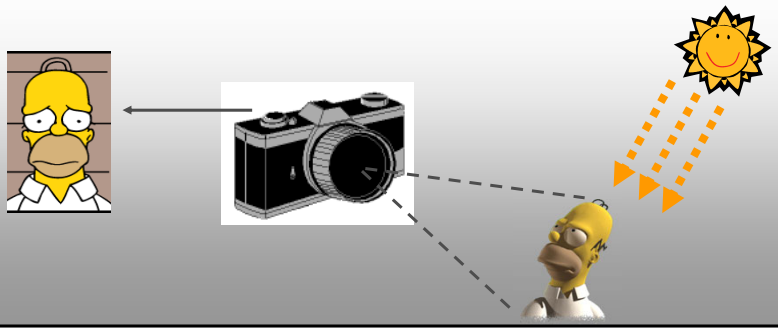
1

What is an image?

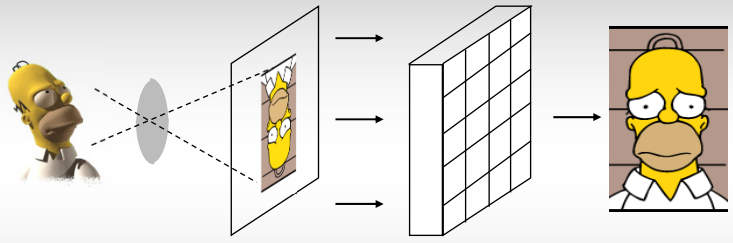
Projection of a 3D scene onto a ***2D plane***

f(x,y) = light intensity at position ***(x,y)*** in this plane

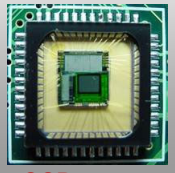


2

What is an image?



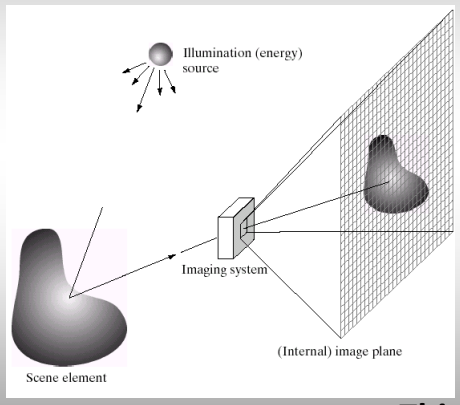
World | Camera | Digitiser | Digital Image

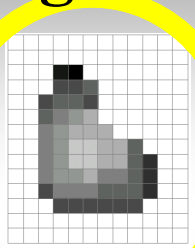


CCD sensor

3

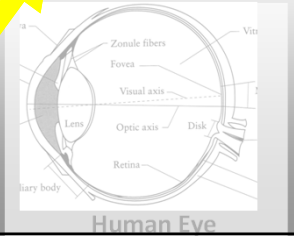
What is an image?





Digital image

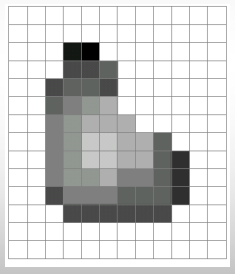
This is our focus



4

What is an image?

A grid (matrix) of pixel intensity values



=

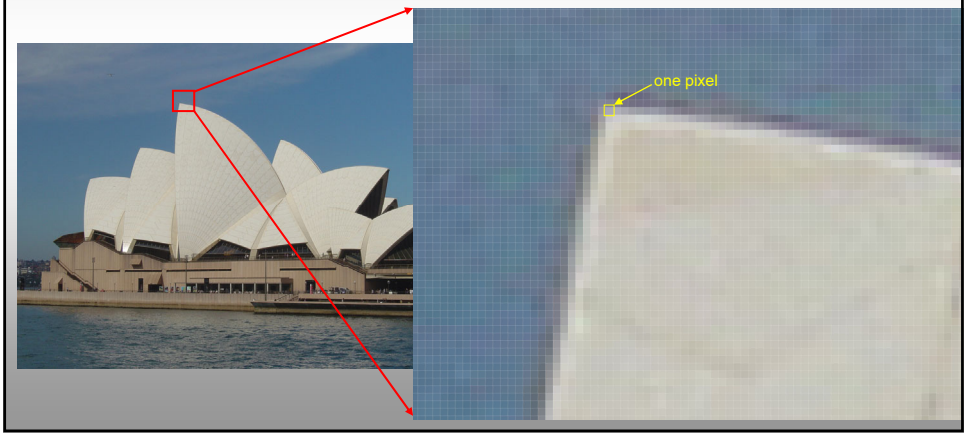
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	15	0	255	255	255	255	255	255	255
255	255	255	75	75	75	255	255	255	255	255	255
255	255	75	95	95	75	255	255	255	255	255	255
255	255	96	127	145	175	255	255	255	255	255	255
255	255	127	145	175	175	175	255	255	255	255	255
255	255	127	145	200	200	175	175	95	255	255	255
255	255	127	145	200	200	175	175	95	47	255	255
255	255	127	145	145	175	127	127	95	47	255	255
255	255	74	127	127	127	95	95	95	47	255	255
255	255	255	74	74	74	74	74	74	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255

