Images and Video

Audiovisual Processing CMP-6026A

Dr. David Greenwood

david.greenwood@uea.ac.uk

SCI 2.16a University of East Anglia

October 29, 2021

Content

Images

Arguably the most important scientific instrument to date, practical photography with a camera arrived in 1839.

Simultaneously claimed by Louis Daguerre and William Henry Fox Talbot, and preceded by far less useful solutions.

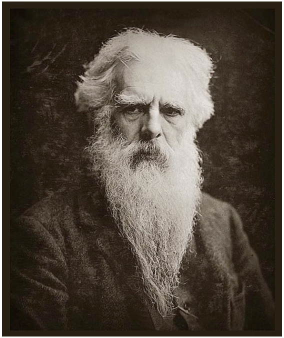

Figure 1: Eadweard Muybridge

Eadweard Muybridge 1830-1904

Proved a galloping horse lifts all four hooves off the ground at one point in its sequence of motion.

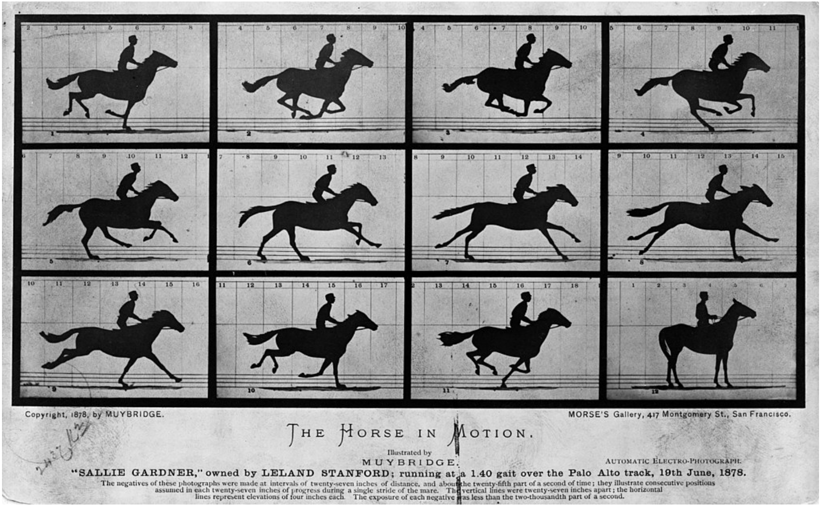

Figure 2: Sallie Gardner - public domain image

Perhaps the earliest movie?

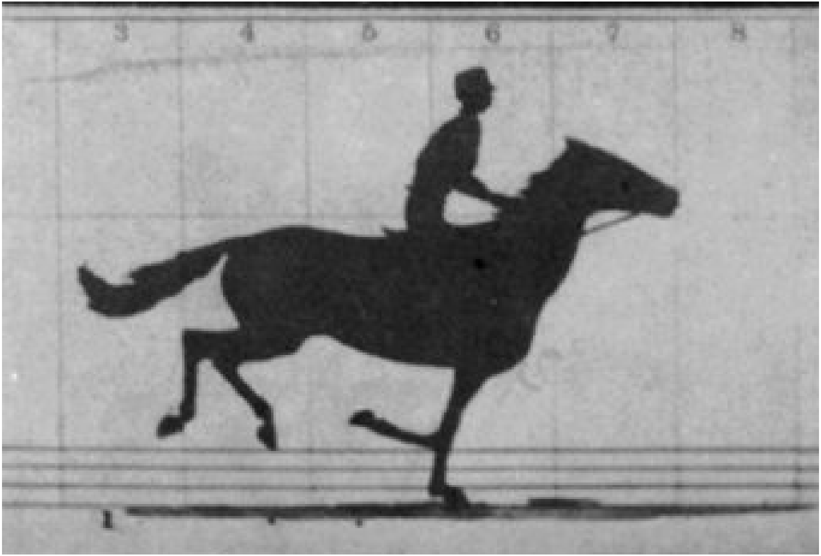

Figure 3: horse animation

Efficiently describe complex information. . .

