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COMP-2032

Introduction to Image Processing

Lecture 2

Digital Images and Point Processing

Learning Outcomes

IDENTIFY

1. Digital Images Formation
2. Acquiring & Using Colour Images
3. Colour spaces
4. Intensity Transform

Before ALL that…

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LET'S PLAY KAHOOT

Get Ready Everyone!

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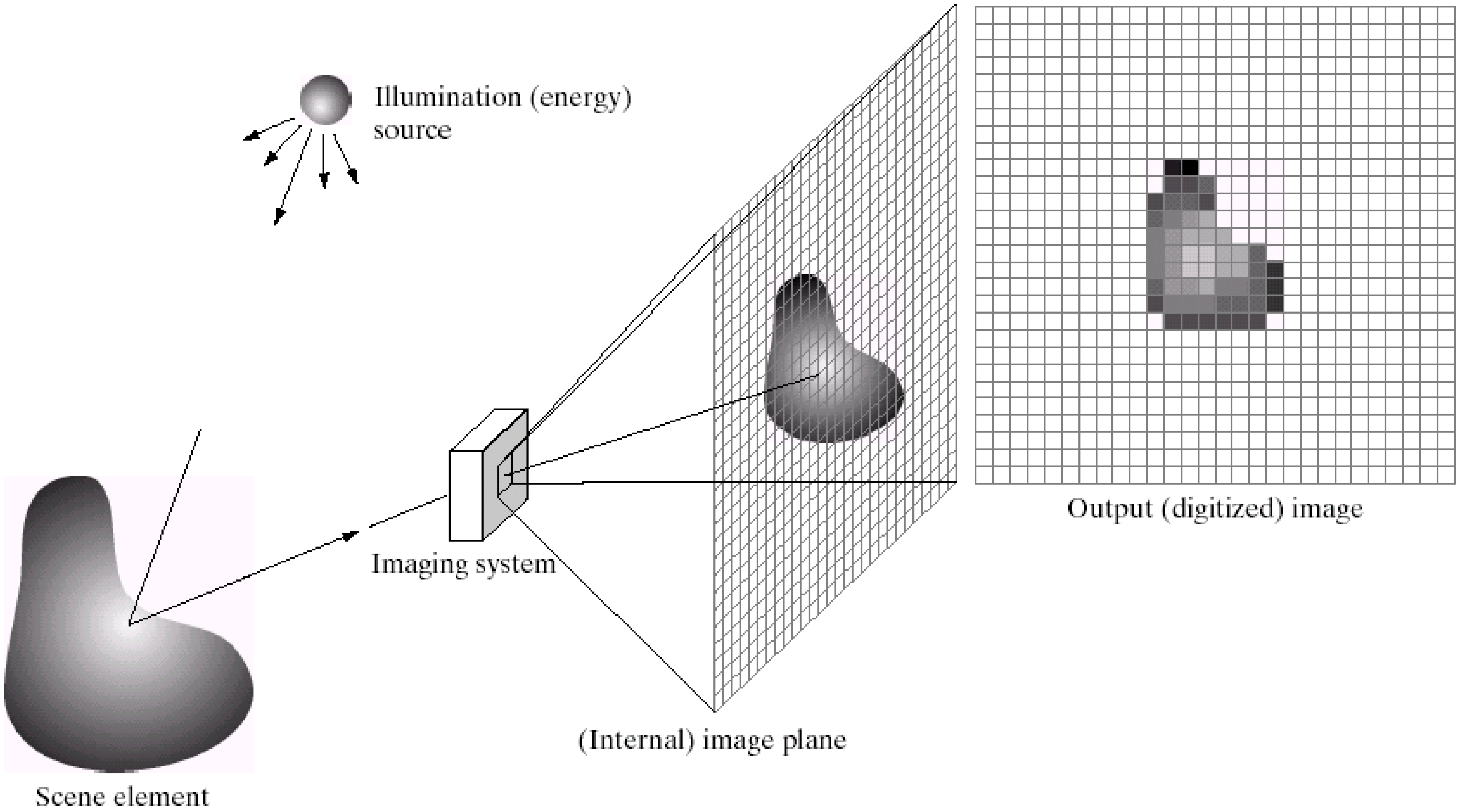
Digital Image Formation

Image Formation & Acquisition



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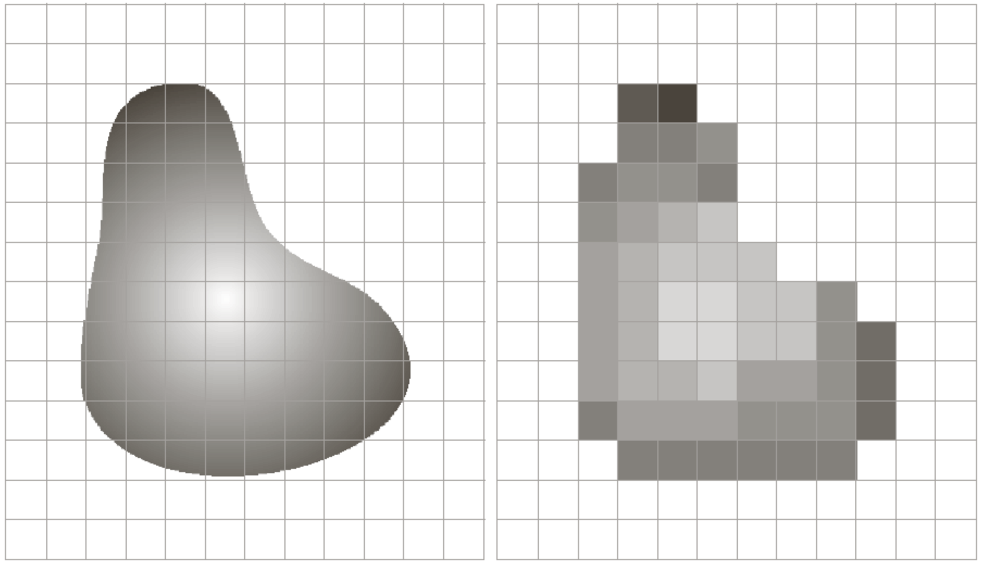
Sampling & Quantisation