(Gray-scale images – 1 byte/pixel: 0 = **black**, 255 = **white**)

5

What is an image?

Remember **digitising** implies the image is only an *approximation* of a real scene



6

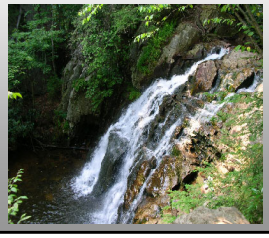
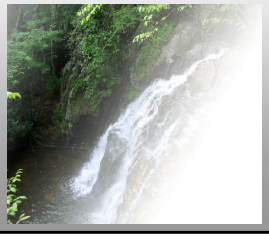
What is an image?

Common image formats:

1 sample (8 bits per pixel) – grayscale

3 samples (24 bits per pixel) – **RGB**

4 samples (32 bits per pixel) – **RGB** and alpha channel (opacity)

7

Image Processing Operations

Neighbourhood: use data from adjacent pixels to modify a pixel value

Global: use statistics on the whole image to process pixel values

Point: each pixel is processed independently of all others

Geometric: pixels are modified according to the structural content

Temporal: individual frames of a sequence are considered i.e., inter-frame (MPEG)

8

Image Processing Operations

Neighbourhood: use data from adjacent pixels to modify a pixel value

Global: use statistics on the whole image to process pixel values

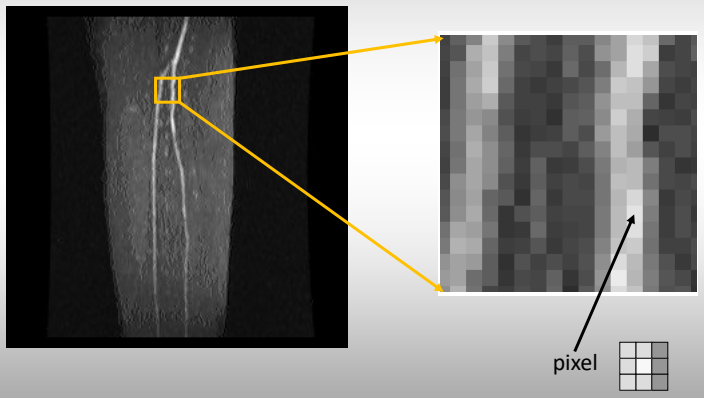
Point: each pixel is processed independently of all others

Geometric: pixels are modified according to the structural content

Temporal: individual frames of a sequence are considered i.e., inter-frame (MPEG)

9

Neighborhood Relationships



10

Important because…

Provides context for individual pixels

Neighbourhood relations determine image features

Typical neighbourhood operations:

- Noise reduction
- Filtering
- Edge detection & enhancement

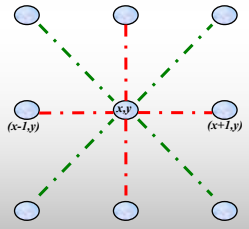
11

Neighborhood Operations

12

Neighborhood Relationships

For a centre pixel *p* at *(x,y)* its neighbours are:



***p* has 4 horizontal and vertical neighbours – denoted as $N_4(p)$**

&

As above, with 4 diagonal neighbours – denoted as $N_8(p)$

Every pixel is **1 unit** distance from *(x,y)*

Some may be outside image if *(x,y)* is on a border

13

Pixel Connectivity

Establishes the boundary of objects and regions

Group together in the same region by assuming pixels having same intensity (colour)

