COMP2005

Digital Images and Point Processes

TODAY’S LECTURE ..

1. Digital Image Formation
2. Acquiring and Colour Images
3. Colour Spaces
4. Intensity Transform

Digital Image Formation & Acquisition

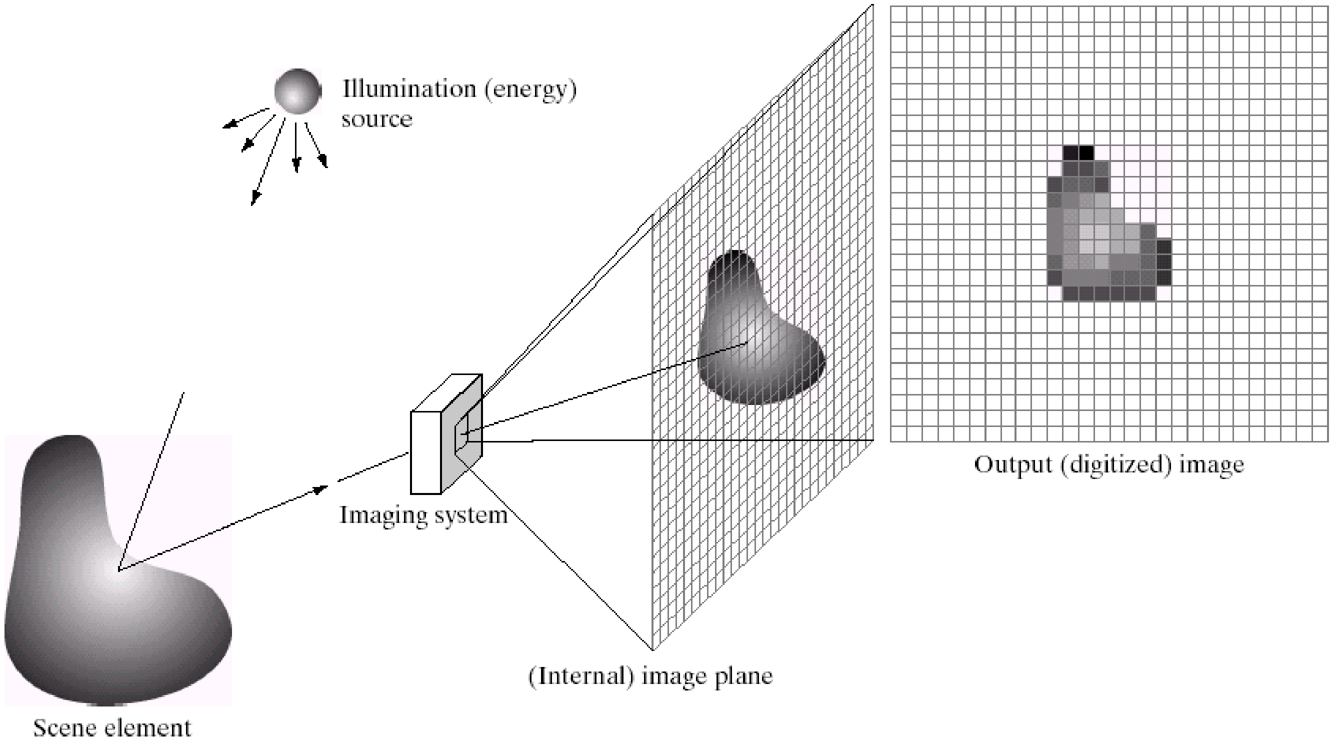
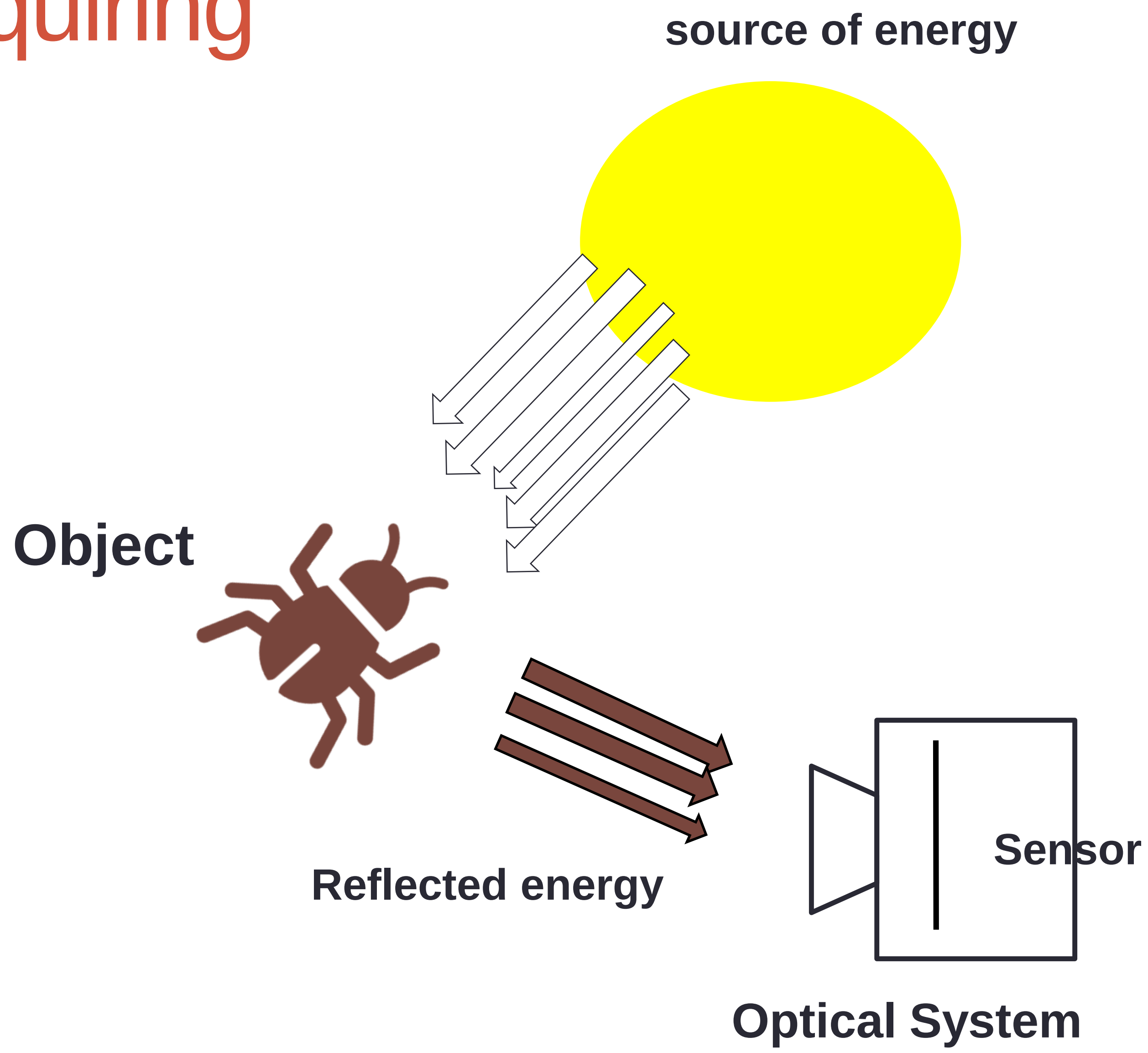
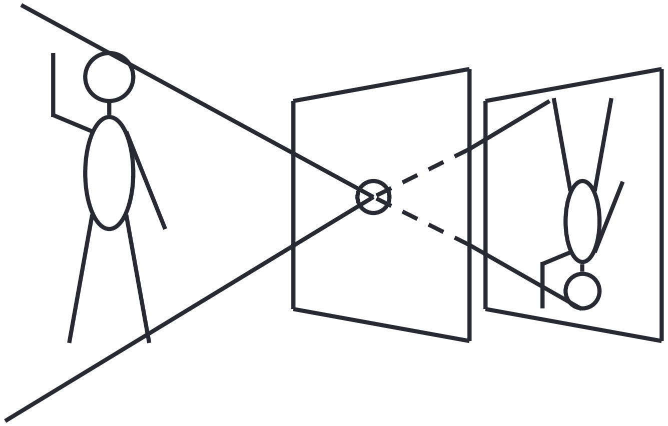


