Introduction to Digital Image Processing with MATLAB® Asia Edition

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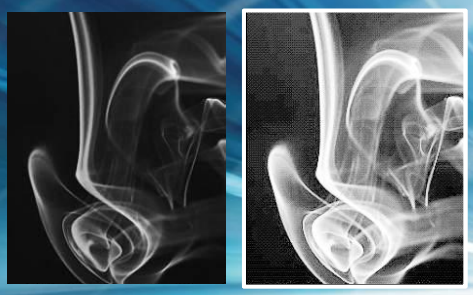

Chapter 4: Point Processing

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4.1 Introduction

- Any image-processing operation transforms the gray values of the pixels.
- Image-processing operations may be divided into three classes based on the information required to perform the transformation.

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4.1 Introduction

From the most complex to the simplest, they are as follows:

- **Transforms**
- **Neighborhood processing**
- **Point operations**

FIGURE 4.1

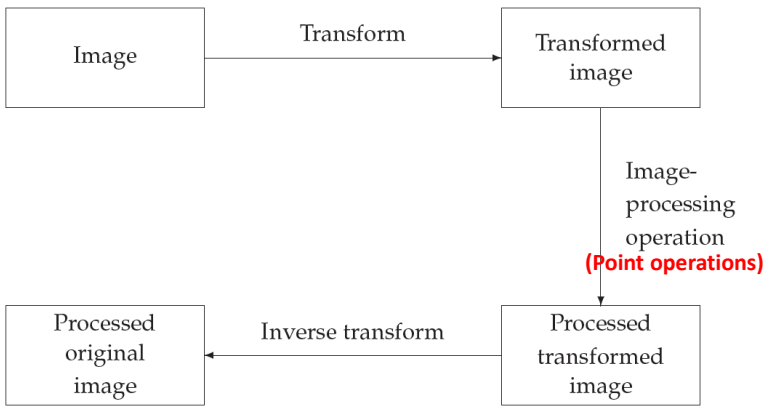


FIGURE 4.1 *Schema for transform processing.*

4.2 Arithmetic Operations

- These operations act by applying a simple function

$$y = f(x)$$

- In each case we may have to adjust the output slightly in order to ensure that the results are integers in the 0 . . . 255 range **(type uint8)**

FIGURE 4.2

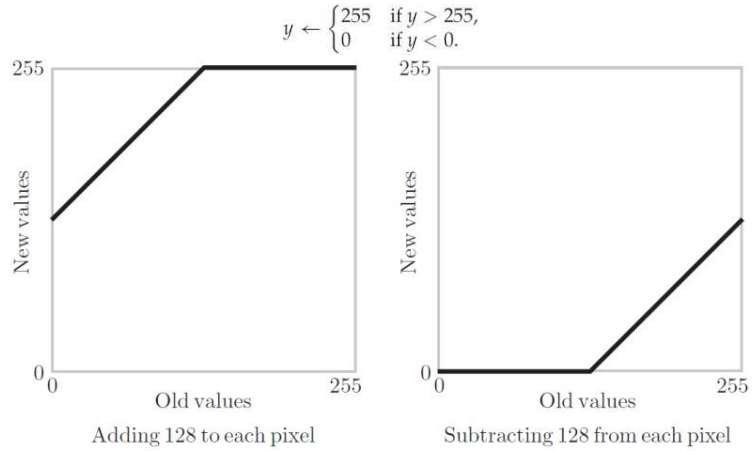


FIGURE 4.2 *Adding and subtracting a constant.*

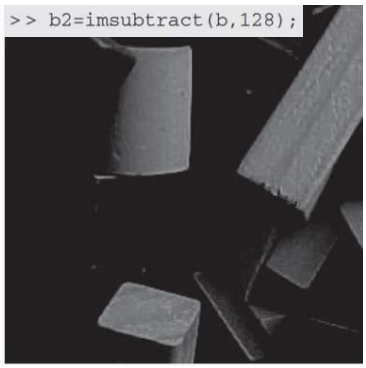
FIGURE 4.3

```
>> b=imread('blocks.tif');
```

```
>> b1=imadd(b,128);
```

(a)

```
>> b2=imsubtract(b,128);
```



(b)