Segmentation – all pixels belonging to an object have an intensity value > some threshold

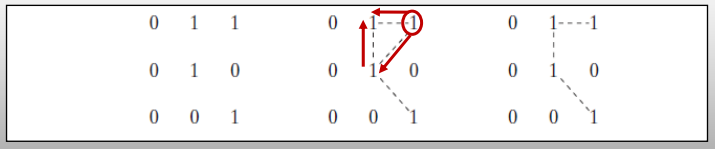
Idea is to determine if two pixels are adjacent

14

Pixel Connectivity

Three types of connectivity: ***4***, ***8*** and ***mixed (m-connectivity)***

m-connectivity is a variation of 8-connectivity that avoids multi-paths

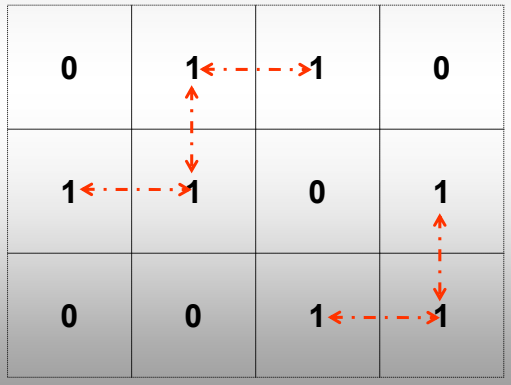


8-connectivity
Two paths between pixels

m-connectivity
Only a single path between pixels

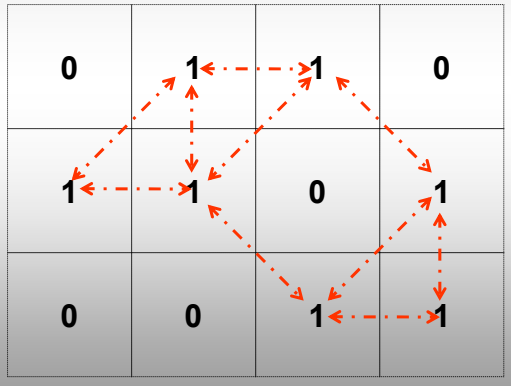
15

4–connectivity Example



16

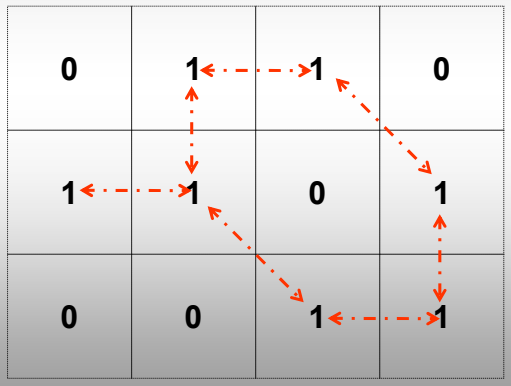
8–connectivity Example



Note a number of ambiguities

17

m–connectivity Example



18

Global Measures

Reflect pixel distribution information

Basis of image compression methods i.e., JPEG

Low probability of a pixel value = fewer bits (often zero) being assigned

Higher probability of a value = more bits

Measures include ***mean*** and ***variance*** – based on ***image statistics***

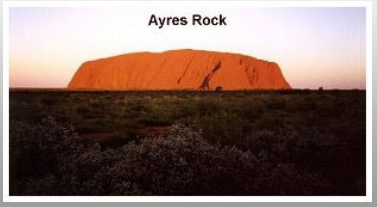
19

Image Statistics – Mean

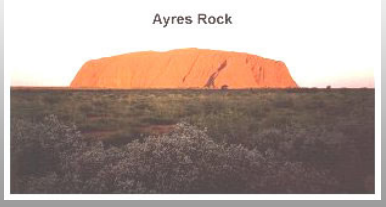
Measure of image brightness

$$\bar{x} = \frac{1}{N} \sum_{k=0}^{N-1} p_k$$

where N is the total number of pixels p



$\bar{x} = 115$



$\bar{x} = 163$

20

Image Statistics – Variance

Reflects how much pixel values vary from the mean

Standard deviation σ or ***variance*** σ^2 used:

$$\sigma^2 = \frac{1}{N}\sum_{k=0}^{N-1} p_k^2 - \bar{x}^2$$

Larger σ^2 means greater contrast (variance) – but can mean higher noise

21

Image Statistics – Variance

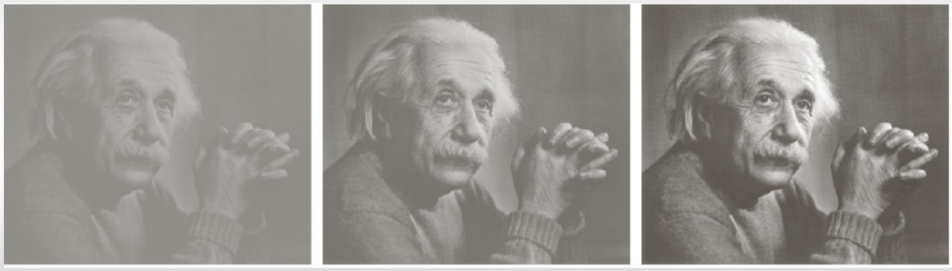
Contrast is the pixel value variation across the image i.e., σ

σ=57

σ=9

22

Image Statistics – Variance



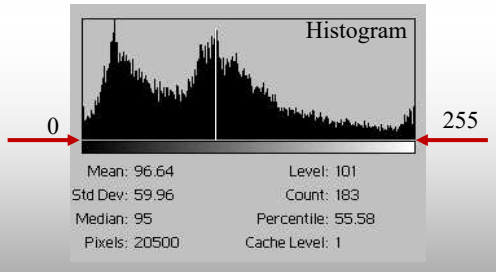
$\sigma = 14.3$ $\sigma = 31.6$ $\sigma = 49.2$

23

Histograms

Graphical representation of the number of occurrences (frequency) of each pixel value

8-bit gray level image

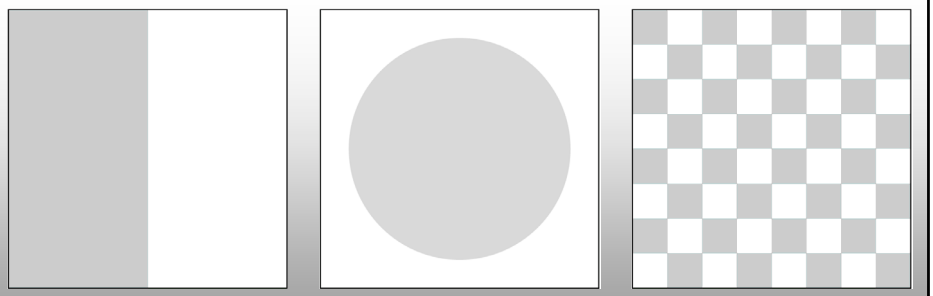


x-axis = gray-scale range [0, 255]
y-axis = corresponding number of pixels at each value

24

Histograms

Do not encode **spatial** information on *where* each pixel is located

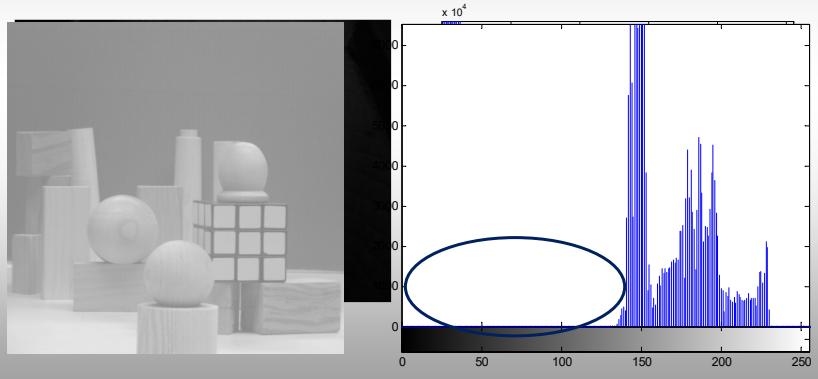


Same histogram

25

Why use Histograms?