Image Acquiring



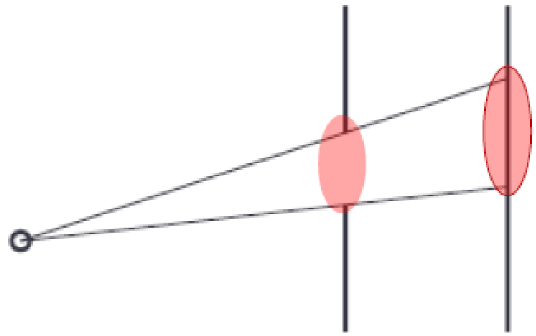
A Simple Camera Model

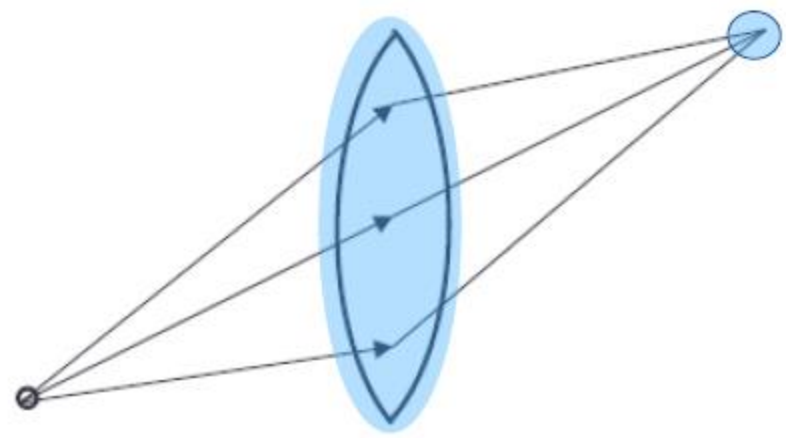
- A simple camera model is the pinhole camera model
  - Light passes through a small hole and falls on an image plane
  - The image is inverted and scaled
  - Early cameras used this approach



