_{min}}$ to g'_{min}
- mapping $\frac{64}{g_{min}} - \frac{128}{g_{max}}$ to STRETCH FUNC
- mapping $\frac{128}{g_{max}} - 255$ to $g'_{max} = 255$

ex2



- mapping $0 - \frac{100}{g_{min}}$ to $g'_{min} = 0$
- mapping $\frac{100}{g_{min}} - \frac{150}{g_{max}}$ to STRETCH FUNC
- mapping $\frac{150}{g_{max}} - 255$ to $g'_{max} = 255$

$\frac{255-0}{150-100} = 5.1$

Stretching the lowest and highest grayscale range to 0 to 255

$g'_{max} = 255$, $g'_{min} = 0$

$$\frac{255-0}{g_{max} - g_{min}} \cdot (in[i] - g_{min}) + g'_{min}$$

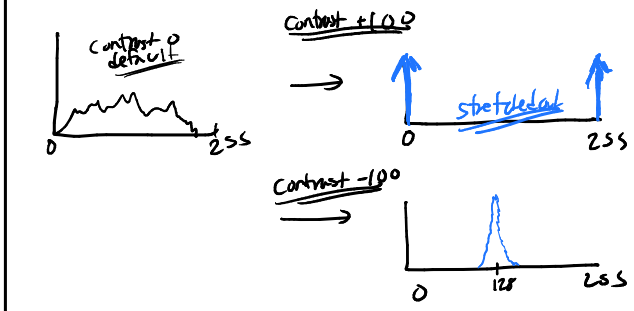
- say image only got grayscales from 100 to 150

brightness = 0

- $in[i] = 100 \rightarrow$ should be 0 $\leftarrow \frac{255}{50}(100 - 100) + 0$
- $in[i] = 130 \rightarrow \frac{255}{50}(130 - 100) + 0$
- $in[i] = 150 \rightarrow$ should be 255 $\leftarrow \frac{255}{50}(150 - 100) + 0$
- $in[i] = 0 \rightarrow 0 \leftarrow \frac{255}{50}(0 - 100) + 0$

i) find smallest intensity in pic

1) $\left(\text{contrast}\left(in[i] - g_{min}\right) + \text{brightness}\right) = val$ (0 to 255 output)
2) if $val < 0 \rightarrow$ set 0
3) if $val > 0 \rightarrow$ set 255



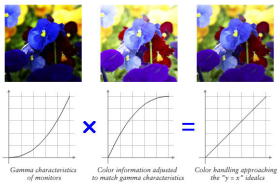
← answer

answer

output_pixel = middle_of_range (128) + (in[i] − middle_of_range (128)) * contrast + brightness

Gamma Correction

- Controls brightness of image.
- If you want to accurately displayed image → need to do contrast correction.
- not properly corrected → image can look bleached out or too dark



- monitor has its own gamma that affects the pic
- cancel out that gamma = gamma correction

$s = cr^{\gamma}$

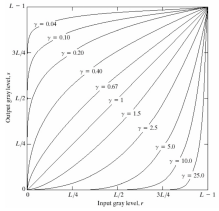
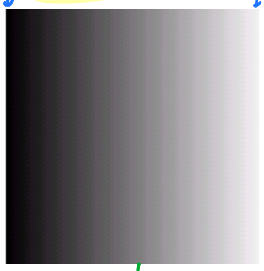


FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

- c and γ are (+) constants
- $c = \gamma = 1$ → identity function (input image = output image)
- This power-law curve
  - maps narrow range of dark vals to wider range
  - vice versa

Monitor Gamma Correction

input scale



monitor adds its gamma

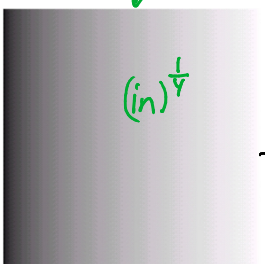
$(in)^{\gamma}$ → Monitor → $(in)^{\gamma}$ bad

Image on monitor

$(in)^{\gamma}$

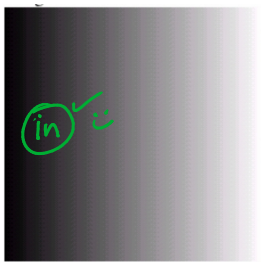
monitor's gamma makes image darker!

