Computer Graphics and Image Processing Introduction

Part 3 – Image Processing

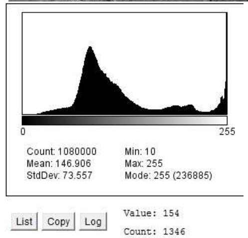
Lecture 2 Image histogram and applications

Image Histograms

In an image processing context, the histogram of an image refers to the distribution (count, probabilities, cumulative count) of the pixel intensity values.

The histogram shows the number of pixels in an image at each different intensity value found in that image

For an 8 bit image, each pixel has an intensity value between 0 and 255.



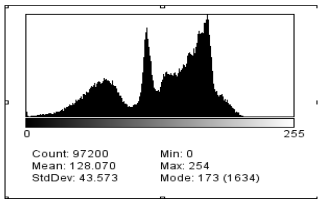
Assume you have a greyscale image containing N pixels (m rows by n columns e.g. m*n=N)

- Each pixel has an intensity value *k* where *k* is an integer from 0 to 255.

The histogram for that image records the number of pixels that equal each value of *k*. To compute the histogram:

- The image is scanned in a single pass
- A running count of the number of pixels found at each intensity value is kept.
- These values are graphed to construct a suitable histogram

Images and histograms (examples)



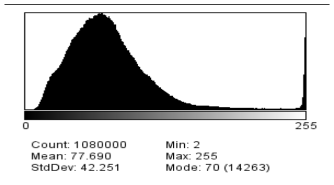
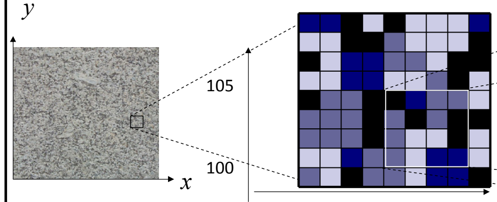


Image Histogram-example



0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

Let's look at a very reduced image size for simplicity sake

Image Histogram-example

0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

Is an image uniquely defined by its histogram ?

0	0	25	30
30	50	75	75
75	105	150	150
150	175	175	205

Image Cumulative Histogram

An Image cumulative histogram is a mapping that counts the cumulative number of pixel intensity values in all of the bins up to the current bin.

The cumulative histogram *Mi* of a histogram *mj* is given by:

$$M_i = \sum_{j=1}^{i} m_j$$

The cumulative histogram is useful for some image correction operations that use histograms as input e.g. Image histogram equalisation.

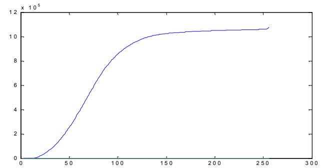
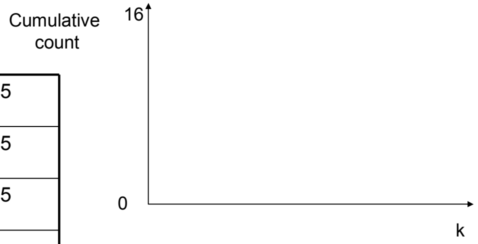


Image Cumulative Histogram example

0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0



Uses of Histograms

An image histogram is a useful tool for assessing the brightness and contrast of an image.

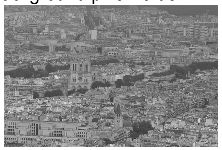
The histogram for the accompanying dark image shows the majority of intensity values distributed to the left.

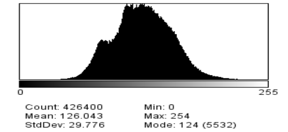
The histogram for the accompanying light image shows the majority of intensity values distributed to the right.

Image contrast

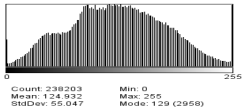
The **Contrast** of an image I is the difference in visual properties that makes the representation of an object in an image distinguishable (i.e. darker or brighter) from other objects and the background.

- Look at brightness and colour of objects
- One possible way to compute contrast: $\frac{I_{\mathrm{max}} - I_{\mathrm{min}}}{I_{\mathrm{max}} + I_{\mathrm{min}}}$, $\frac{I - I_{\mathrm{b}}}{I_{\mathrm{b}}}$, with b background pixel value





Higher contrast



Linear mapping (brightness)

- Brightness: the brightness of a greyscale image f can be adjusted by adding a constant bias b to the image pixel values. The new image (g) pixel values are give by:

$$g(x, y) = f(x, y) + b$$

b>0 →

- If b > 0, brightness is increased
- If b < 0, it is decreased

Linear mapping (contrast)

- Contrast: the contrast of a greyscale image f can be adjusted by applying a constant gain a and bias b to the original image. The new image g pixel values are given by:

$$g(x,y)=af(x,y)+b$$

a>1 →

a<1 →

Contrast adjustment

Contrast adjustment (also called normalisation) increases the dynamic range of intensities in low-contrast images.