FIGURE 4.3 *Arithmetic operations on an image: adding or subtracting a constant. (a) b1: Adding 128; (b) b2: Subtracting 128.*

FIGURE 4.4

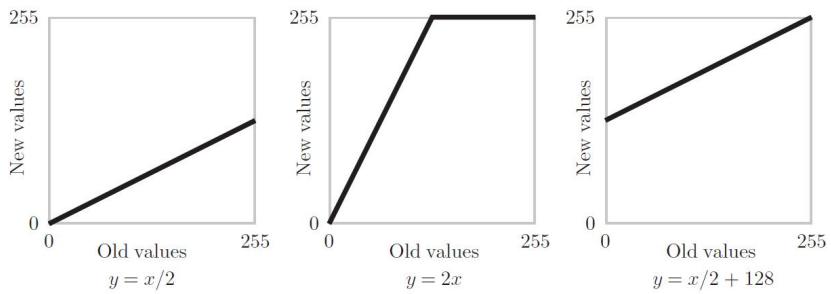


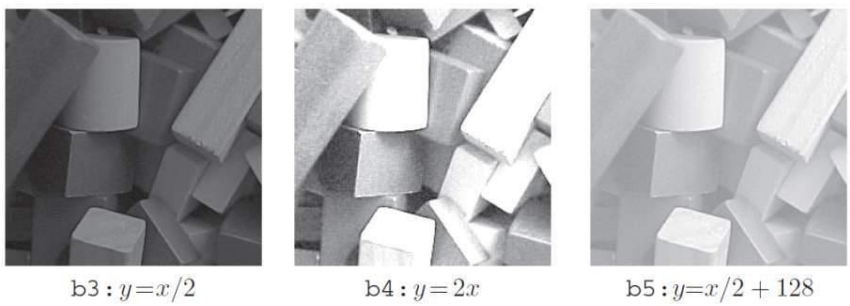
FIGURE 4.4 *Using multiplication and division.*

TABLE 4.1

TABLE 4.1 *Implementing pixel multiplication by MATLAB commands.*

$y = x/2$	`b3=immultiply(b,0.5);` or `b3=imdivide(b,2)`
$y = 2x$	`b4=immultiply(b,2);`
$y = x/2 + 128$	`b5=imadd(immultiply(b,0.5),128);` or `b5=imadd(imdivide(b,2),128);`

FIGURE 4.5



b3 : $y=x/2$ b4 : $y=2x$ b5 : $y=x/2+128$

FIGURE 4.5 *Arithmetic operations on an image: multiplication and division.*

4.2 Arithmetic Operations

COMPLEMENTS

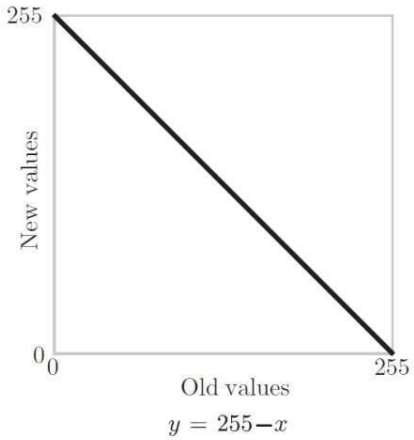
- The **complement** of a grayscale image is its photographic negative
- **type double** (0.0~1.0)

```
1-m
```

- **type uint8** (0~255)

```
255-m
```


FIGURE 4.6




```
>> bc=imcomplement(b);
>> imshow(bc)
```

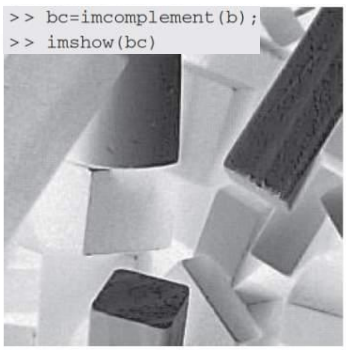


FIGURE 4.6 *Image complementation.*

4.3 Histograms

- A graph indicating the number of times each gray level occurs in the image

```
a = [10 10 10 10 10;
     20 20 20 20 10;
     50 50 50 50 50;
     90 90 90 50 50]
```