Sampling Digitisation of the spatial coordinates

Digitisation of the light intensity function **Quantisation**



Sampling determines *spatial resolution,* **quantisation determines** *grey level, colour or radiometric resolution*

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Sampling

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

- 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

Nyquist Rate

Artefacts that result from under-sampling **Aliasing**

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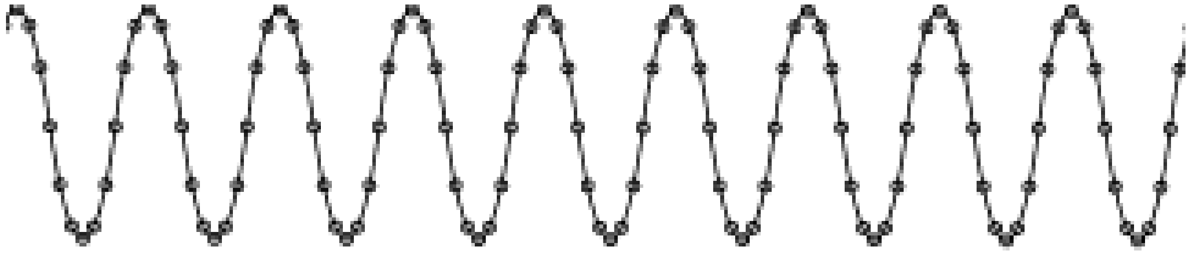
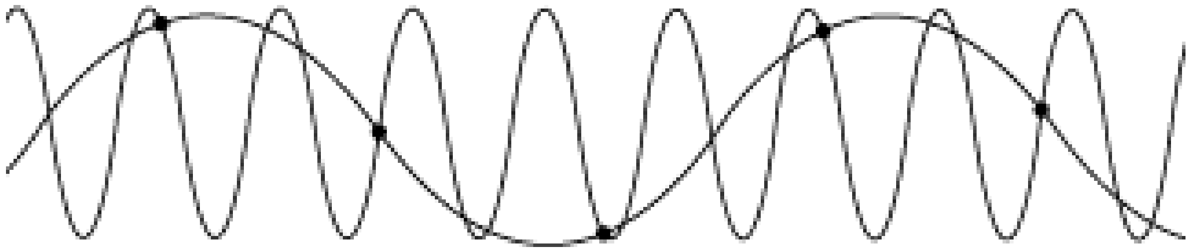
Aliasing

- 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



Adequately Sampled Signal



Aliased Signal Due to Undersampling

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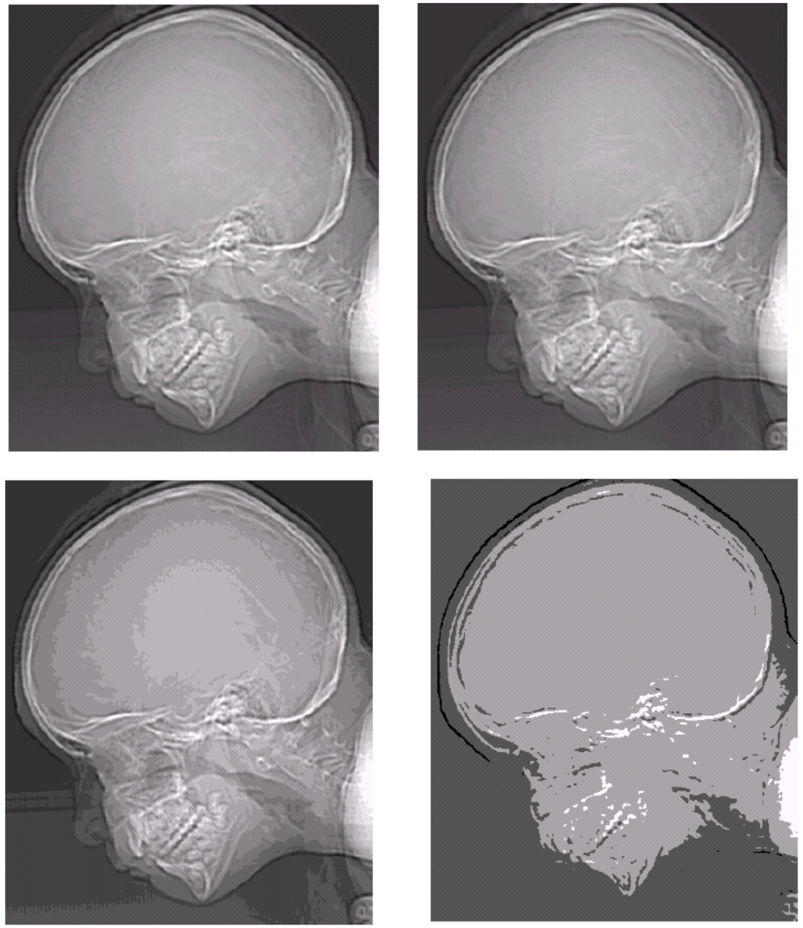
Quantisation

How many grey levels to store? ?