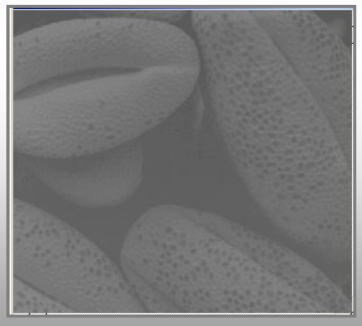
An under-exposed image and its histogram

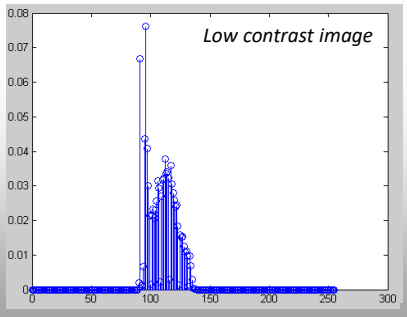


26

Histograms

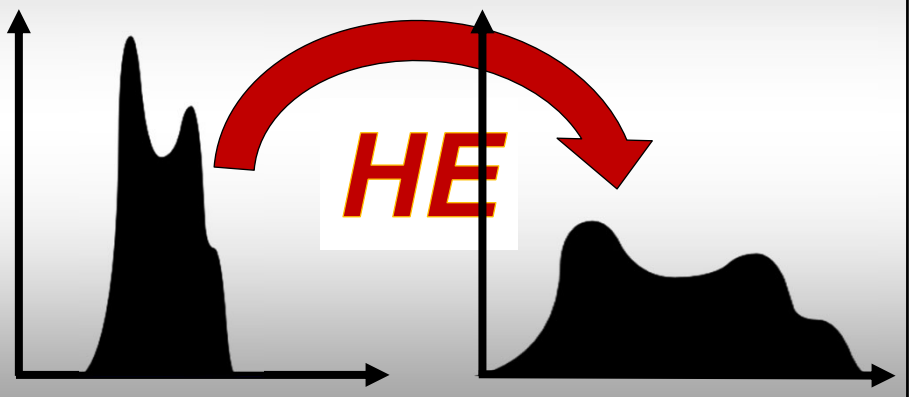
Histogram shape provides useful information for contrast enhancement





27

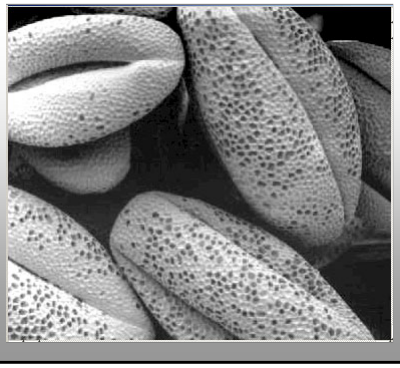
Histogram Equalisation

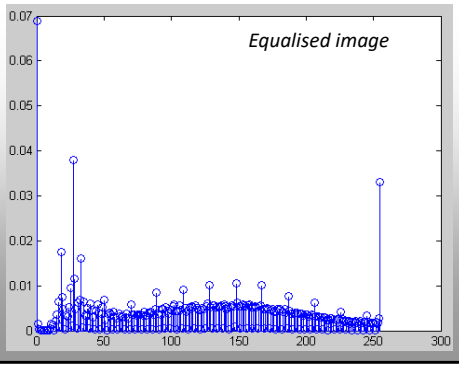


28

Histogram Equalisation

Aim: maximise contrast by redistributing (equalise) pixel values so as to approximate a uniform (flat) histogram