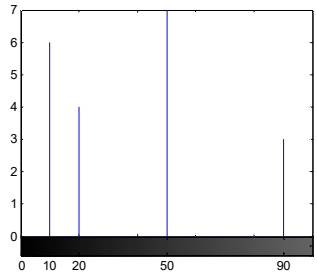


FIGURE 4.8

```
>> p=imread('pout.tif');
>> imshow(p),figure,imhist(p),axis tight
```

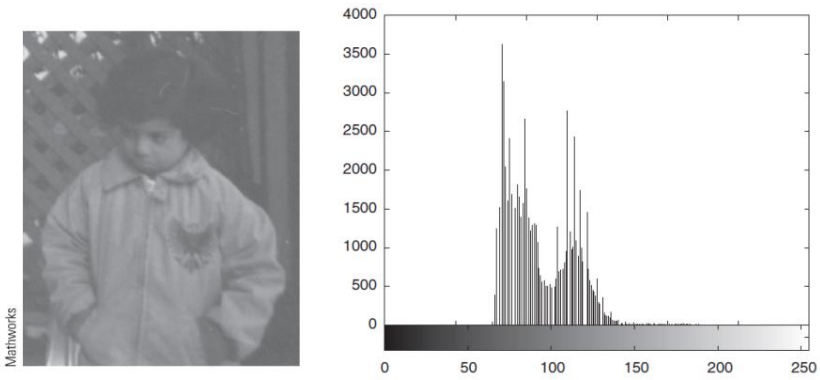


FIGURE 4.8 *The image* `pout.tif` *and its histogram.*

4.3.1 Histogram Stretching

- A table of the numbers n_i of gray values

Gray level i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n_i	15	0	0	0	0	70	110	45	70	35	0	0	0	0	0	15

(with n = 360, as before)

- We can stretch out the gray levels in the center of the range by applying the piecewise linear function

FIGURE 4.9

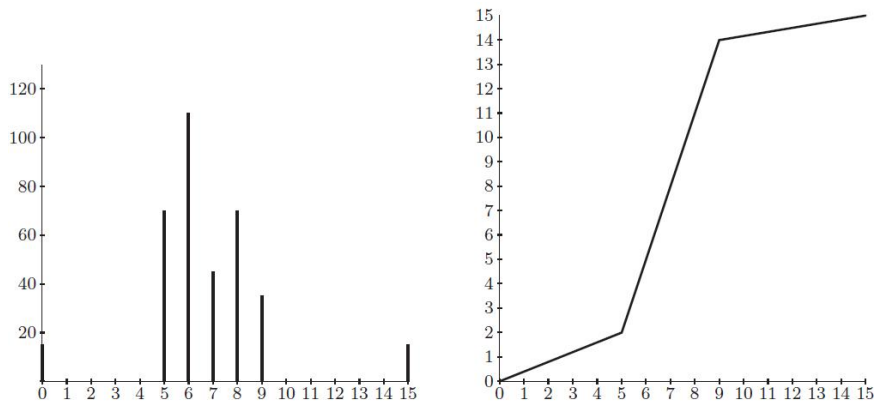


FIGURE 4.9 *A histogram of a poorly contrasted image and a stretching function.*

4.3.1 Histogram Stretching

$$j = \frac{14-2}{9-5}(i-5)+2$$

- where i is the original gray level and j is its result after the transformation

i	5	6	7	8	9
j	2	5	8	11	14

- This function has the effect of stretching the gray levels 5–9 to gray levels 2–14

4.3.1 Histogram Stretching

- the corresponding histogram

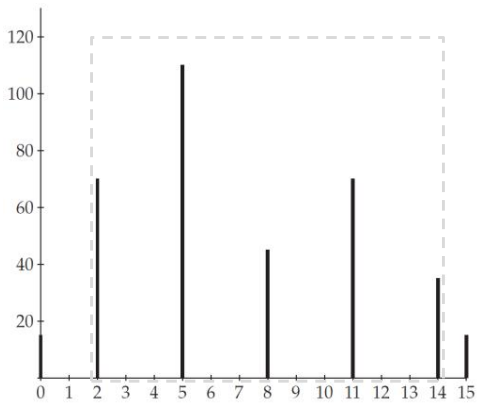


FIGURE 4.10

- **Use of `imadjust`**

```
imadjust(im,[a,b],[c,d])
```

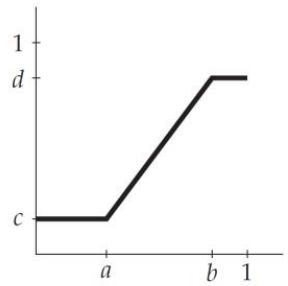


FIGURE 4.10 *The stretching function given by* `imadjust`.