- Determines the number of levels of colour/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 & compression

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Re-Sampling & 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…

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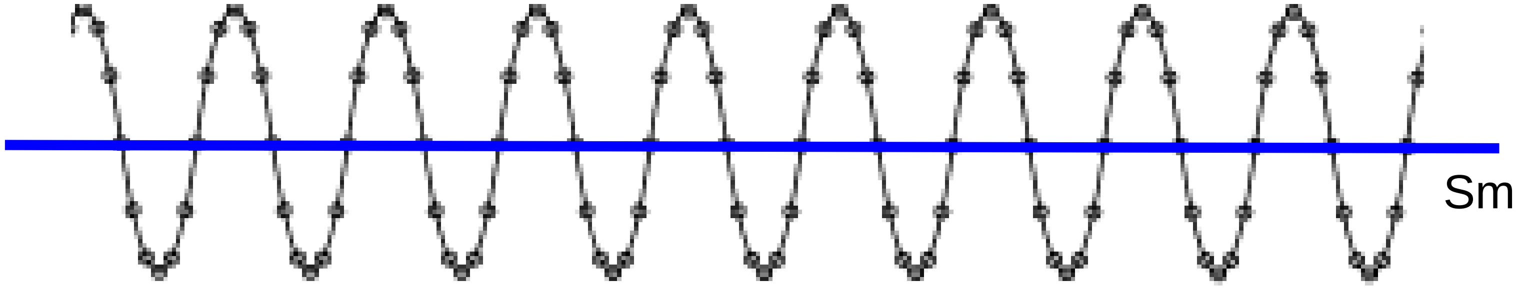
Anti-Aliasing

- 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



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Re-Sampling & Re-Sizing

26	37
35	44

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

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

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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 image

Super-resolution methods exist that combine multiple exposures of the same scene, and so have more than one measurement of each pixel

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Key Points

Sampling & 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

REMEMBER

Be aware of the Nyquist rule when choosing an image resolution; it can introduce artefacts that are difficult to remove

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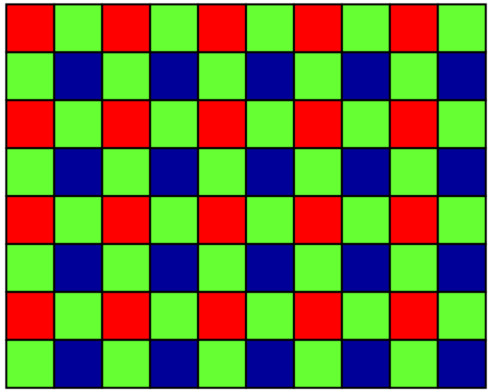
Acquiring & Using Colour Images

Acquiring Colour Images

IMPORTANT

- 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 & 3 CCDs to capture each colour channel independently
- Necessary for some scientific purposes, not for general use
- Single CCD colour cameras use **Bayer pattern**



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

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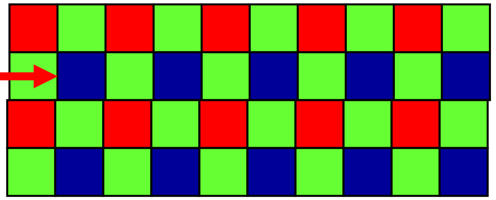
Bayer Pattern

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



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

Pattern is repetitive so there are a finite number of sets of filters that can surround each sensor

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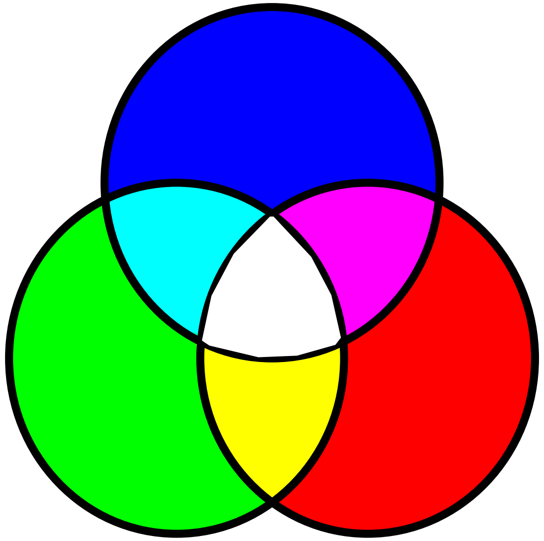
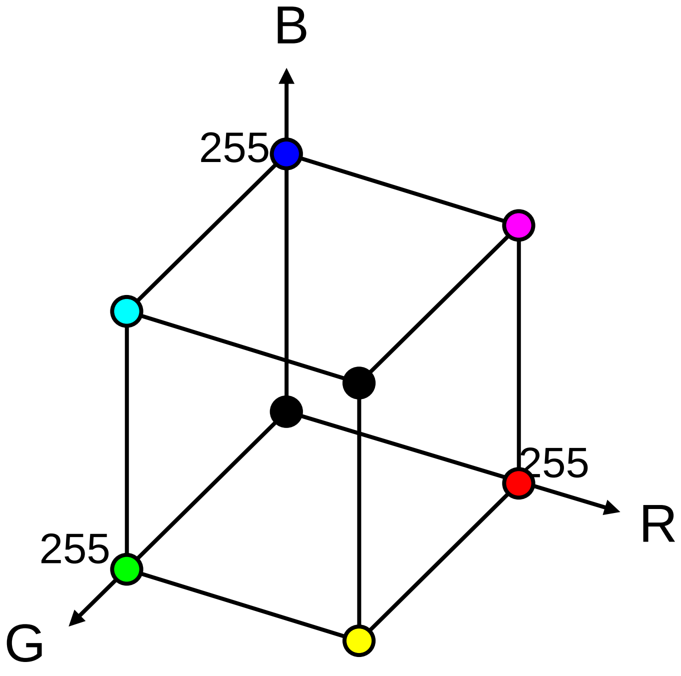
Representing Colour: RGB

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

INTERESTING FACT





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

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An RGB Example

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

REMEMBER


Colour Image


Red


Green


Blue

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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…*