Real vs Pinhole Cameras

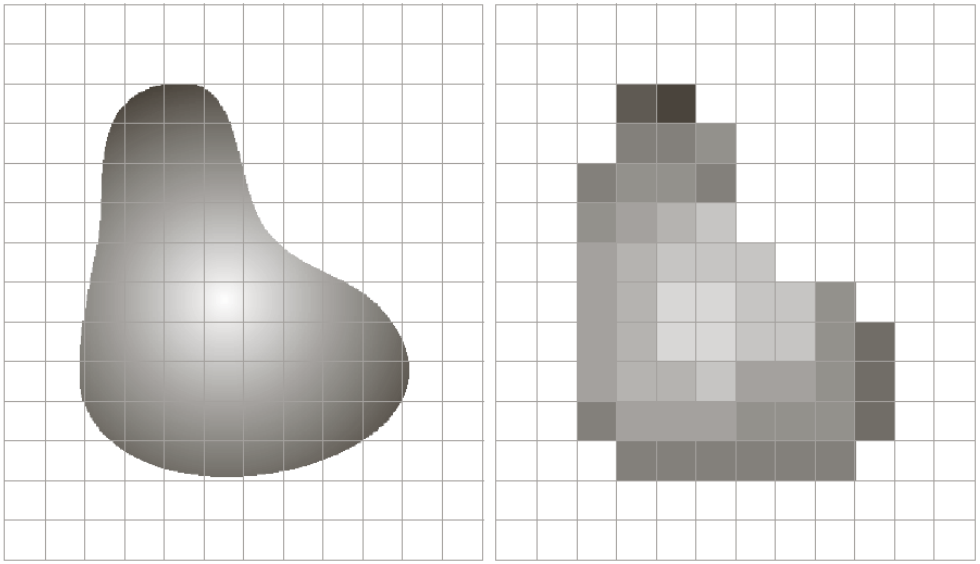
- Real cameras do not have ‘pinholes’
- A pinhole lets very little light in, leading to long exposures
- Larger holes lead to blurred images
- A lens can make a large hole act like a small one





Sampling and Quantisation

- Sampling : Digitisation of the spatial coordinates
- Quantisation : Digitisation of the light intensity function



Sampling determines ***spatial resolution***

Quantisation determines ***grey level, colour or radiometric resolution***

How much of the light energy is quantized

Sampling

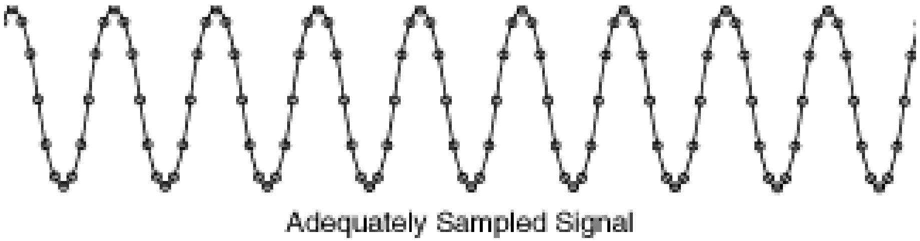
How many samples to take? i.e. how many pixels in the image?

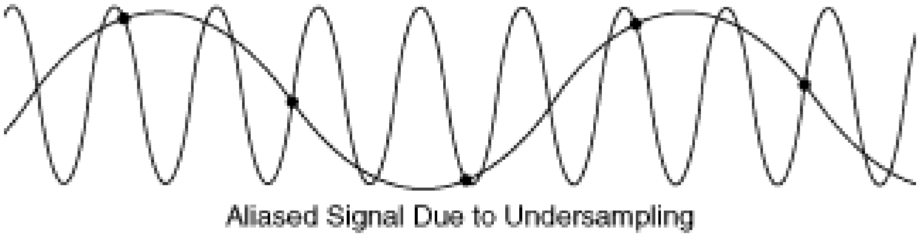
The Nyquist Rate

- Samples must be taken at a rate that ***is twice the frequency of the highest frequency component to be reconstructed***.
- Under-sampling: sampling at a rate that is too coarse, i.e., is below the Nyquist rate.
- Aliasing: artefacts that result from under-sampling.

Aliasing

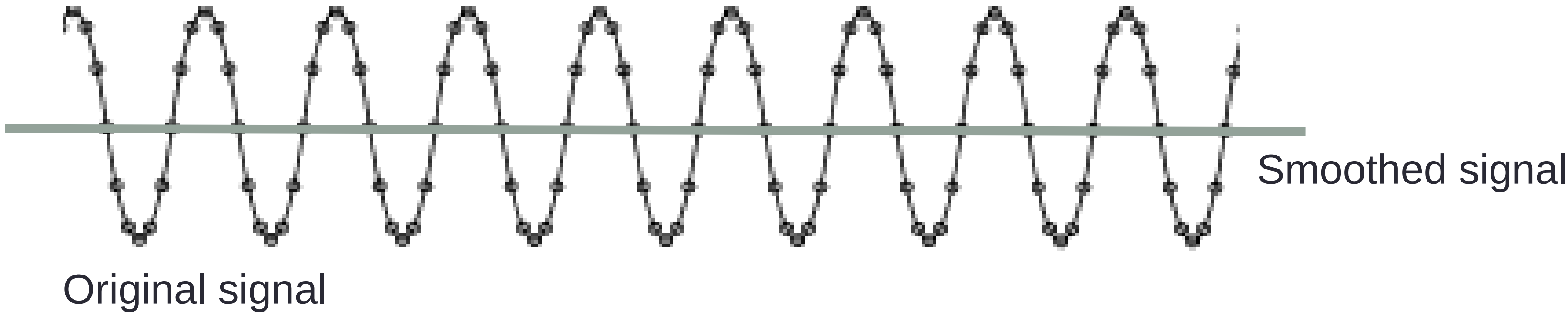
- Aliasing occurs when two signals (images) become indistinguishable when sampled
- In our case the two signals are the true image (the image that would be seen if there were no quantisation) and the one reconstructed by the human vision system from a sampled image