4.3.1 Histogram Stretching

- `imadjust` is designed to work equally well on images of type `double`, `uint8`, or `uint16`
- the values of *a*, b, c, and d must be between 0 and 1
- the function automatically converts the image `im` (if needed) to be of type `double`

4.3.1 Histogram Stretching

- Note that `imadjust` does not work quite in the same way as shown in Figure 4.9
- The `imadjust` function has one other optional parameter: the `gamma` value

$$y = \left(\frac{x-a}{b-a}\right)^{\gamma}(d-c)+c$$

FIGURE 4.11

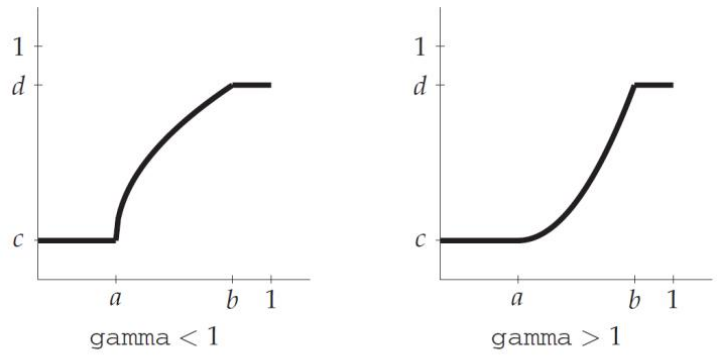


FIGURE 4.11 *The `imadjust` function with `gamma` not equal to 1.*

FIGURE 4.12

```
>> t=imread('tire.tif');
>> th=imadjust(t,[],[],0.5);
>> imshow(t),figure,imshow(th)
```

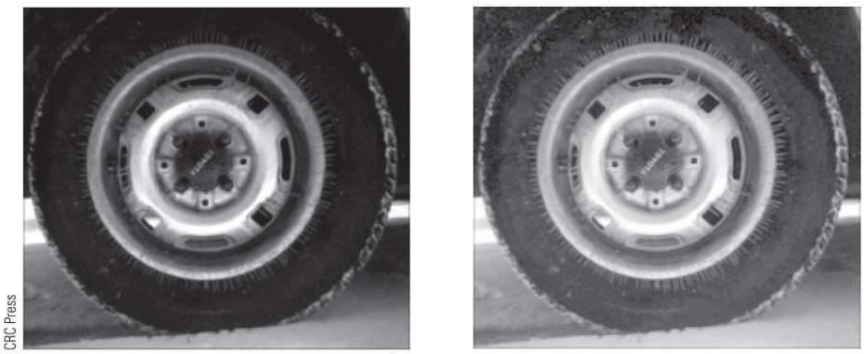


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FIGURE 4.12 *The tire image before and after adjustment with the gamma value.*

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FIGURE 4.13

```
>> plot(t,th,'.'),axis tight
```

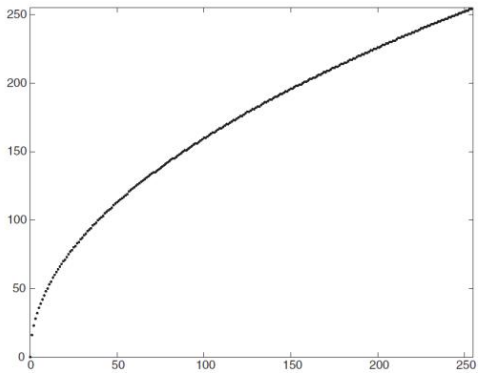

FIGURE 4.13 *The function used in Figure 4.12.*

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4.3.1 Histogram Stretching

- **A PIECE WISE LINEAR-STRETCHING FUNCTION**

$$y = \frac{b_{i+1} - b_i}{a_{i+1} - a_i}(x - a_i) + b_i$$

- The heart of this function will be the lines

```
pix=find(im >= a(i) & im < a(i+1));
out(pix)=(im(pix)-a(i))*(b(i+1)-b(i))/(a(i+1)-a(i))+b(i)
```