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Colour Vs. Greyscale

We can convert an RGB image to greyscale using:

$$I = 0.30R + 0.59G + 0.11B$$

Average | Original | Weighted

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Break

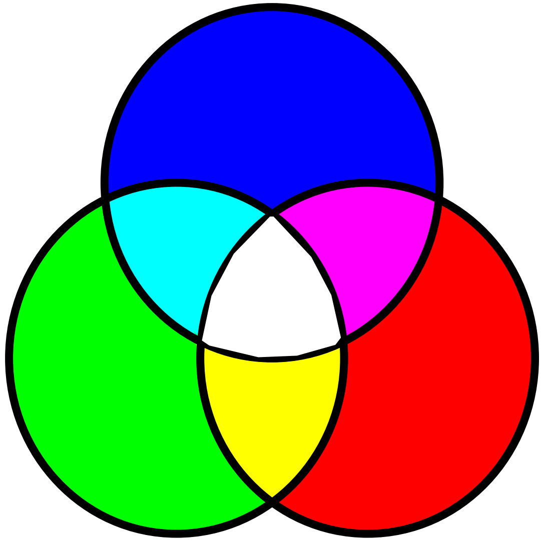
Colour Spaces

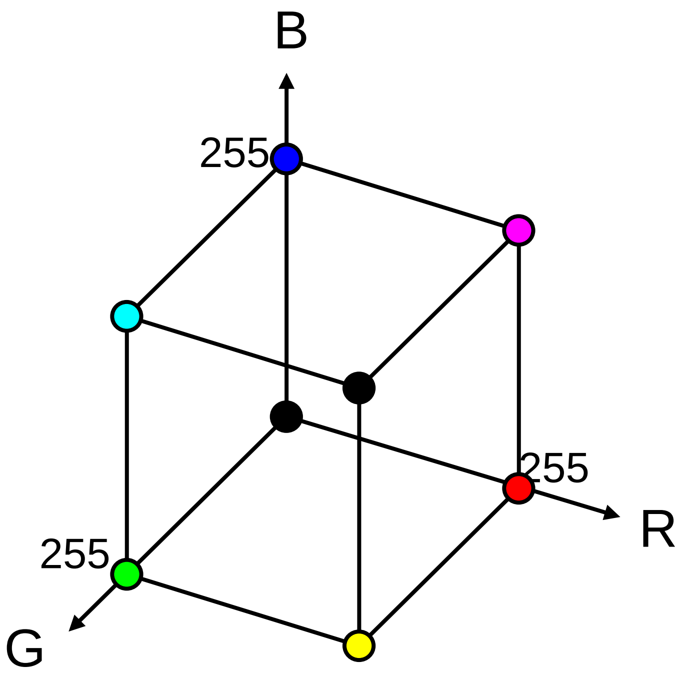
Representing Colour: RGB

Let's Walk DOWN Memory Lane

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

INTERESTING FACT





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

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Alternative Colour Spaces

- RGB is OK, but there are other general & 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*

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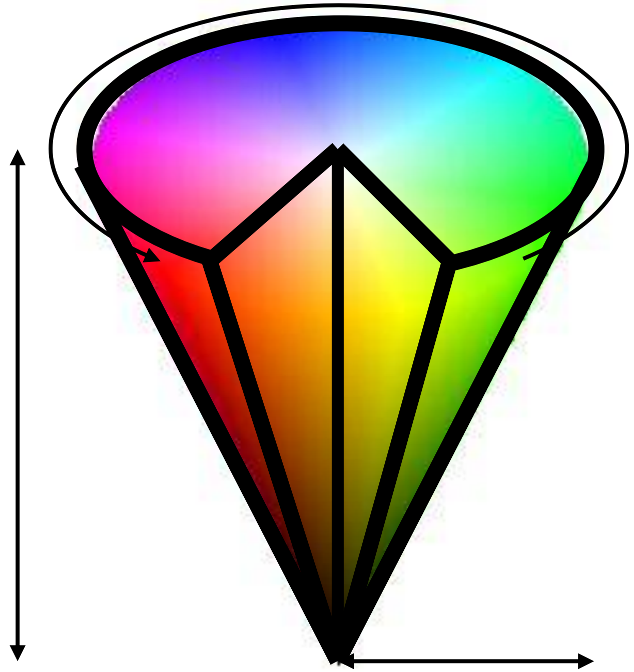
HSV Space



Value indicates how dark light the colour is

Hue indicates the angle around the colour wheel

Saturation indicates how strong the colour is

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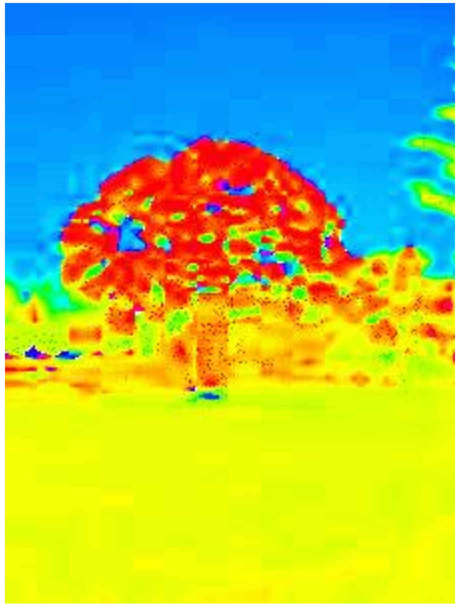
HSV Space

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

What makes it DIFFERENT to RGB Space?

Colour Image



Hue

(presented as a colour image)

Saturation

Value

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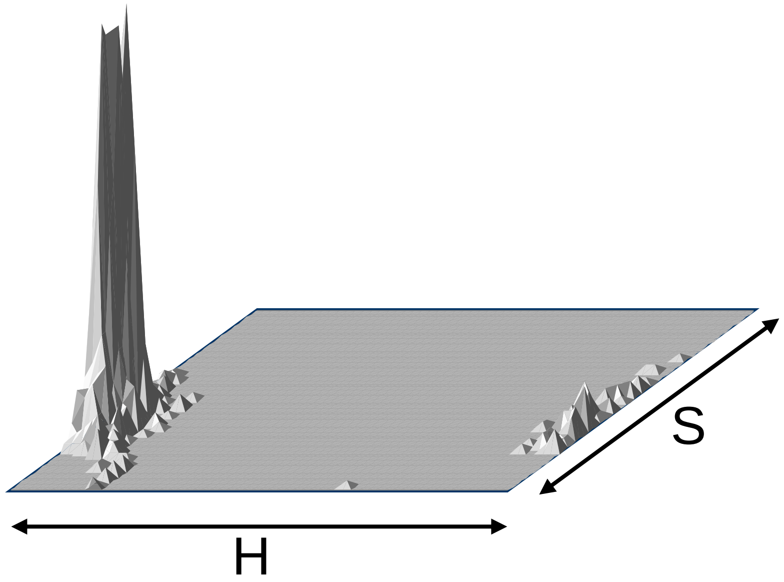
Hue, Saturation & SKIN