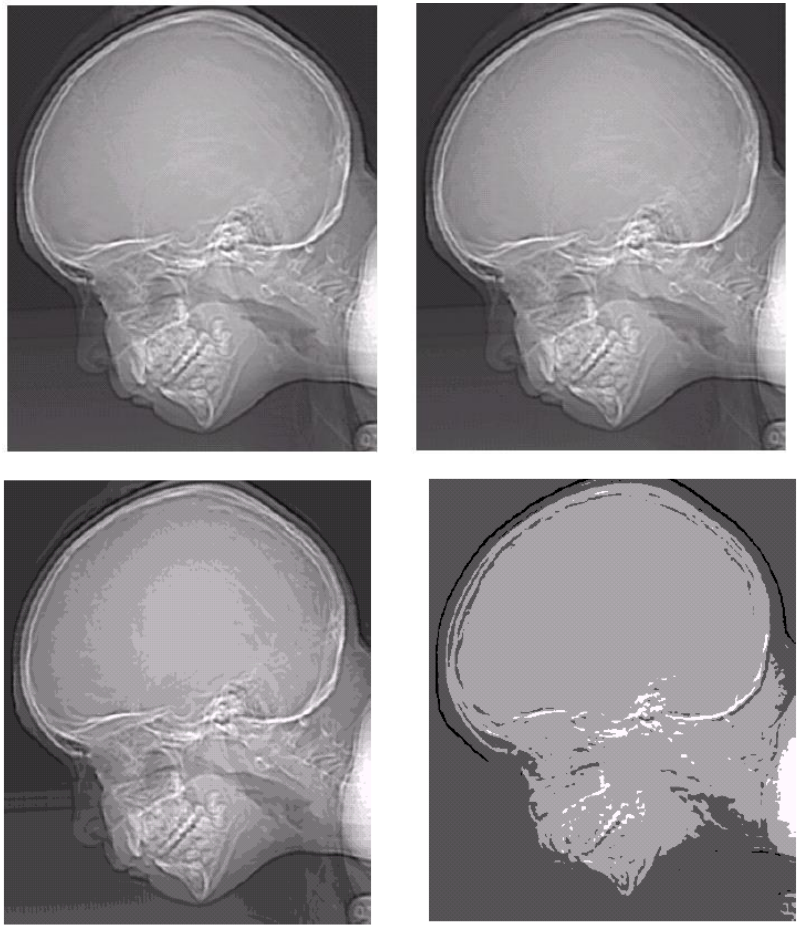
Anti-aliasing

- Aliasing can be introduced when an image is resampled, if the sampling rate of the new image is less than the Nyquist rate of the original
- Smooth out high frequency signals before sampling so its impossible to “see” the alias



Quantisation

- How many grey levels to store?
- Determines the number of levels of color/intensity to be represented at each pixel
    - 256, 64, 16, 4



- Sampling and quantisation occur naturally during image acquisition, but can also be applied to existing images
    - e.g. during resizing and compression

Re-Sampling and Re-Sizing

- Most basic form of image processing

25	26	28	40
26	27	40	42
27	42	43	43
28	44	46	45

26	37
35	44

- When ***downsampling***, need to compute a summary pixel value from each local area:

pick one, mean, weighted mean….

Re-Sampling and Re-Sizing

26	37
35	44

26	?	37	?
?	?	?	?
35	?	44	?
?	?	?	?

- When ***upsampling***, need to **interpolate** from the known values ***to produce an estmate at the unknown pixels***.
- Average the known values in a local region centred on each unknown pixel, fit some kind of function through known values….

Re-quantisation

- Pixel values are integers in a fixed range
- Grey level resolution can be dropped by dividing each pixel value by a constant**, but there is a side effect**

- Can't increase grey level resolution of a single pixel
- **Super-resolution methods** exist that combine multiple exposures of the same scene, and so have more than one measurement of each pixel

Key Points

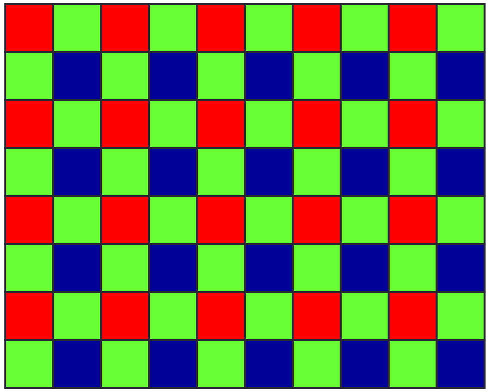
- Sampling and quantisation are often under user control during image capture and have a significant effect on the image
- Both can be changed to some extent after capture, but the resulting images are often approximations
- Be aware of the Nyquist rule when choosing an image resolution; it can introduce artefacts that are difficult to remove

ACQUIRING COLOUR IMAGES

Acquiring Colour Images

- Each pixel in a grey level image contains one value. Colour requires **three**
- **RGB** model inspired by the **retina** is an obvious choice for use in cameras
- Some (expensive) cameras use complex optics and **3 CCDs** to capture each colour channel independently
- Necessary for some scientific purposes, not for general use

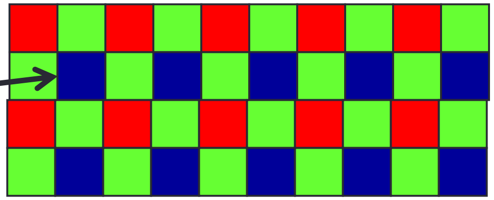
- Single CCD colour cameras use the **Bayer Pattern**:



- Each CCD cell lies under a red, green or blue filter

Bayer Pattern

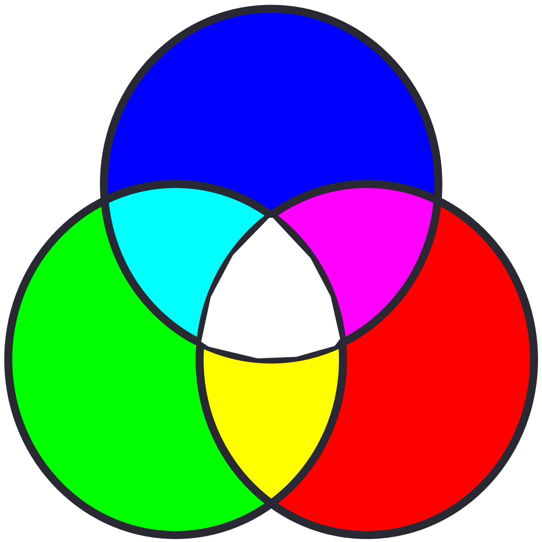
- One colour value is measured, but two are **estimated** at each pixel
- Here
  B is measured, G is the mean of the 4-neighbours, R is the mean of the diagonals
- Pattern is repetitive so there are a finite number of sets of filters that can surround each sensor

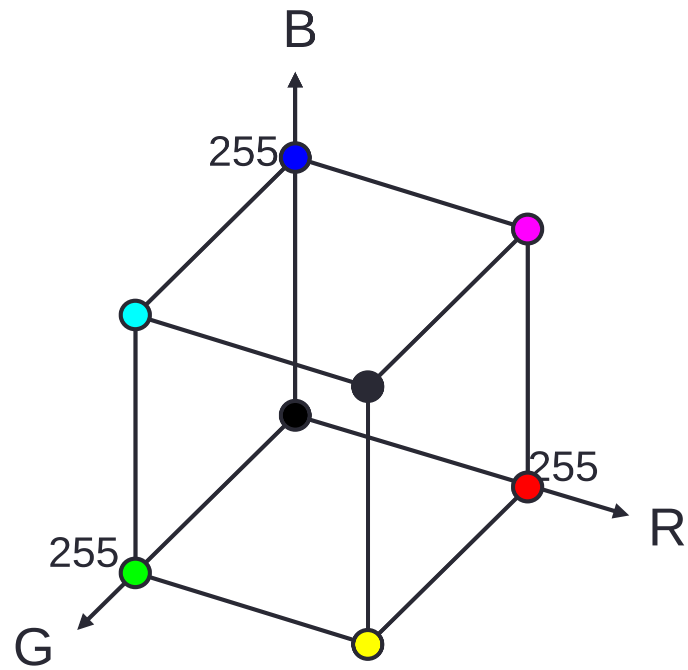


- More green elements as our eye is more sensitive to green light than red or blue

Representing Colour: RGB

- Most common starting point
- Retinal cells are sensitive to three primary colours R, G, B
- Light, not pigments





- RGB is additive, other colours are made by mixing these together

An RGB Example

- Colour images are 3D arrays
- Display software interprets them to produce a colour view

Colour Image

Red

Green

Blue

- RGB is used in image acquisition, but that doesn't mean we have to use it in image processing

Colour vs Greyscale

- Sometimes we want a single value at each pixel
  - Makes processing easier
  - Reduces the amount of information
  - Makes some of the theory simpler
- Many image processing methods were developed for single value images
- This value is usually the intensity or grey level
- Early CCDs only produced grey level; rare now
  - We can compute the grey value using a simple average of red, green, and blue
  - But our eyes are more sensitive to green light so...

Colour vs Greyscale

- We can convert an RGB image to greyscale using

$$i = 0.30r + 0.59g + 0.11b$$

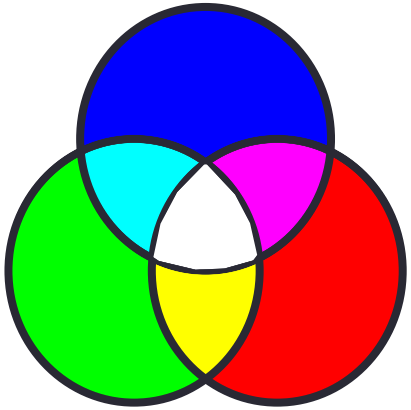
Average Original Weighted

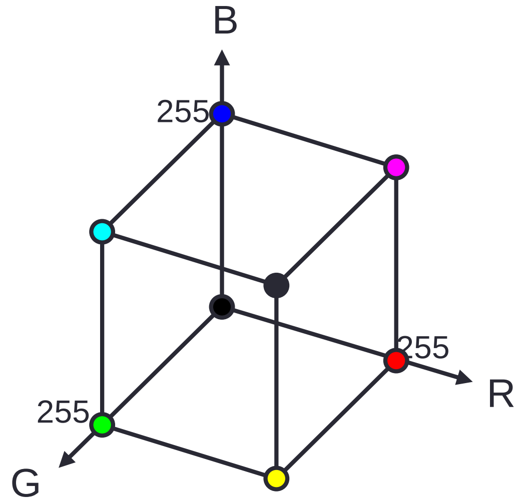

BREAK

COLOUR SPACES

Representing Colour: RGB

- Most common starting point
- Retinal cells are sensitive to three primary colours R, G, B
- Light, not pigments





