VC 18/19 – TP4
Colour and Noise

Mestrado em Ciência de Computadores

Mestrado Integrado em Engenharia de Redes e Sistemas Informáticos

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Outline

- Colour spaces
- Colour processing
- Noise

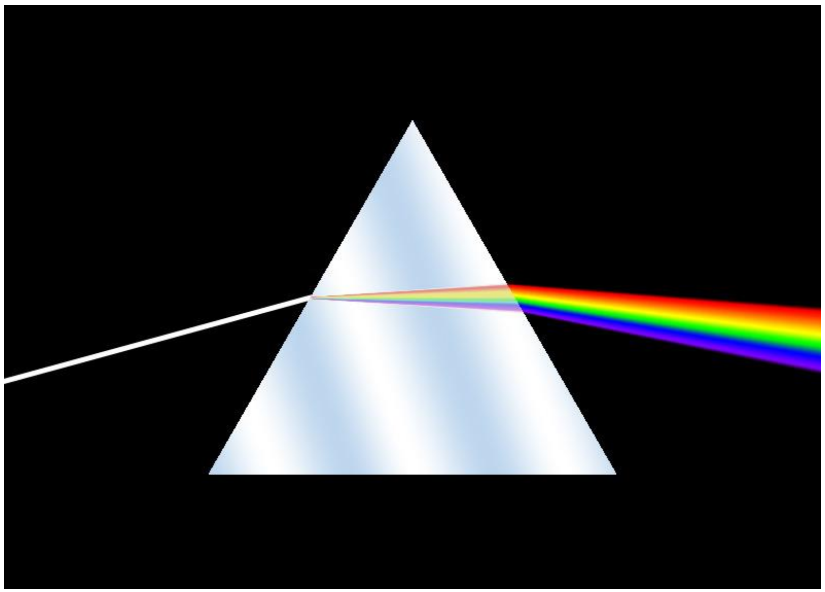
Topic: Colour spaces

- Colour spaces
- Colour processing
- Noise

For a long time I limited myself to one colour – as a form of discipline

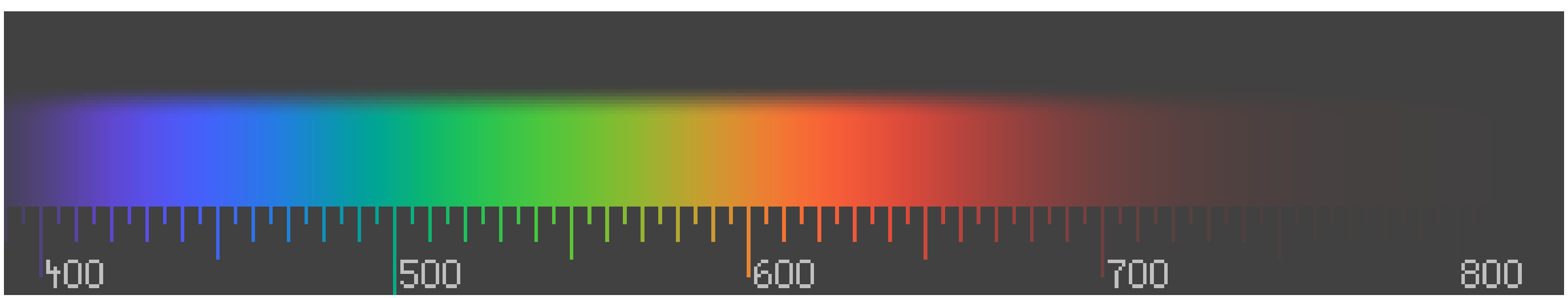
Pablo Picasso

What is colour?