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



Histogram back-projection

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Key Points

Colour space transformation is an example of a point process

Alternative 3D colour spaces exist

REMEMBER

Not all applications require all 3 colour planes to be considered, & application-specific colour spaces exist

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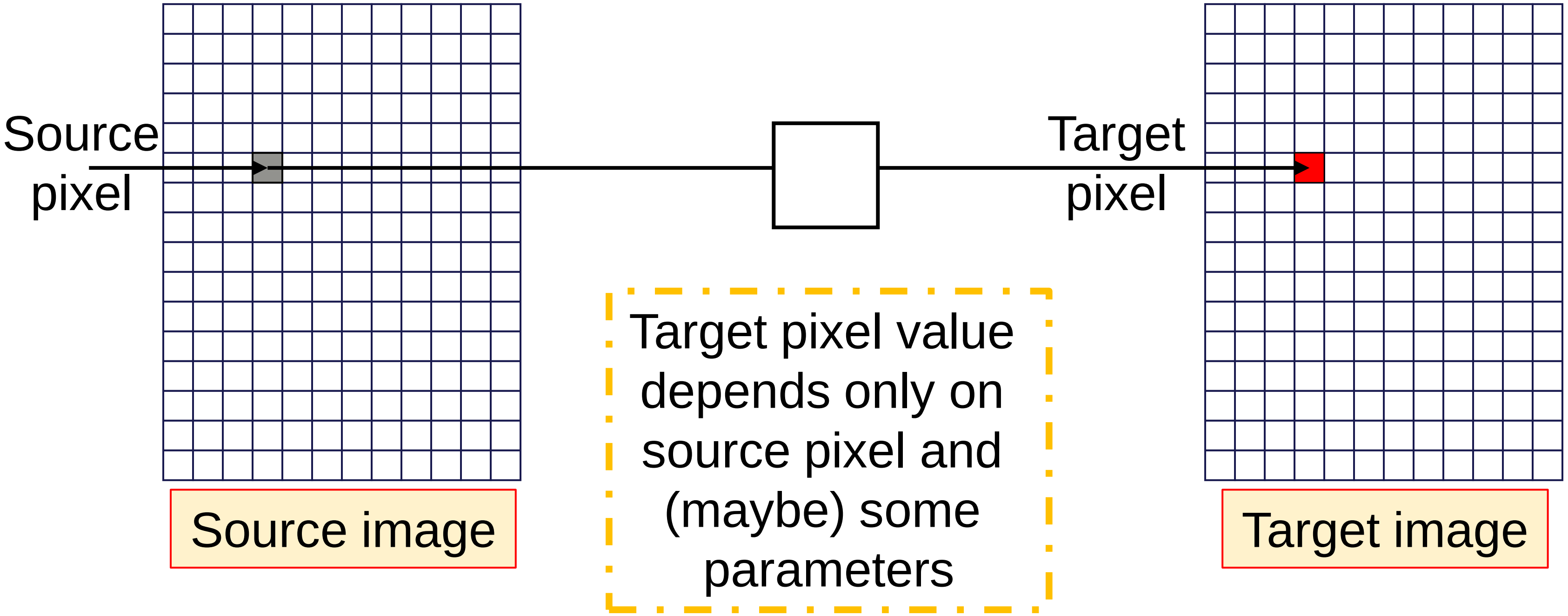
Intensity Transform

Intensity Transform



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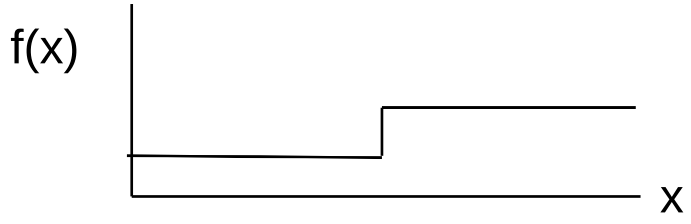
Linear Transforms

2

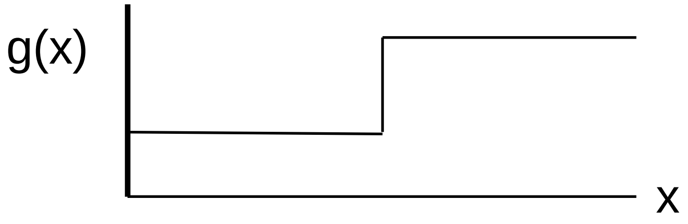
Commonly used point processes are multiplication by and addition of a constant, i.e.,