- RGB is additive, other colours are made by mixing these together

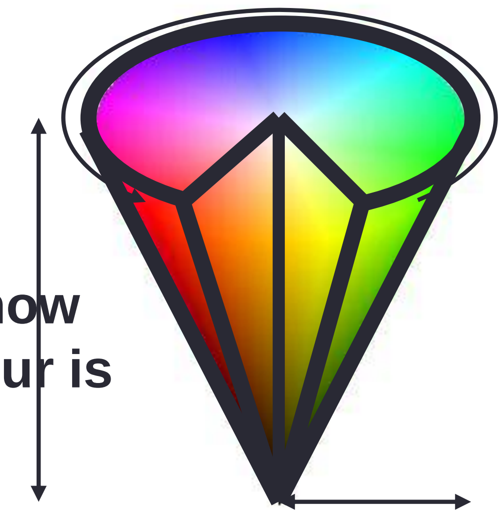
Alternative Colour Spaces

- RGB is OK, but there are other general and application-specific colour spaces……
- If you want to work with plants you might use just G, or 'greenness':

$$G - (R + B)/2$$

- HSV is based on colour rather than light
  - Hue - what general colour is it
  - Saturation - how strongly coloured is it
  - Value - how bright or dark is it

HSV Space



Hue indicates the angle around the colour wheel

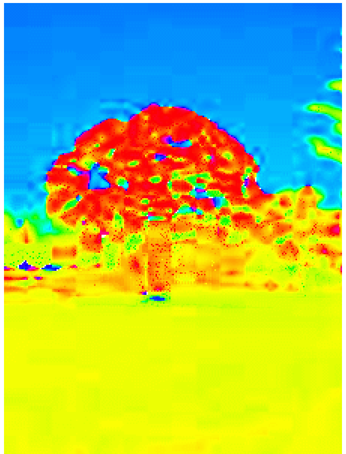
Value indicates how dark light the colour is

Saturation indicates how strong the colour is

HSV Example

- HSV separates colour from intensity (value) making it less sensitive to illumination changes

Colour Image



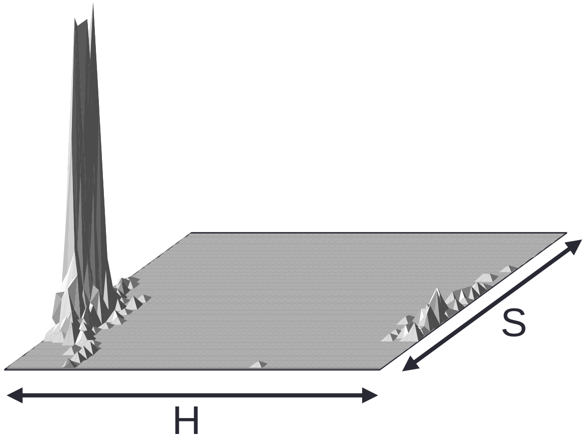
Hue (presented as a colour image)

Saturation

Value

Hue, Saturation and Skin

- We don't always need all 3 colour values
- Human skin is tightly clustered in H,S space



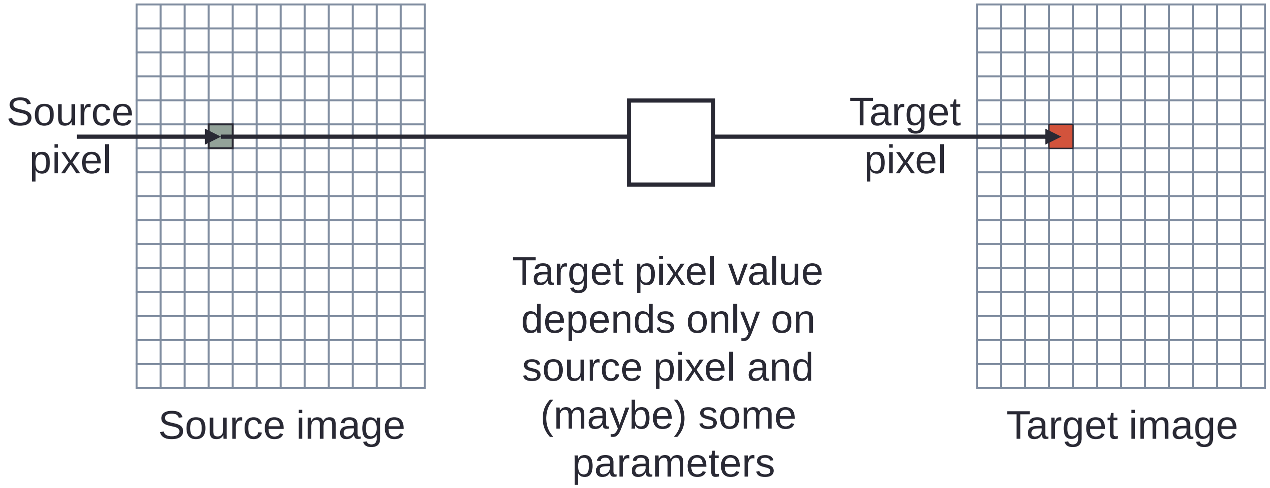
Histogram back-projection

Key Points

- Colour values are often interpolated; don’t assume they are 100% reliable unless you have a 3 CCD camera
- Colour space transformation is an example of a point process
- Alternative 3D colour spaces exist
- Not all applications require all 3 colour planes to be considered, and application-specific colour spaces exist.