Gamma Correction: Before putting thru monitor change input image to cancel out monitor gamma



$(in)^{\frac{1}{\gamma}}$

$(in)^{\frac{1}{\gamma}}$ → Monitor → in good



in ✓

Code

$$c \cdot \left(\frac{in[i]}{c}\right)^{1/gamma}$$

c = 255

float

Spreading out dark vals by $\gamma < 1$

$s = cr^{\gamma}$

$s = (1)r^{\gamma}$

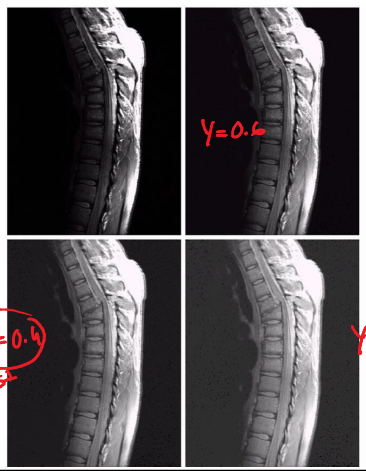


FIGURE 3.8 (a) Magnetic resonance (MR) image of a fractured human spine. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 0.6, 0.4$, and 0.3, respectively. (Original image for this example courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Y=0.6

Y=0.4 best

Y=0.3

Fixing washed-out image $\gamma > 1$

FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0$, and 5.0, respectively. (Original image for this example courtesy of NASA.)

Y=3.0

Y=4.0

Washed-out image. Shrink graylevel range ⇨ $\gamma > 1$

(b) $\gamma = 3.0$ (suitable)

(c) $\gamma = 4.0$ (suitable)

(d) $\gamma = 5.0$ (High contrast; the image has areas that are too dark; some detail is lost)

Y=5.0
- high contrast
- some areas too dk
- info lost bec in[i] < 0 → becomes

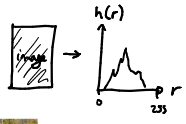
Histogram

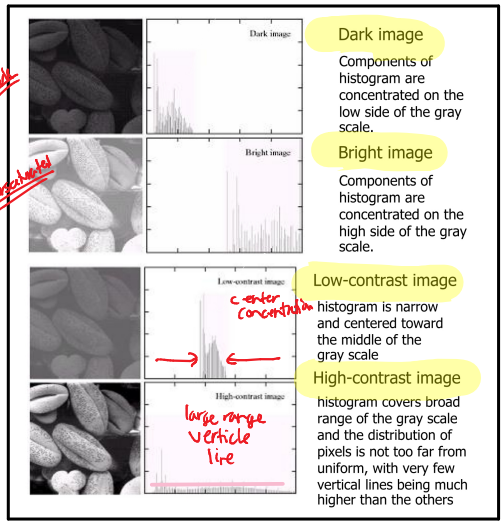
- a histogram with gray lvls from [0, L-1] is

$h(r_k) = n_k$

r_k = k^{th} gray lvl
n_k = grayscale freq

The k^{th} gray level
particular grayscale frequency: The # of pixels in the image with that grayscale