where `im` is the input image and `out` is the output image

FIGURE 4.14

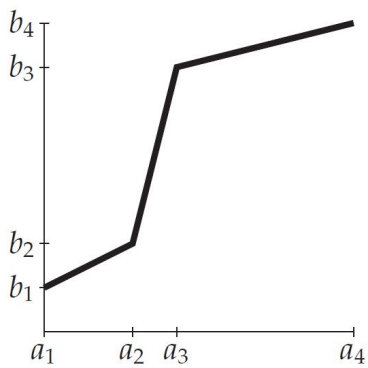

FIGURE 4.14 *A piecewise linear-stretching function.*

FIGURE 4.16

Refer to figure 4.15

```
>> th=histpwl(t,[0 .25 .5 .75 1],[0 .75 .25 .5 1]);
>> imshow(th)
>> figure,plot(t,th,'.'),axis tight
```

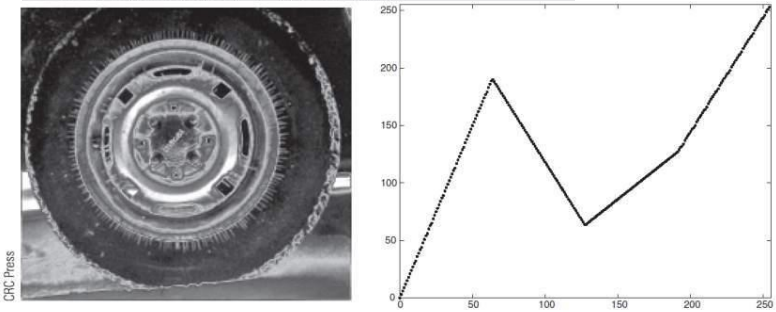

FIGURE 4.16 *The tire image after piecewise linear-stretching and piecewise linear-stretching function.*

4.3.2 Histogram Equalization

- An entirely automatic procedure
- Suppose our image has L different gray levels, 0, 1, 2, . . . , L − 1, and gray level i occurs n_i times in the image

$$\left(\frac{n_0 + n_1 + \cdots + n_i}{n}\right)(L-1)$$

Where $n = n_0 + n_1 + n_2 + \cdots + n_{L-1}$

4.3.2 Histogram Equalization

- **EXAMPLE** Suppose a 4-bit grayscale image has the histogram shown in Figure 4.17, associated with a table of the numbers n_i of gray values

Gray level i	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
n_i	15	0	0	0	0	0	0	0	0	70	110	45	80	40	0	0

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FIGURE 4.17

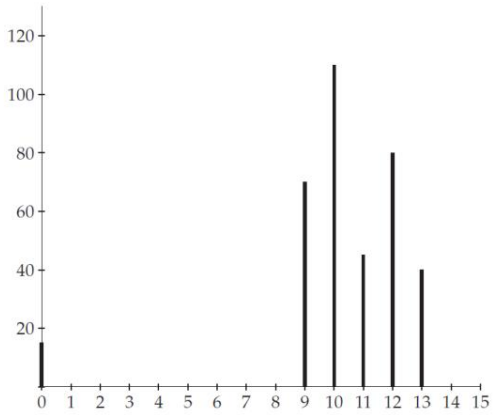

FIGURE 4.17 *Another histogram indicating poor contrast.*

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4.3.2 Histogram Equalization

$(L\text{-}1)/n$

Gray level i	n_i	Σn_i	$(1/24)\Sigma n_i$	Rounded value
0	15	15	0.63	1
1	0	15	0.63	1
2	0	15	0.63	1
3	0	15	0.63	1
4	0	15	0.63	1
5	0	15	0.63	1
6	0	15	0.63	1
7	0	15	0.63	1
8	0	15	0.63	1
9	70	85	3.65	4
10	110	195	8.13	8
11	45	240	10	10
12	80	320	13.33	13
13	40	360	15	15
14	0	360	15	15
15	0	360	15	15