INTENSITY TRANSFORM

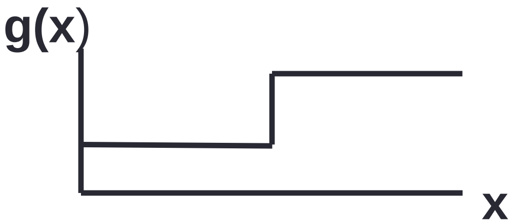
Intensity Transforms

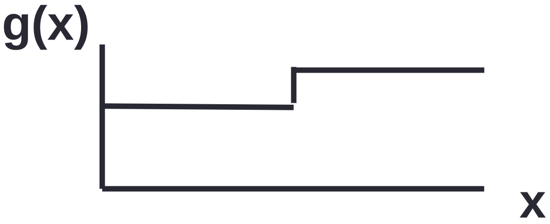


Linear Transforms

- Two commonly used point processes are multiplication by and addition of a constant, i.e. $g(x,y) = a.f(x,y) + b$

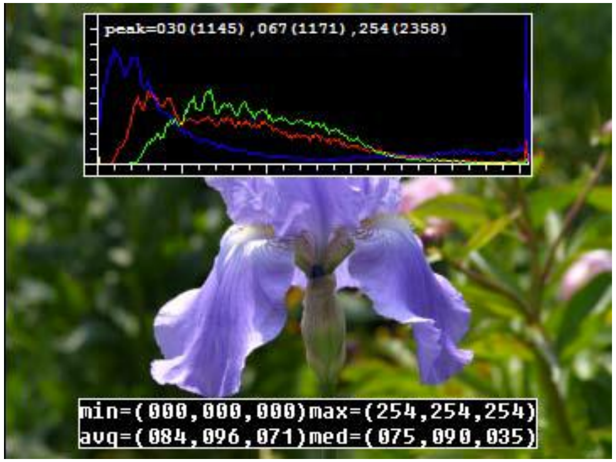
- **a** is the ***gain***, and controls *contrast*, ***b*** is the ***bias***, and controls *brightness*



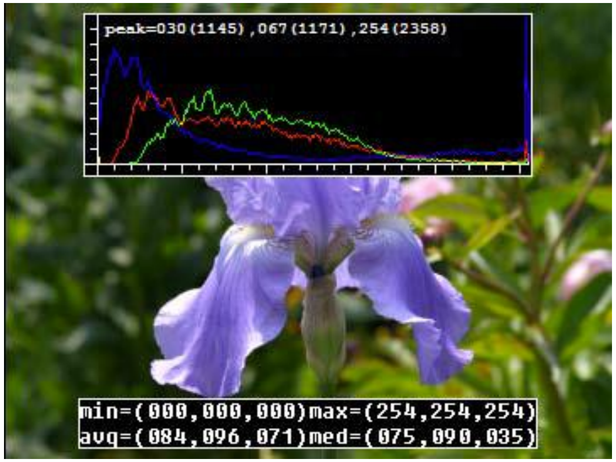


Gain

- $g(x,y) = 1.1.f(x,y) + 0$



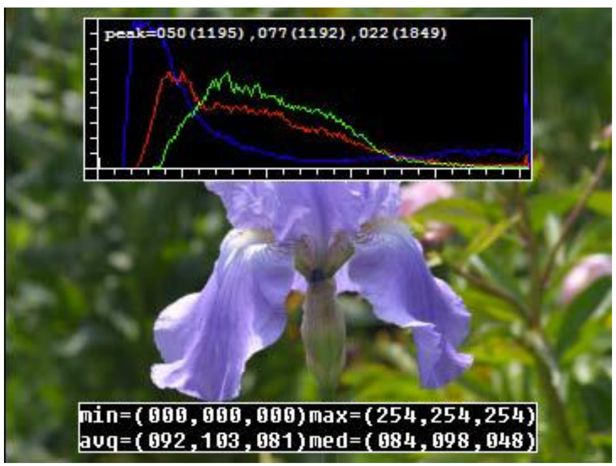
f(x,y)



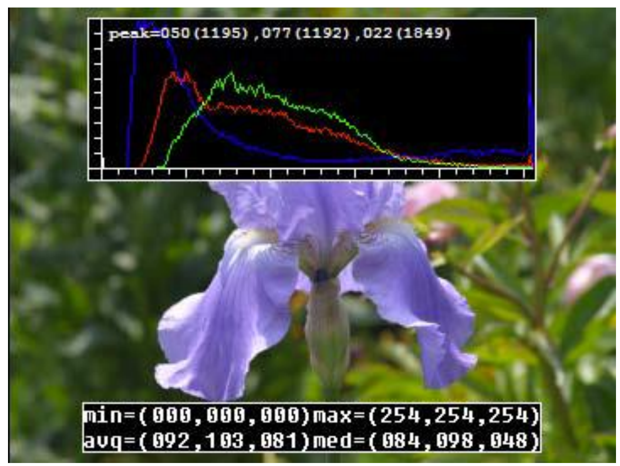
g(x,y)

Bias

- g(x,y) = 1.f(x,y) + 16



f(x,y)



g(x,y)