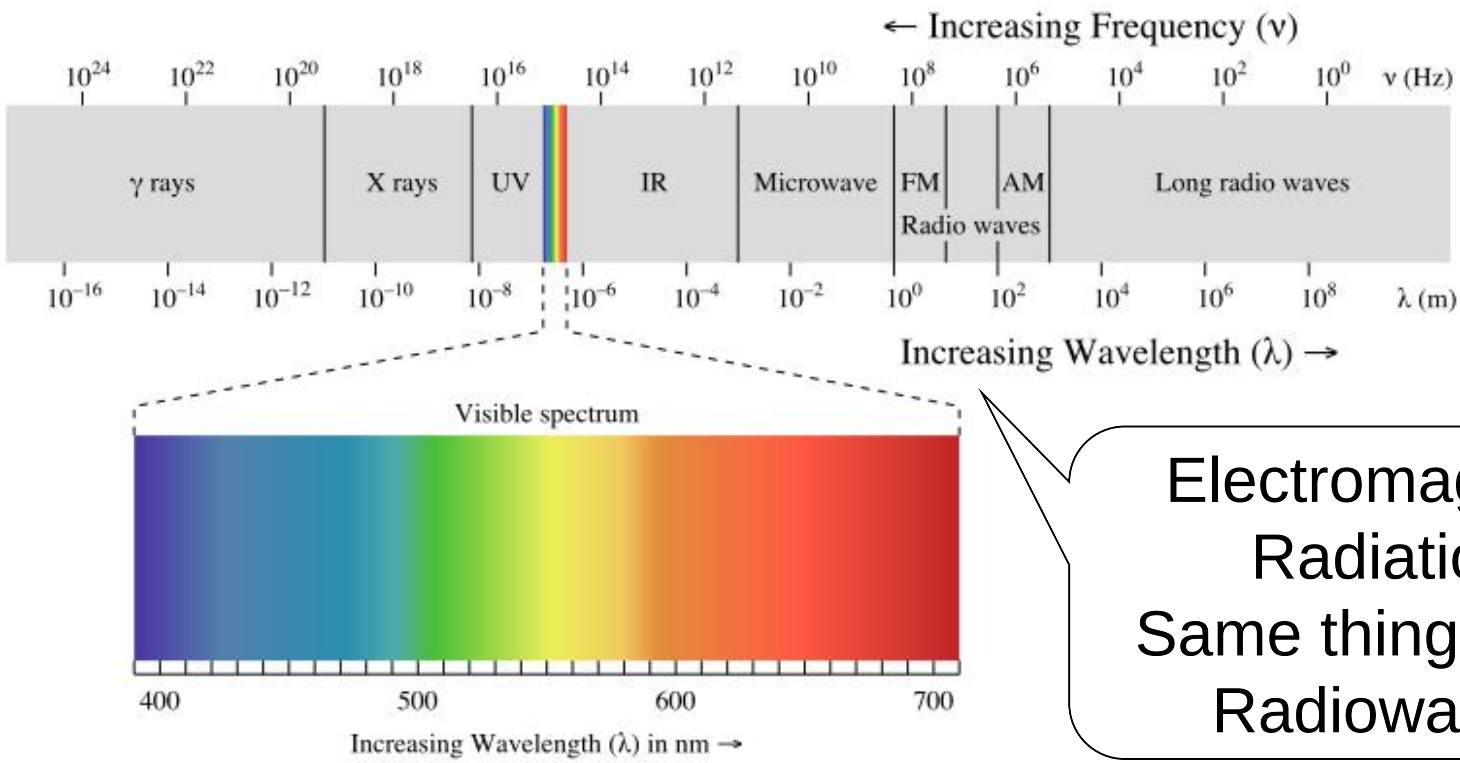


Optical Prism dispersing light

Visible colour spectrum



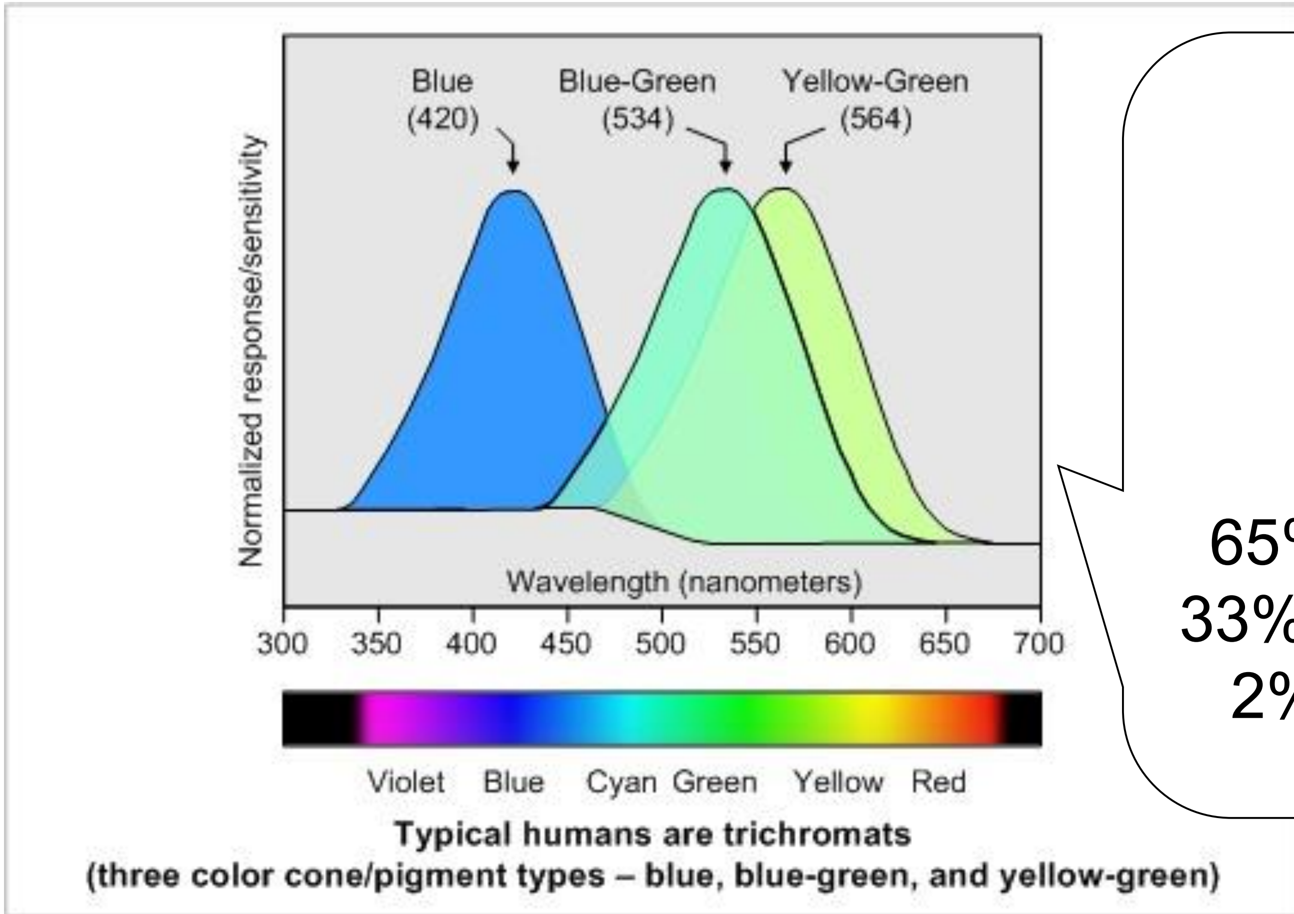
Visible Spectrum



Electromagnetic Radiation.
Same thing as FM Radiowaves!

http://science.howstuffworks.com/light.htm

How do we see colour?