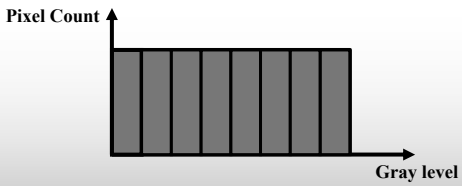


29

Histogram Equalisation

It is *trial & error* to determine if image benefits

Flat histogram not always desirable as human visual system is non-linear

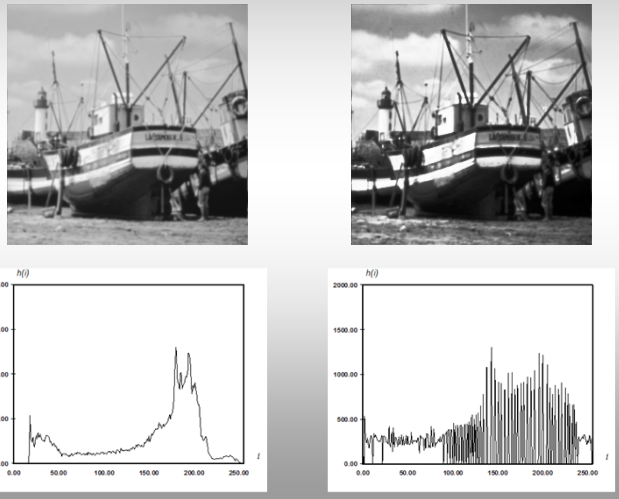


HE can be applied to just part of an image

Even if histogram is uneven, HE is still a powerful image enhancement technique

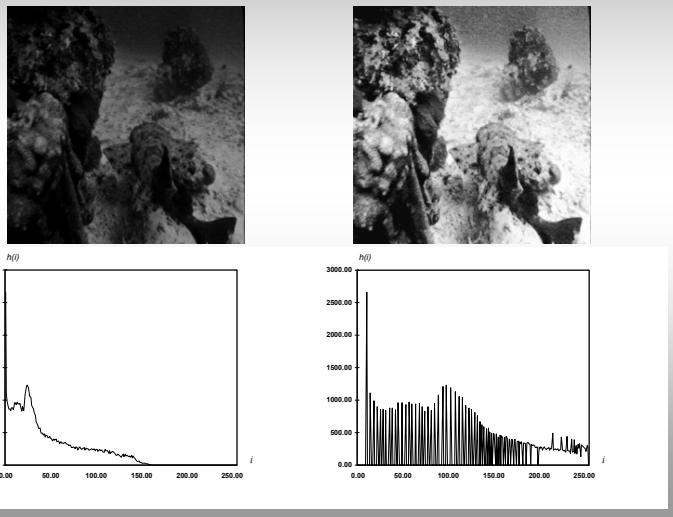
30

Histogram Equalisation



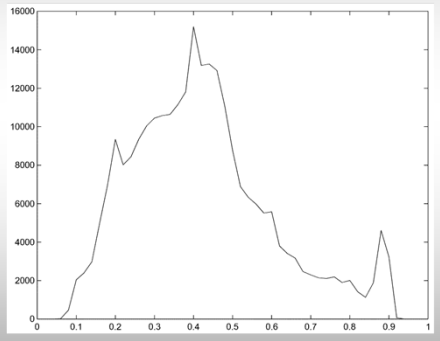
31

Histogram Equalisation



32

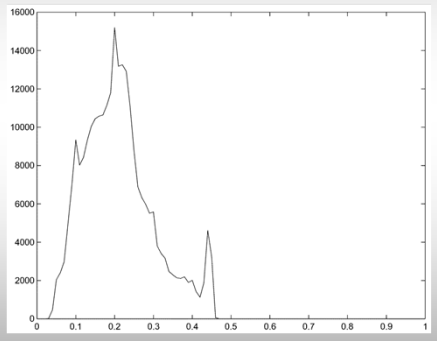
HE Example



Original

33

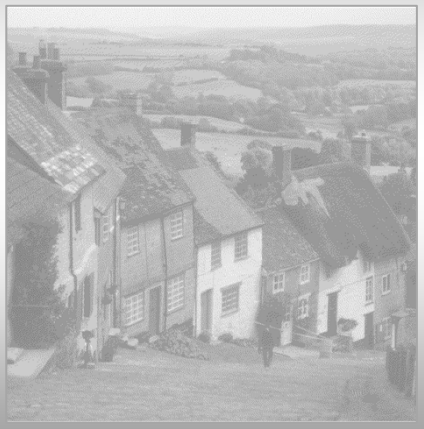
HE Example

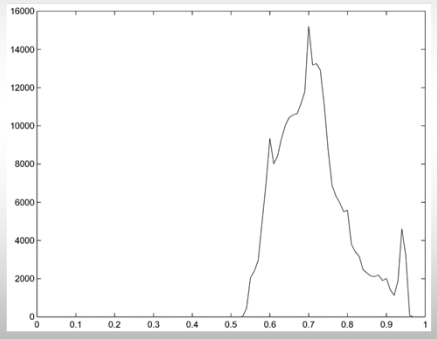