Images may have low contrast because:

- They were taken in poor illumination conditions
- The image sensor dynamics were poor.
- The lens aperture was incorrectly set.

Contrast adjustment attempts to improve the contrast in an image by ‘stretching’ the values it contains to span a larger range of values; typically the full range of pixel values that the image type allows typically 0 to 255 in an 8 bit greyscale image.

Contrast and Stretching

If we denote the **new** upper and lower limits of the image pixel values as g_{max} and g_{min}, then each pixel value ***of the original image f*** is scaled to a new value g_{out} using the following function:

$$g_{out} = (f - c)\left(\frac{g_{max} - g_{min}}{d - c}\right) + g_{min}$$

c and *d* are the lowest and highest pixel values considered for stretching in the image respectively. They are not necessarily the minimum and maximum pixel values

Computed values below 0 are set to 0, and values above 255 are set to 255.

Simply selecting *c* and *d* as the **new** maximum and minimum values in the image can cause unrepresentative scaling due to the presence of outliers.

A more robust approach is to use the 5th and 95th percentiles of the image histogram.

Contrast Stretching example

Stretch image values to 0-255 using the input image min and max pixel values as stretching boundaries

0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

$$g_{out} = (f - c)\left(\frac{g_{max} - g_{min}}{d - c}\right) + g_{min}$$

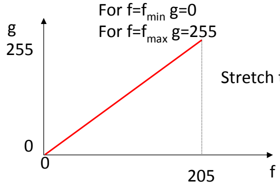
Image histogram and linear mapping

0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

0	62	93	93
218	37	130	93
187	255	37	31
187	187	218	0

Histogram

For $f=f_{min}$ g=0
For $f=f_{max}$ g=255



Stretch to 0-255

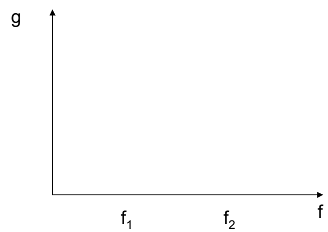
Stretch mapping

Linear mapping (gain and bias)

Find the mapping equation to transform image f into image g using f1 and f2 as initial image stretching boundaries and g1 and g2 as the maxima for the new image g

$$a = \left(\frac{g_2 - g_1}{f_2 - f_1}\right)$$

$$b = g_1 + -f_1\left(\frac{g_2 - g_1}{f_2 - f_1}\right)$$



Linear Mapping example

Compute the pixel values of image g transformed from input image f by a linear mapping of gain a and bias b

f

0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

g

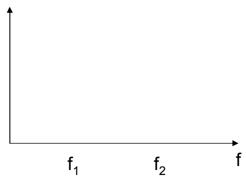


Image histogram and linear mapping

f

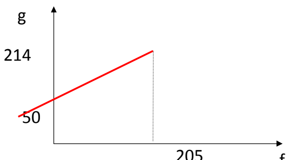
0	50	75	75
175	30	105	75
150	205	30	25
150	150	175	0

g

50	90	110	110
190	74	134	110
170	214	74	70
170	170	190	50

g=0.8f+50
a=0.8, b=50
a,b mapping

f=0 g=50
f=205 g=214



Histogram Equalisation

Histogram equalisation redistributes pixel intensity values in an attempt to flatten (evenly distribute) the Image histogram, thus increasing the dynamic range and as a result increasing the image contrast.

The method is useful in images with backgrounds and foregrounds that are both bright or both dark.

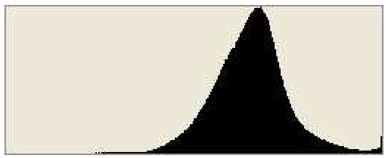
It tends to reveal details that would be otherwise hidden.

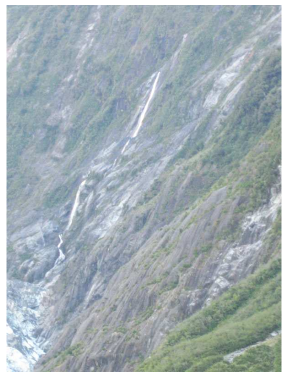
It often produces unrealistic effects in photographs, but is very useful in scientific images such as x-ray, satellite or thermal images.

Histogram equalisation differs from Contrast stretching in that it uses non-linear transfer functions to map between pixel intensity values in the input and output images.

Histogram Equalisation

An example of an image with poor contrast is shown on the left.
The histogram confirms what we can see by visual inspection: this image has poor dynamic range.





Histogram Equalisation

The same image after equalisation is shown to the left.
Now the Image histogram shows a much more even distribution of values.
What will the cumulative histogram for this image look like?