Figure 4: Times Square - CC BY-NC-SA

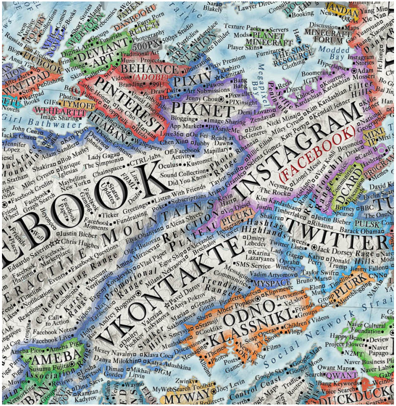

Figure 5: Map of the Internet - Halcyon Maps

Map of the Internet

Image data can contain data other than photographs.

A map of the Internet in 2021

Processing Images

Figure 6: image enhancement and restoration

Processing Images

Figure 7: image compression for transmission and storage

Processing Images

Figure 8: forgery detection

Processing Images

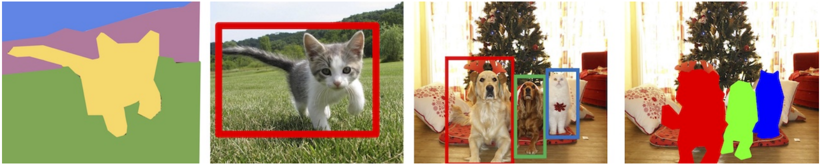

Figure 9: image understanding, classification and recognition

Processing Images

- Image enhancement or restoration
- Transmission or storage
- Evidence
- Image understanding or recognition

Digital Images

How do we represent images on a computer?

Greyscale Images

Figure 10: Cameraman - MIT

- 2D *matrix* of intensity values
- Each value is a single *pixel*
- 0 to 255 for 8 bit images
- 0 is black, 255 is white

Greyscale Images

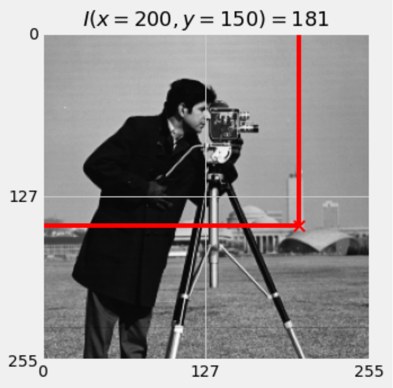

Figure 11: coordinates and intensity

- Can be defined as a function $I(x, y)$
- x, y are the *coordinates* of the pixel
- $I(x, y)$ is the *intensity* of the pixel

Caveat

- Data coordinates have the origin at the *lower* left.
- The origin is at the *top* left corner for images.
- Indexing 2D matrices is row, column order.

Colour Images

Figure 12: Astronaut Eileen Collins - NASA

- 3D *matrix* of intensity values
- Height x Width x Channels
- Each triple value is a single pixel
- (0, 0, 0) is black
- (255, 255, 255) is white

Colour Images

Colour images can be defined as a *set* of functions:

- $R(x, y)$ for red
- $G(x, y)$ for green
- $B(x, y)$ for blue

Colour Images

Figure 13: RGB colour image

Colour Images

- Can also allow a definition of transparency.
- Often referred to as *alpha*.
- Still a 3D matrix, but with 4 channels.

Sampling and Quantisation

In order to become suitable for digital processing, an image function $f(x, y)$ must be digitized both spatially and in amplitude.

Sampling

To digitise an image we discretise it by sampling spatially on a regular grid.

Sampling

The number of samples determines the **resolution** of the image.

Sampling

A **pixel** (picture element) at (x, y) is the image intensity at the grid point indexed by the integer coordinate (x, y).

Sampling

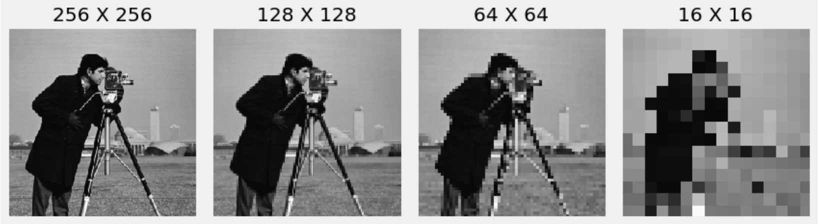

Figure 14: Sampling

We can sample the image at various resolutions.

Sampling

Figure 15: bicubic interpolation

NOTE: Here we use bi-cubic interpolation to display the images.

Sampling

You have already encountered sampling in the context of audio.

In audio the real signal is in the *time* domain.

For images, the real signal is in the *spatial* domain.

Quantisation

Definition
Transform a real-valued sampled image to one that takes a finite number of distinct values.