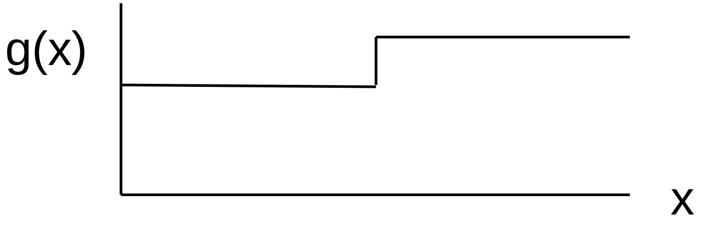
$$g(x,y) = a.f(x,y) + b$$



a Is the *gain***,** and controls **contrast**

Is the *bias*, and controls **brightness** **b**





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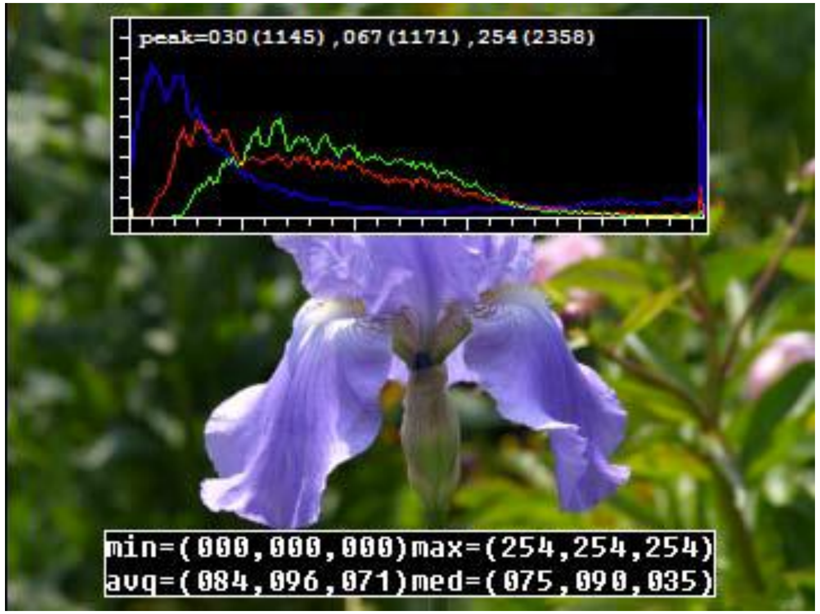
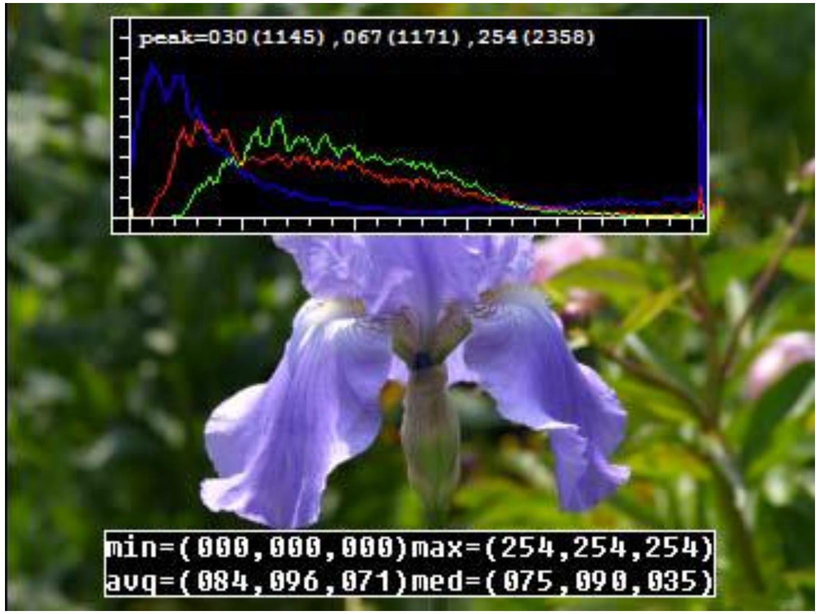
Gain

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



f(x,y)



g(x,y)

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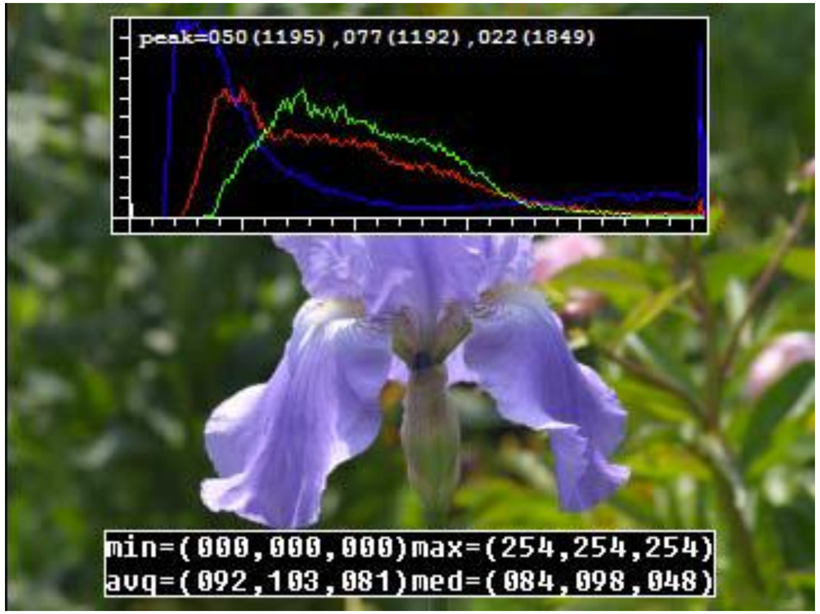
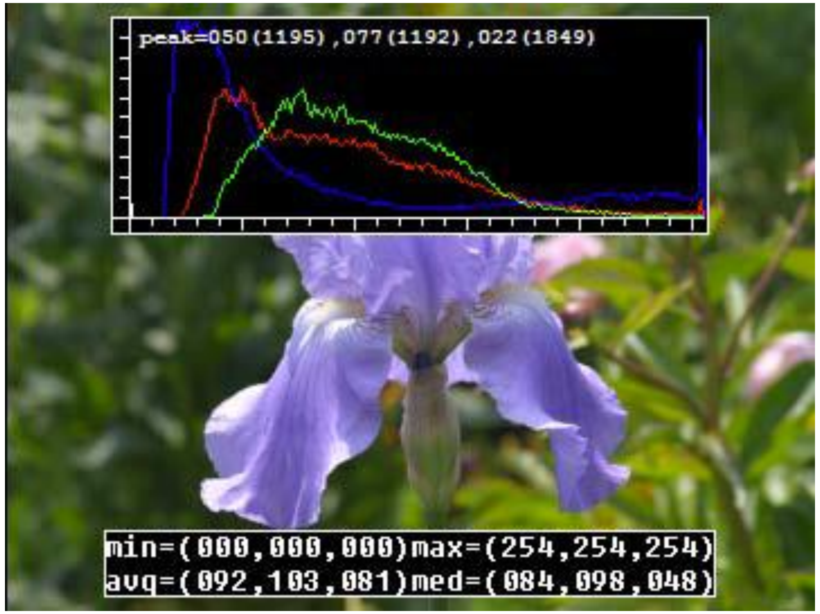
Bias

$$g(x,y) = 1.1.f(x,y) + 16$$



f(x,y)



g(x,y)