FIGURE 4.18

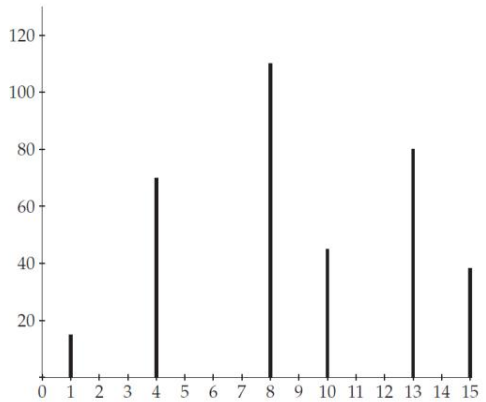

FIGURE 4.18 *The histogram of Figure 4.17 after equalization.*

FIGURE 4.19

```
>> p=imread('pout.tif');
>> ph=histeq(p);
>> imshow(ph),figure,imhist(ph),axis tight
```

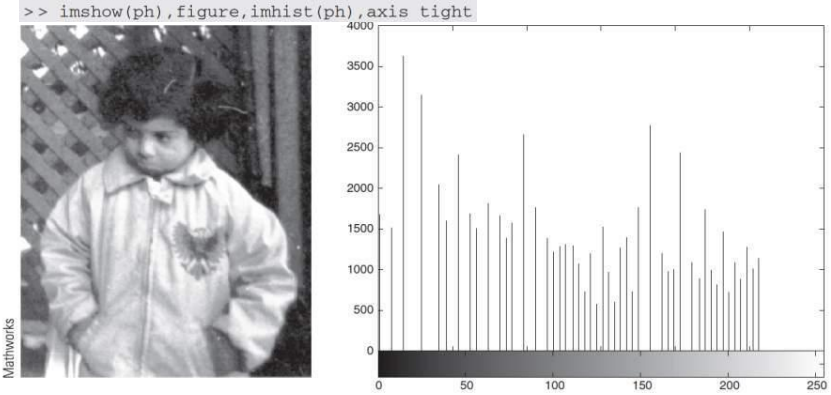

FIGURE 4.19 *The histogram of Figure 4.8 after equalization.*

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FIGURE 4.20

```
>> en=imread('engineer.tif');
>> e=imdivide(en,4);
>> imshow(e),figure,imhist(e),axis tight
```

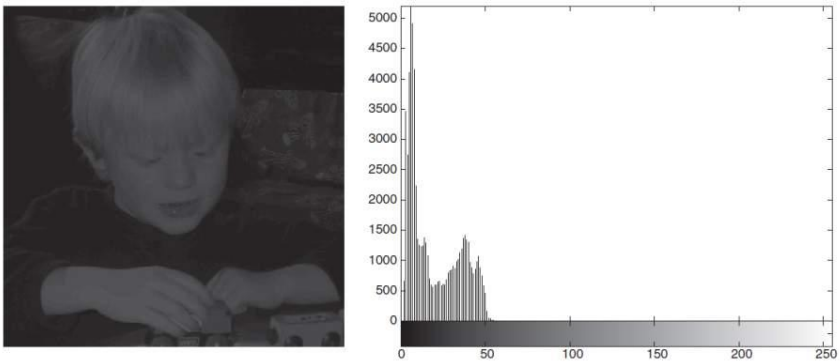

FIGURE 4.20 *The darkened version of* `engineer.tif` *and its histogram.*

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FIGURE 4.21

```
>> eh=histeq(e);
>> imshow(eh),figure,imhist(eh),axis tight
```