Quantisation

A pixel is usually represented by 8 bits, representing 256-levels.

- In grayscale 0-255 represent black to white.
- More or fewer bits can be used for a larger or greater range of values.

Quantisation

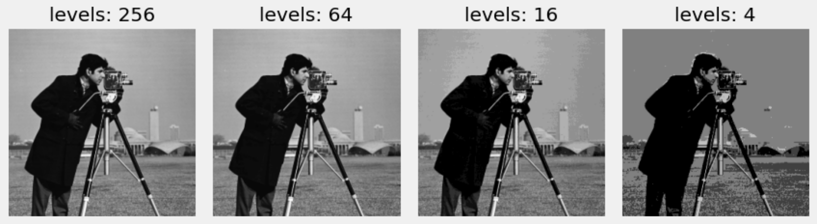

Figure 16: Quantisation

Image Capture

Digital Photography

The Camera

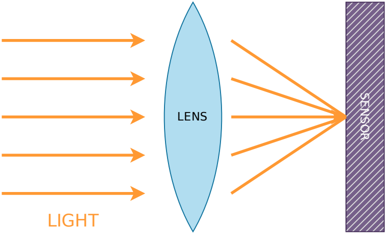

Figure 17: The Camera

- The **shutter** opens briefly.
- Light enters via the **aperture**.
- The **lens** focuses the rays.
- An image is formed on the **sensor**.

The Camera

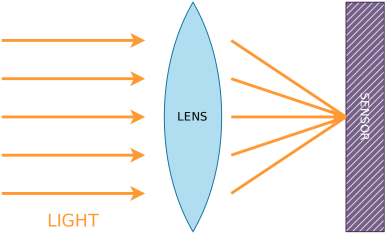

Figure 18: The Camera

- The sensor comprises millions of **photo-sites**.
- The photo-sites collect photons.
- Sites only measure **brightness**.
- How do we determine color?

Bayer Filters

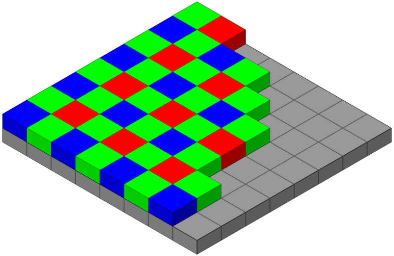

Figure 19: Bayer Filter

- Assign each photo-site a filter.
- Red filter *allows* red light.
- Red filter *blocks* blue-green.
- We can separate the intensities of red, blue and green.

Bayer Filters

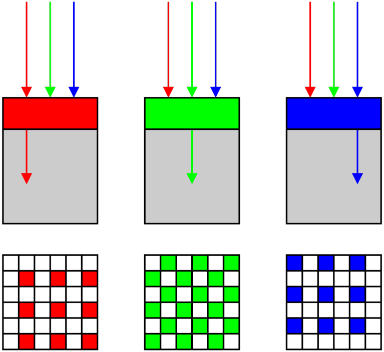

Figure 20: Bayer Filter

- Filtering results in missing values.
- Missing values must be *interpolated*.
- Manufacturers have their own algorithms.
- Simplest method is linear interpolation.

Bayer Interpolation

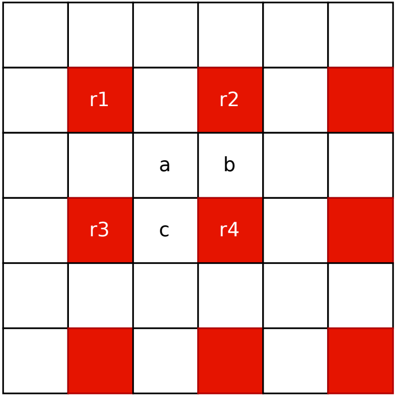

Figure 21: linear interpolation

- $a = (r_1 + r_2 + r_3 + r_4)/4$
- $b = (r_2 + r_4)/2$
- $a = (r_3 + r_4)/2$

Bayer Interpolation

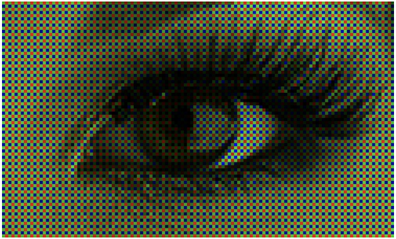

Figure 22: Bayer pattern

Figure 23: after interpolation

Colour Perception

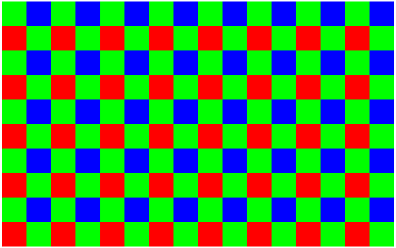

Figure 24: bayer pattern

- Twice as many green pixels.
- Less noise than uniform distribution.
- Humans are more sensitive to green.