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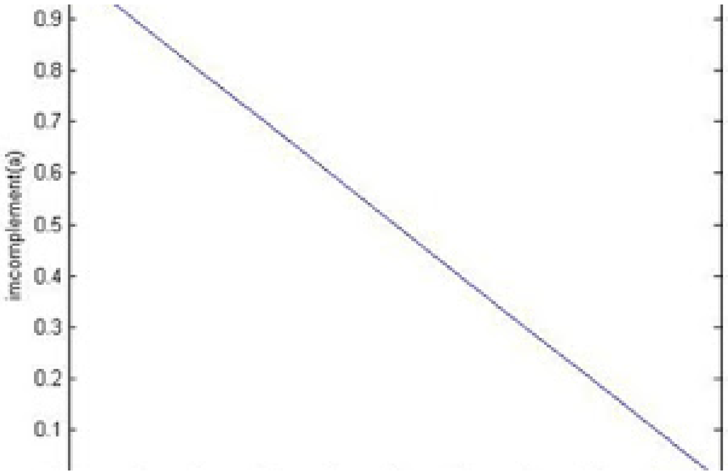
Negation

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





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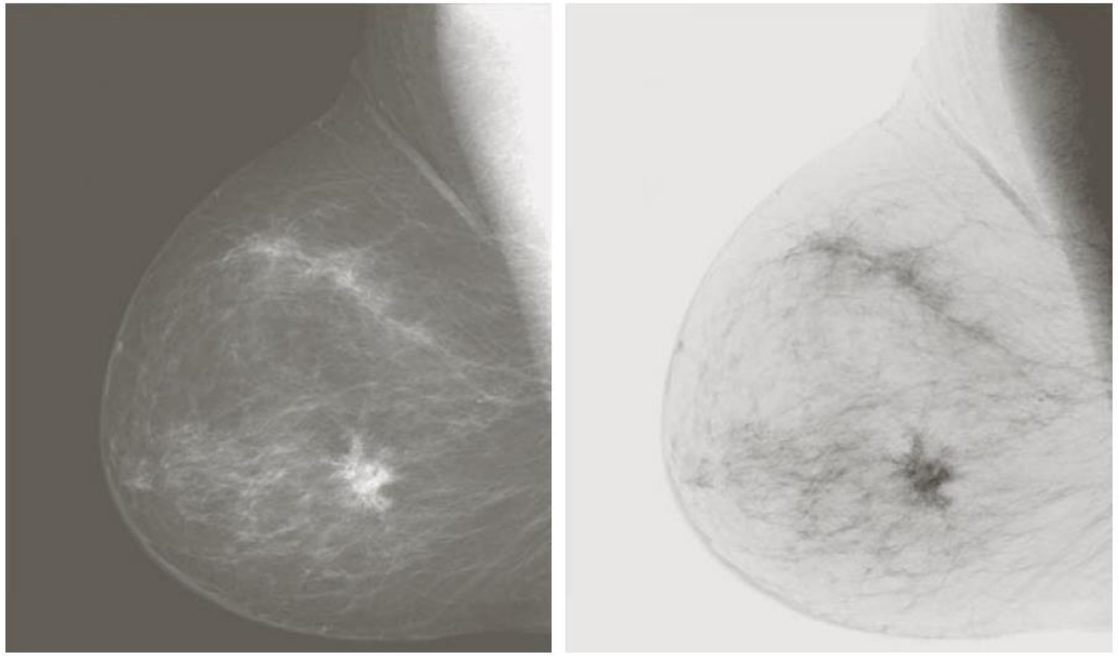
Negation

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



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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 transform 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

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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

Purpose

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

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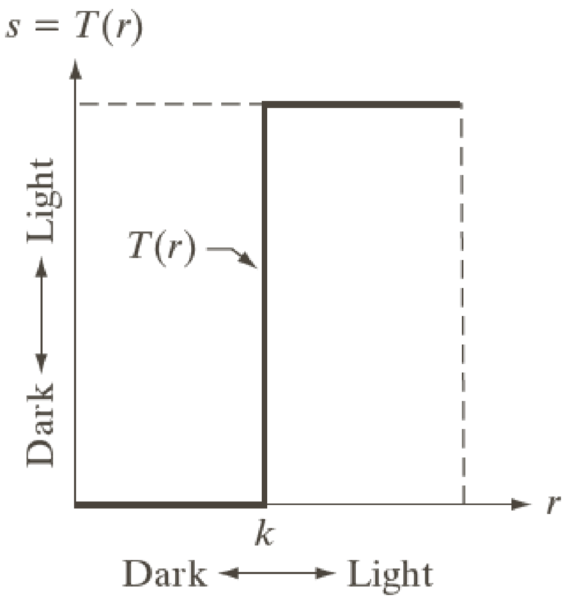
Non-linear Transform

Thresholding



Can be done to highlight grey levels, or as the simplest form of image segmentation