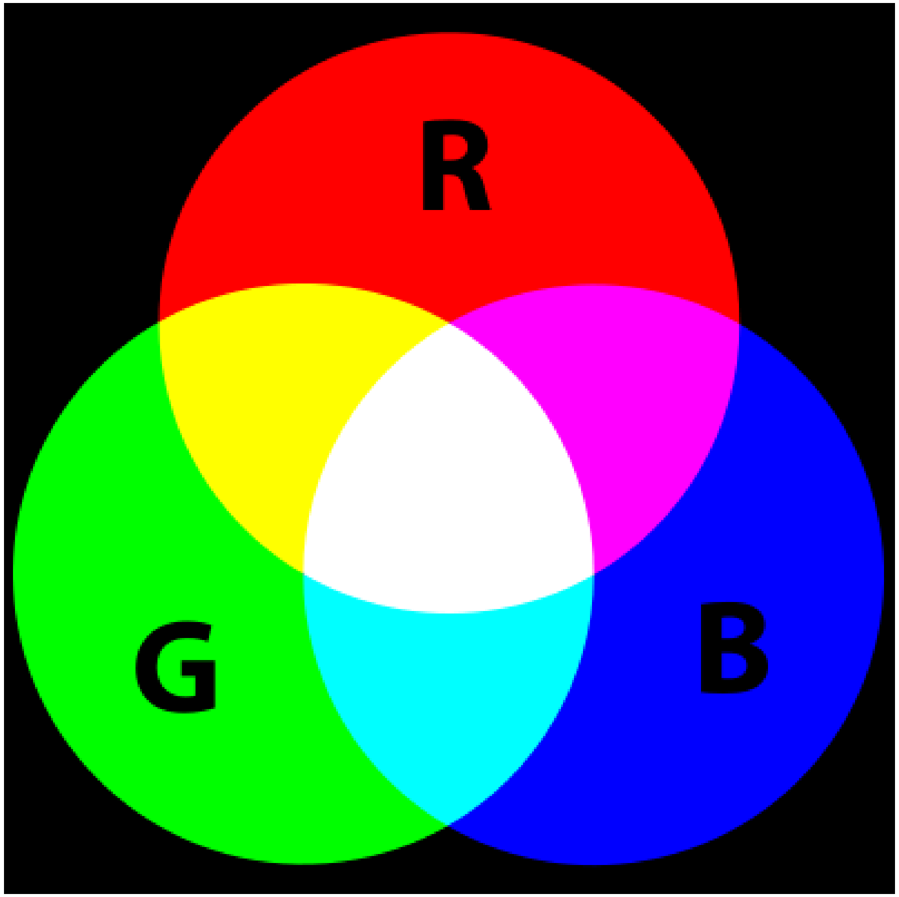


Human Colour Sensors: Cones

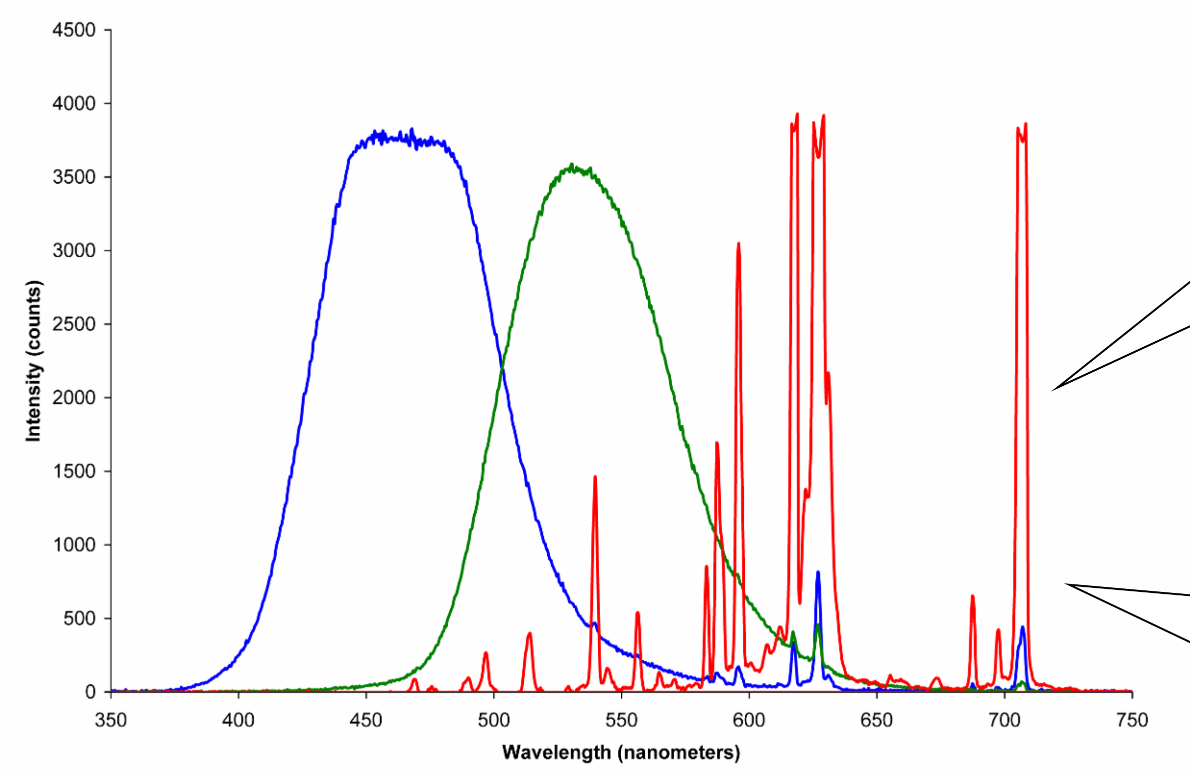
65% 'Red' cones
33% 'Green' cones
2%'Blue' cones

Primary Colours

- Not a fundamental property of light.
- Based on the physiological response of the human eye.
- Form an additive colour system.



Example: Television