Colour Perception

Colour is not a physical phenomenon - it is how humans perceive light of different wavelengths (analogous to perception of frequency in audio waveforms)

Colour Perception

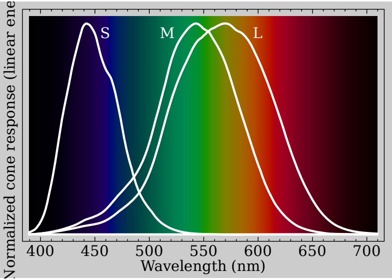

Figure 25: receptor response

Visible spectrum and receptor response for “normal” vision.

- S: Short cone response
- M: Medium cone response
- L: Long cone response

Colour Perception

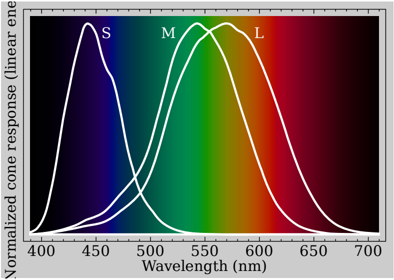

Figure 26: receptor response

Wavelengths perceived as green trigger both M and L cone cells in the eye.
Abnormalities in the cone response leads to colour blindness.

Exposure

Exposure controls the *brightness* of an image.

Pre-image capture

Adjust shutter speed and aperture size to control the amount of light reaching the image sensor.

Post-image capture

Adjust with a *tone* curve; a mapping from input to output pixel intensity.

Tone Curves

As a linear function

$I' = Iw + b$

Tone Curves

As a linear function

$I' = Iw + b$

Caution
Beware of implicit type conversion in your code.

Linear Tone Curves

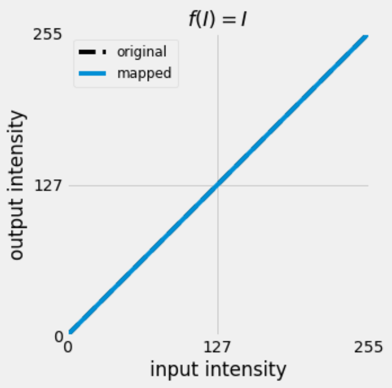

Figure 27: linear tone curve

$$f(I) = I$$

Linear Tone Curves

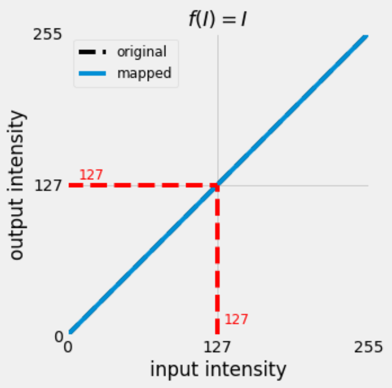

Figure 28: linear tone curve

$$f(I) = I$$

– Output intensity is the same as input intensity
– No change is made to the image