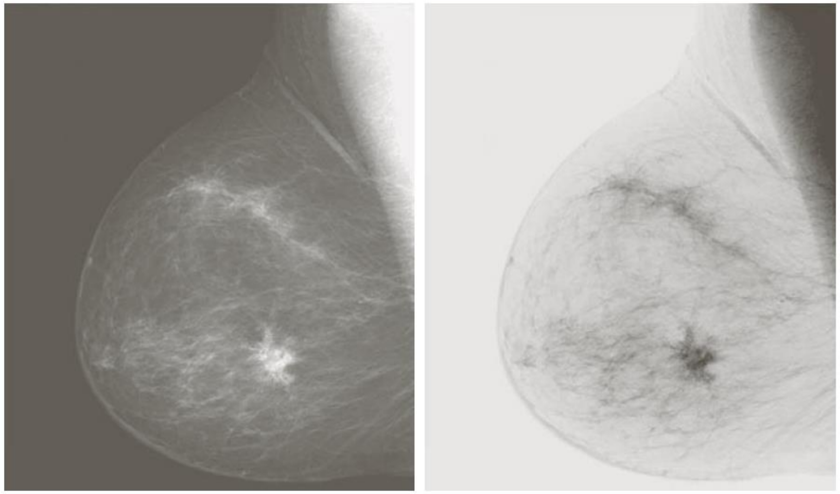
Negation

$$g(x,y) = f_{min} + (f_{max} - f(x,y))$$

$$= -f(x,y) + (f_{min} + f_{max})$$

Negation

- Often used to make fine details more visible, e.g. in digital mammograms:



Dynamic Range

- Digital images are sampled – they contain a fixed number of data values
- Digital image representations can only store a fixed number of values
- Intensity transforms can produce values that are
  - outside that range and so can't be stored
  - clustered in a small part of that range and so are hard to distinguish
- Some intensity transforms need data in a particular range

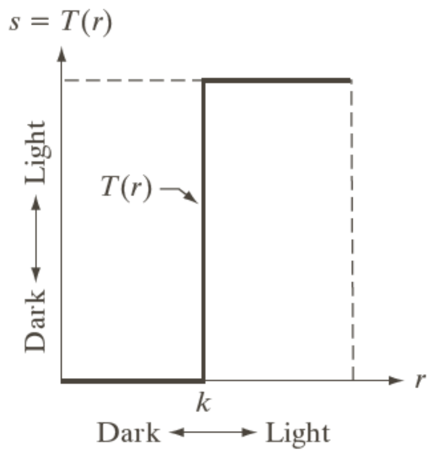
Contrast Stretching

- To convert a source image in which intensities range from min_s to max_s to one in which they range from min_t to max_t

$$g(x,y) = min_t + \frac{(f(x,y) - min_s).(max_t - min_t)}{(max_s - min_s)}$$

Non-linear Transforms

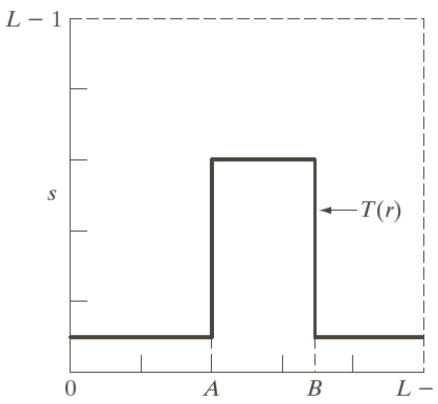
- Thresholding

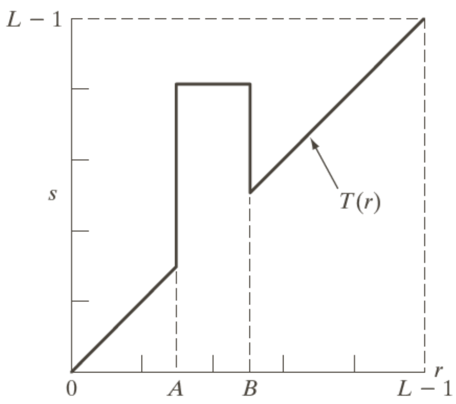


- Can be done to h as the simplest form of image segmentation

Grey Level Slicing

- Highlights a specific range of intensities





Can reduce other grey levels to a lower level…..

….or preserve them

Grey Level Slicing

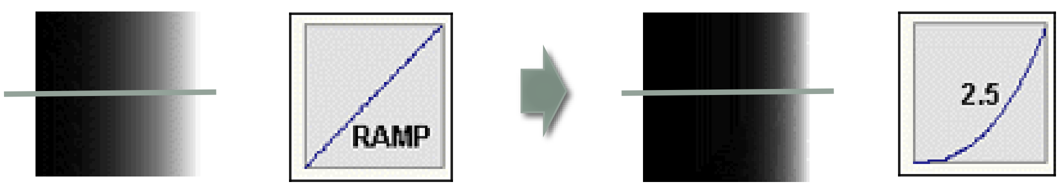
An aortic angiogram

High intensities selected, others reduced to low level

Selected intensities set to black, others (blood vessels & kidneys) preserved

Gamma Correction

- When an image is displayed on a screen, the hardware used effectively applies an intensity transform
- You send a voltage proportional to the intensity of a pixel, the screen displays an intensity that is related to that, but not how you may think



$L \approx V^{2.5}$ depending on device

Gamma Correction

- We need to transform the image, so that it generates a voltage which will display what we want
- Create a new image in which

$$g(x,y) = f(x,y)^{1/2.5}$$

then

$$V = g(x,y)$$

$$L = (f(x,y)^{1/2.5})^{2.5}) = f(x,y)$$

- Gamma Correction because the equation is usually written

$$g(x,y) = f(x,y)^{\gamma}$$

Key Points

- Point processes operate on each pixel independently
- Linear processes change the appearance of the whole image
- Non-linear processes can differentiate objects/image regions

Next Week :

Histogram (Whole Image Understanding)