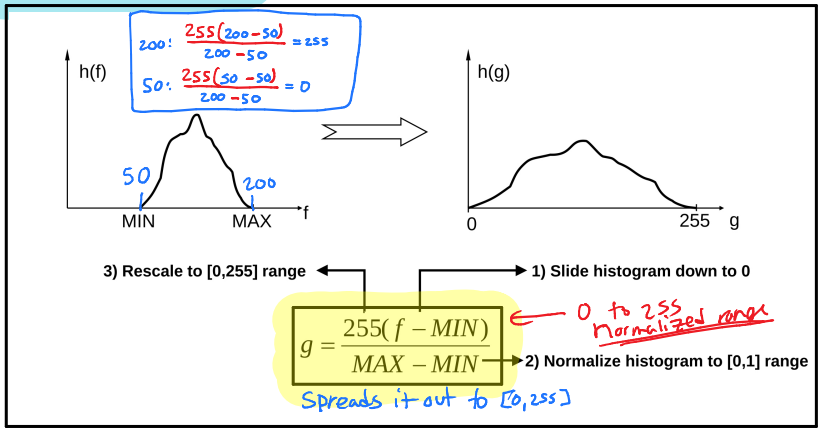
Dark image
Components of histogram are concentrated on the low side of the gray scale.

Bright image
Components of histogram are concentrated on the high side of the gray scale.

Low-contrast image
histogram is narrow and centered toward the middle of the gray scale

High-contrast image
histogram covers broad range of the gray scale and the distribution of pixels is not too far from uniform, with very few vertical lines being much higher than the others

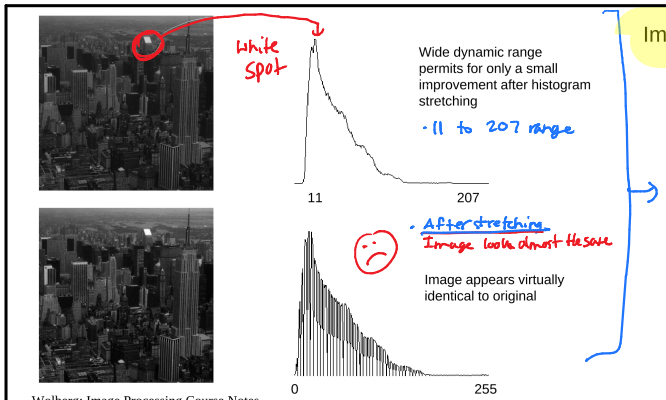
Histogram Stretching



normalization range: MIN to MAX
image range: min_I to max_I

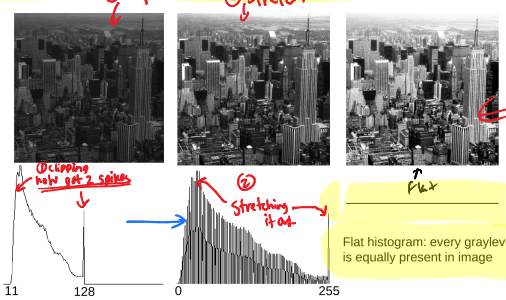
$$g = (in[i] - min_I)\left(\frac{MAX - MIN}{max_I - min_I}\right) + MIN$$

normalized range MIN to MAX



Wolberg: Image Processing Course Notes

Improve effectiveness of histogram stretching by clipping intensities first



Histogram Stretching

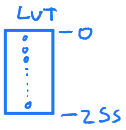
1) clip the histogram first to get side spike
if histo is [0 to 140]
[10 to 128] → 2 side spikes
2) use the func to stretch it

Histogram equalization

1) find the frequency of each grayscale

```
for (i=0; i<MXGRAY; i++)
    H[i] = 0;
for (i=0; i<total; i++)
    H[in[i]] ++;
```

← make a LUT where all is 0



← go thru each pixel value and increment how many times it came up

2) Divide each grayscale entry @ gray level, r_k by the total # of pixels in that image, n

What is the probability that grayscale r_k will be @ this pixel?

$$p(r_k) = \frac{n_k}{n}$$

- r_k = gray level
- n_k = frequency of that gray lvl
- n = totall # of pixels in image

normalized. Sum = 1

```
for (i=0; i<MXGRAY; i++)
    P[i] = LUT[i] / n;
```

P[i]: probability of occurance table

LUT[i]: LUT that has the frequency

n: total # of pixels