Linear Tone Curves

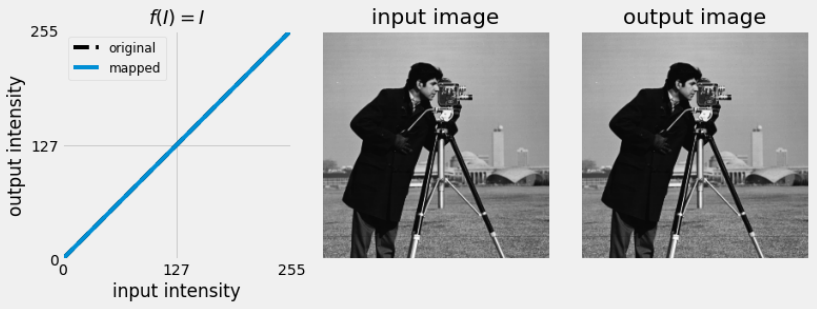

Figure 29: linear tone curve $f(I) = I$

Linear Tone Curves

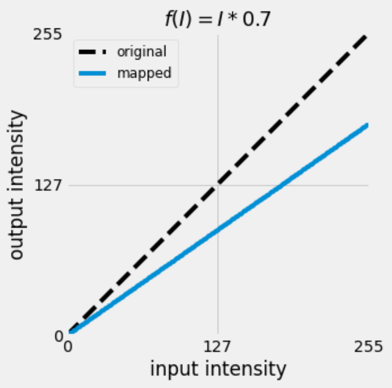

Figure 30: linear tone curve

$$f(I) = I \times 0.7$$

Linear Tone Curves

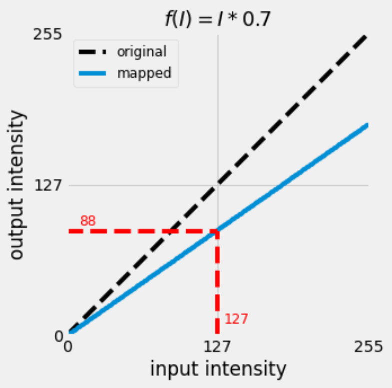

Figure 31: linear tone curve

$$f(I) = I \times 0.7$$

- Output intensity is less than input intensity
- The image appears darker
- Higher input values are effected more than lower input values

Linear Tone Curves

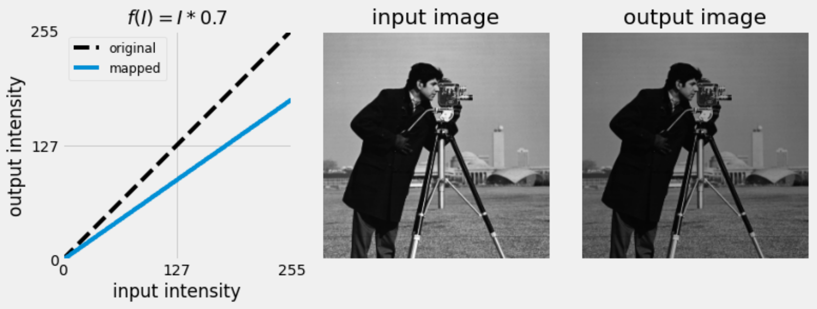

Figure 32: linear tone curve $f(I) = I \times 0.7$

Linear Tone Curves

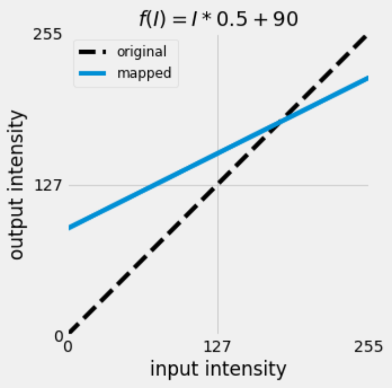

Figure 33: linear tone curve

$$f(I) = I \times 0.5 + 90$$

Linear Tone Curves

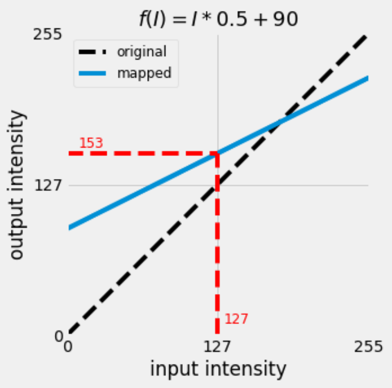

Figure 34: linear tone curve

$$f(I) = I \times 0.5 + 90$$

- Low input values are increased.
- High input values are decreased.
- The image appears to have *lower* contrast.