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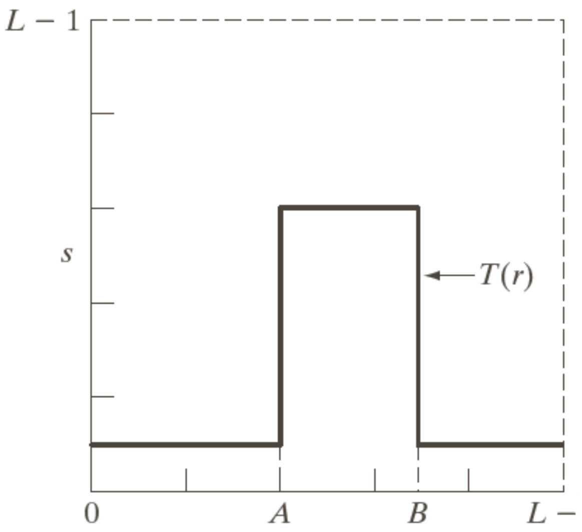
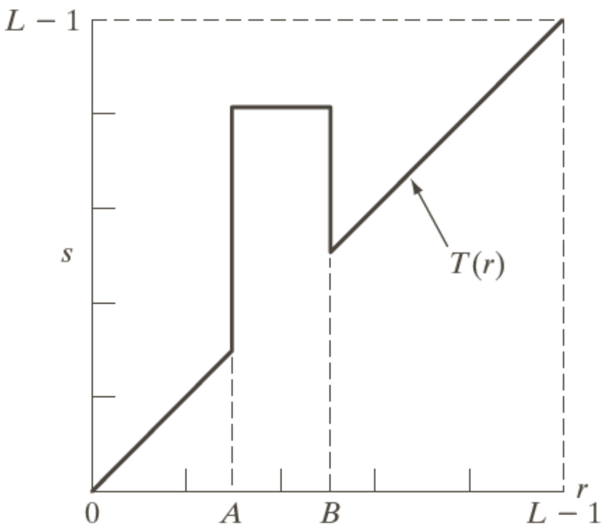
Grey Level Slicing

Highlights a specific range of intensities





Can reduce other grey levels to lower level…

…or preserve them

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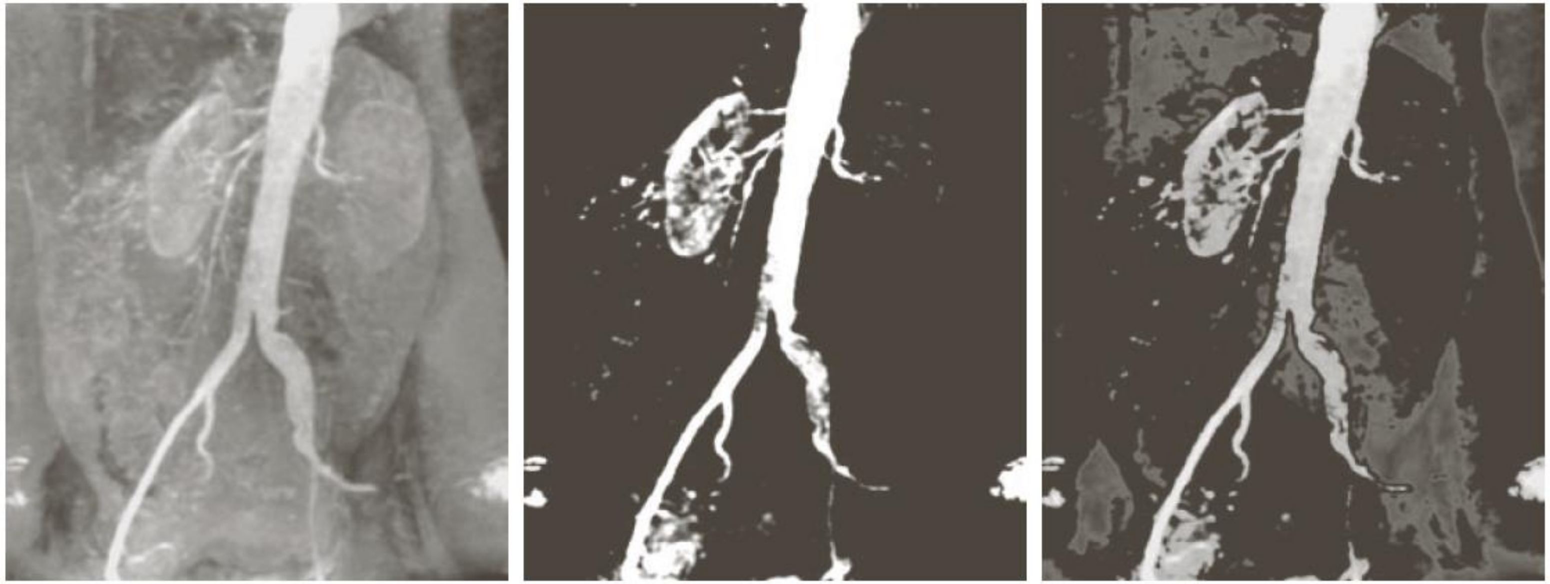
Grey Level Slicing



An aortic angiogram

High intensities selected, others reduced to low level

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

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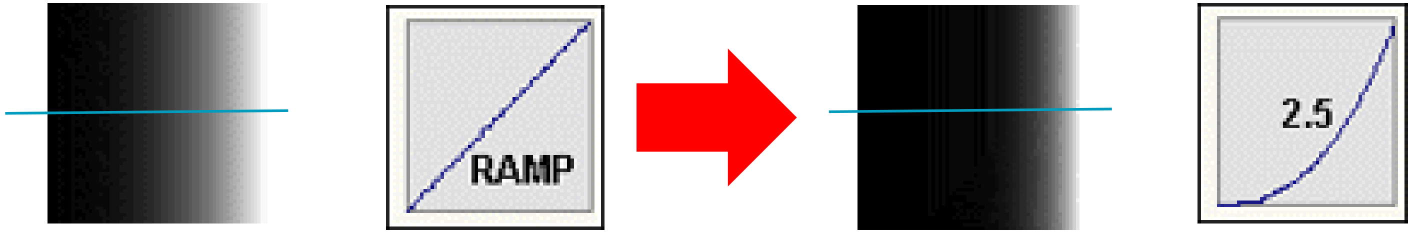
Gamma Correction

- 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

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

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Key Points

Point processes operate on each pixel independently

Linear processes change the appearance of the whole image

REMEMBER

Non-linear processes can differentiate object/image regions

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Summary

1. Digital Images Formation
2. Acquiring & Using Colour Images
3. Colour spaces
4. Intensity Transform

Questions

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NEXT:

Linear Filters