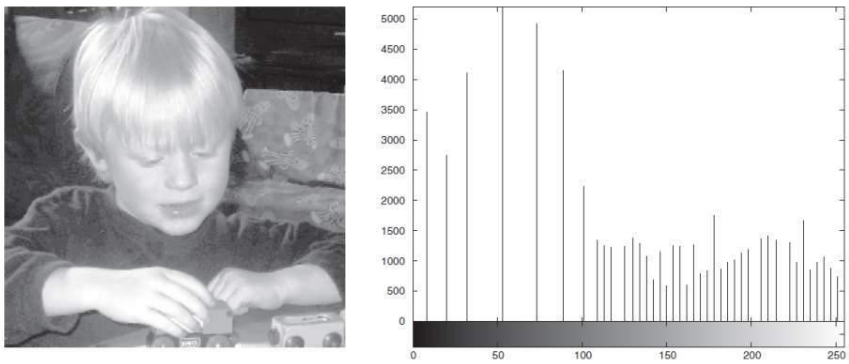

FIGURE 4.21 *The image from Figure 4.20 equalized and its histogram.*

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4.3.2 Histogram Equalization

- **WHY IT WORKS** If we were to treat the image as a continuous function $f(x, y)$ and the histogram as the area between different contours, then we can treat the histogram as a probability density function.

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FIGURE 4.22

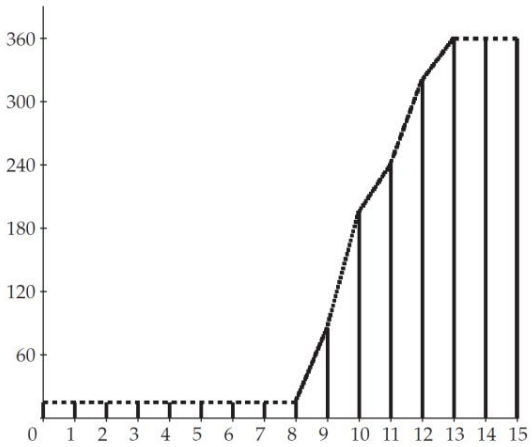


FIGURE 4.22 *The cumulative histogram.*

4.4 Lookup Tables

- Point operations can be performed very effectively by using a **lookup table**, known more simply as an **LUT**
- e.g., the LUT corresponding to division by 2 looks like

Index:	0	1	2	3	4	5	. . .	250	251	252	253	254	255
LUT:	0	0	1	1	2	2	. . .	125	125	126	126	127	127

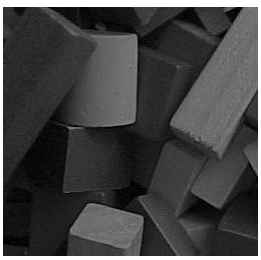
4.4 Lookup Tables

- If `T` is a lookup table in MATLAB and `im` is our image, the lookup table can be applied by the simple command

```
T(im+1)
```

- e.g.,

```
>> T=uint8(floor([0:255]/2));
>> b = b+1;
>> b2 = T(b+1);
```



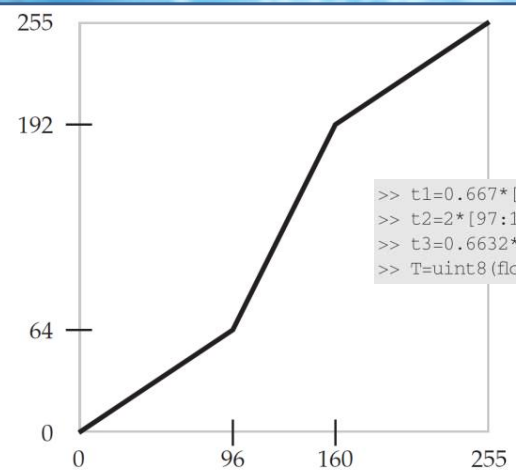
4.4 Lookup Tables

- As another example, suppose we wish to apply an LUT to implement the contrast-stretching function

$$y = \frac{64}{96}x,$$
$$y = \frac{192-64}{160-96}(x-96)+64,$$
$$y = \frac{255-192}{255-160}(x-160)+192$$

$$y = 0.6667x,$$
$$y = 2x - 128,$$
$$y = 0.6632x + 85.8947$$

FIGURE 4.23




```
>> t1=0.667*[0:96];
>> t2=2*[97:160]-128;
>> t3=0.6632*[161:255]+85.8947;
>> T=uint8(floor([t1 t2 t3]));
```

FIGURE 4.23 *A piecewise linear contrast-stretching function.*

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