Linear Tone Curves

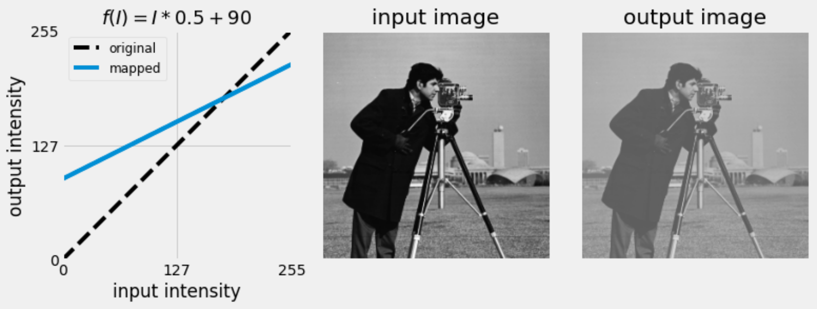

Figure 35: linear tone curve $f(I) = I \times 0.5 + 90$

Linear Tone Curves

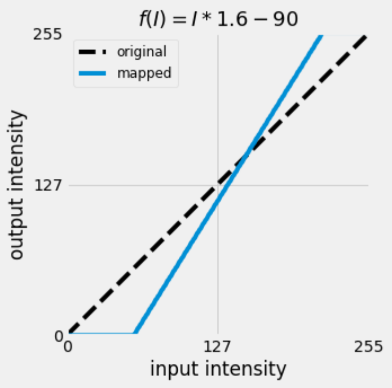

Figure 36: linear tone curve

$$f(I) = I \times 1.6 - 90$$

Linear Tone Curves

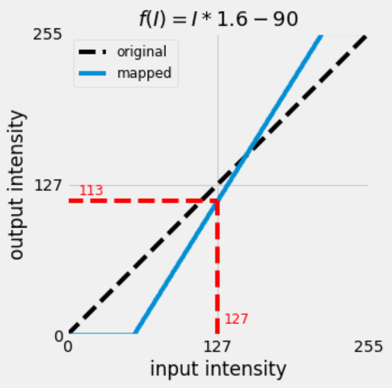

Figure 37: linear tone curve

$$f(I) = I \times 1.6 - 90$$

- High input values are increased.
- Low input values are decreased.
- The image appears to have *higher* contrast.
- Some input values are *clipped*.

Linear Tone Curves

Figure 38: linear tone curve $f(I) = I \times 1.6 - 90$

Gamma Correction

Our eyes perceive brightness on a **logarithmic** scale.

Similar to how we perceive loudness in audio.

Gamma Correction

We have more cells that see in dim light than those that see in bright light.

We are more *sensitive* to low light changes.

Gamma Correction

Cameras measure light on a **linear** scale.

Gamma Correction

Tone curves can be used to adjust images so that they more closely match human perception of a scene.

$$I' = 255 \times \frac{I}{255}^{\frac{1}{\gamma}}$$

Gamma Correction

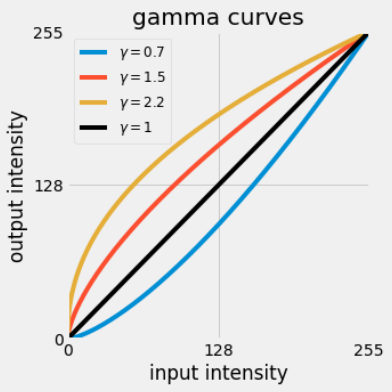

Figure 39: gamma curves

$$I' = 255 \times \frac{I}{255}^{\frac{1}{\gamma}}$$

- End points are unchanged.
- If $\gamma = 1$, image is unchanged.
- If $\gamma > 1$, image appears lighter.
- If $\gamma < 1$, image appears darker.

Gamma Correction

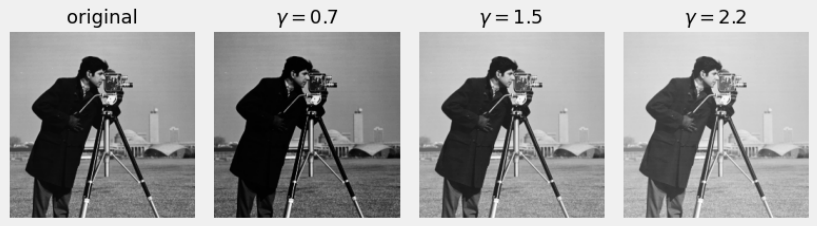

Figure 40: gamma correction

Histograms

A histogram is an approximate representation of the distribution of numerical data.

Histograms

We want to show the frequency, or count, of the values in an image.