Poor Contrast

34

HE Example

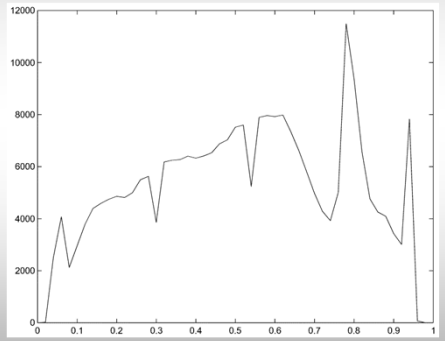




Poor Contrast

35

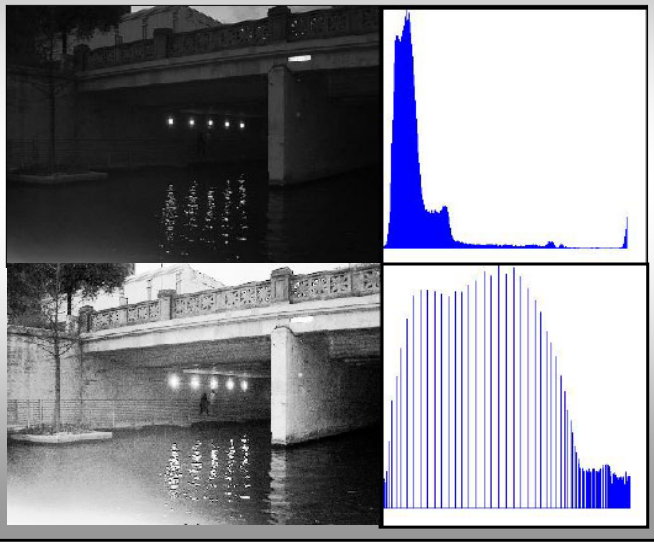
HE Example



Enhanced Contrast

36

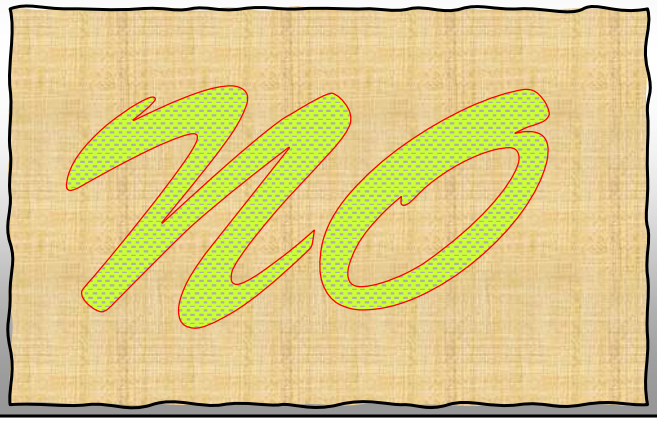
HE Example



37

Question

Is HE always effective for images?

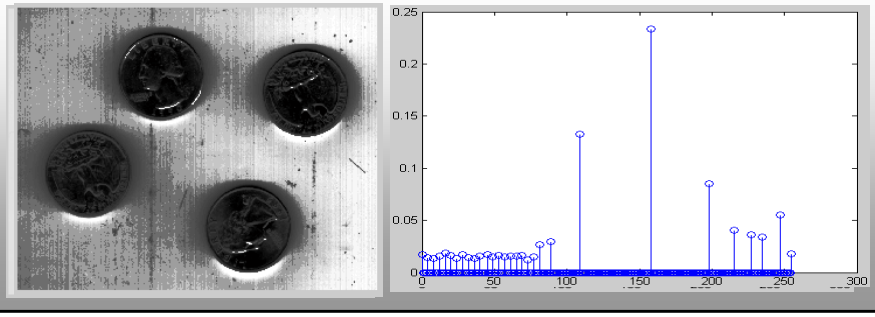


38

HE Warning

In very narrow histograms – HE may not produce a good image

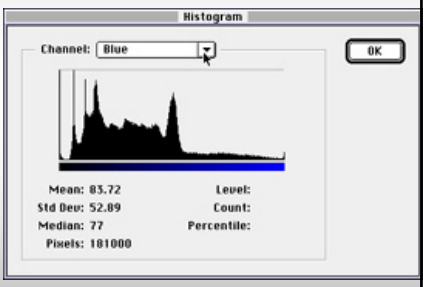
Can produce false edges/regions and *graininess*



39

Colour Image Histograms

Separate histograms for **R**, **G** and **B**



Usually a 3D histogram is created with **R**, **G** & **B** axes

40