Histograms

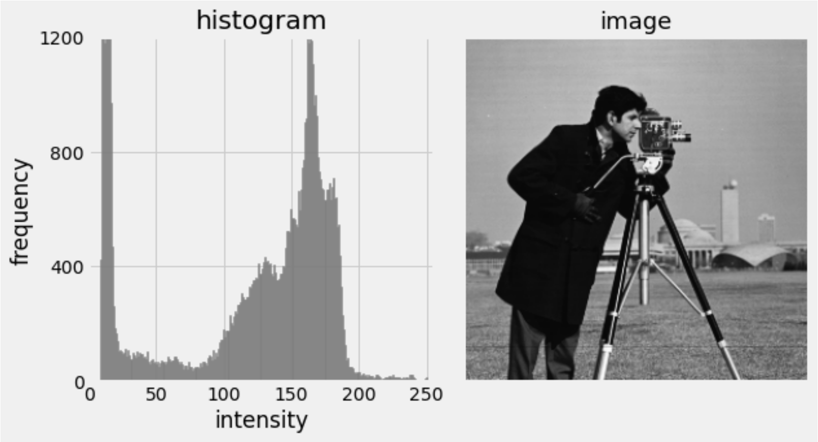

Figure 41: histogram

Histograms

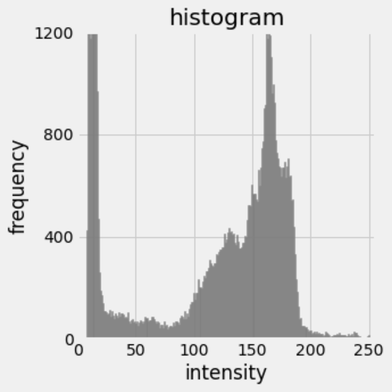

Figure 42: histogram

- Notice the large cluster of values 5 to 25.
- Probably the coat?

Histograms

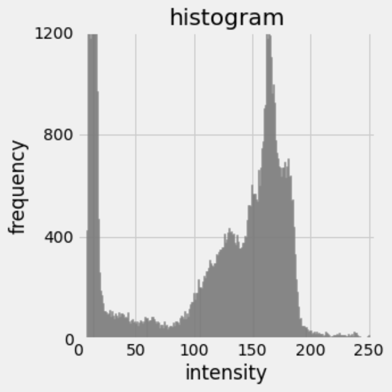

Figure 43: histogram

- Notice the central values.
- 100 to 150 could be grass?
- 150 to 200 could be sky?

Thresholding

Thresholding is the simplest method of segmenting images.

Thresholding

If we wanted to separate the coat from the sky, we could use a threshold.

Thresholding

By observing the histogram we could separate all pixels above or below a value.

Thresholding

$$I_t = I > t$$

Thresholding

Figure 44: threshold image, $t = 75$

Video

We can consider video as a sequence of consecutive images.

Frame Rate (fps)

The rate at which images are captured - or displayed.

Frame Rate (fps)

- 24 fps common for the film industry.
- 25 fps common for the European television industry.
- 29.97 fps common for the American television industry.
- 90 fps common for the virtual reality headsets.

Progressive Scan

- All lines of each frame are drawn in sequence.
- The whole image is drawn at before transmission.

Interlaced Scan

- Odd and even lines are broadcast on alternating frames.
- display device interleaves fields.
- Eye fooled into believing image is being updated, so less apparent flicker.
- Many unpleasant artefacts introduced as a result of interlacing.

Interlaced Scan

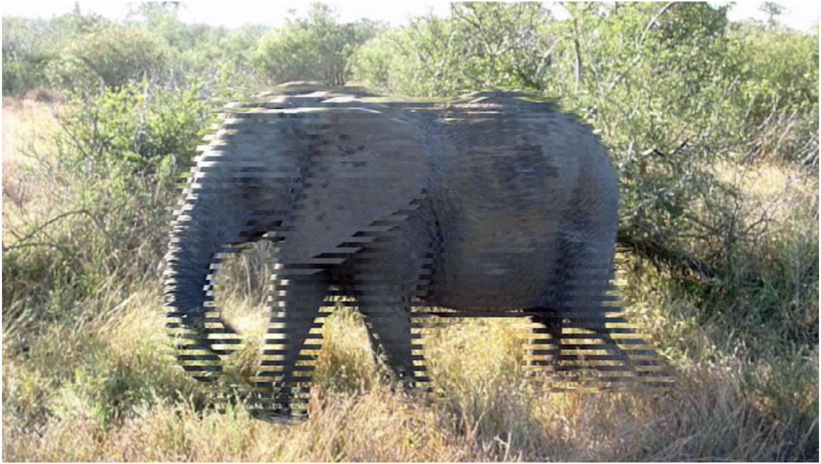

Figure 45: interlaced video is not good for computer vision

Summary

- Introducing images
- Image Sampling and Quantisation
- Image Capture
- Controlling and Analysing Images
- Video