Three types of phosphors very close together

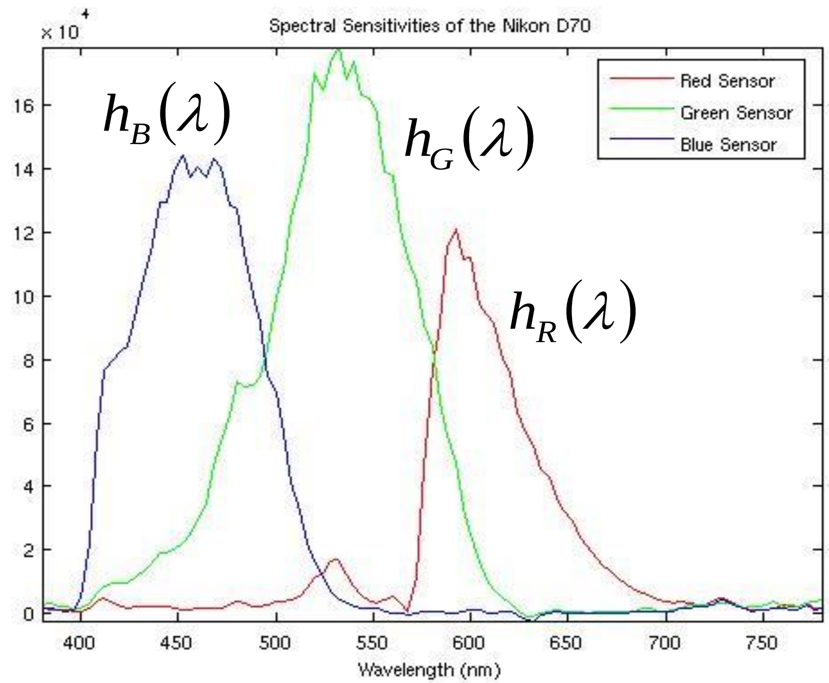
The components are added to create a final colour

http://www.howstuffworks.com/tv.htm

Sensing Colour

- Tristimulus (trichromatic) values (I_R, I_G, I_B)

Camera's spectral response functions: $h_R(\lambda), h_G(\lambda), h_B(\lambda)$



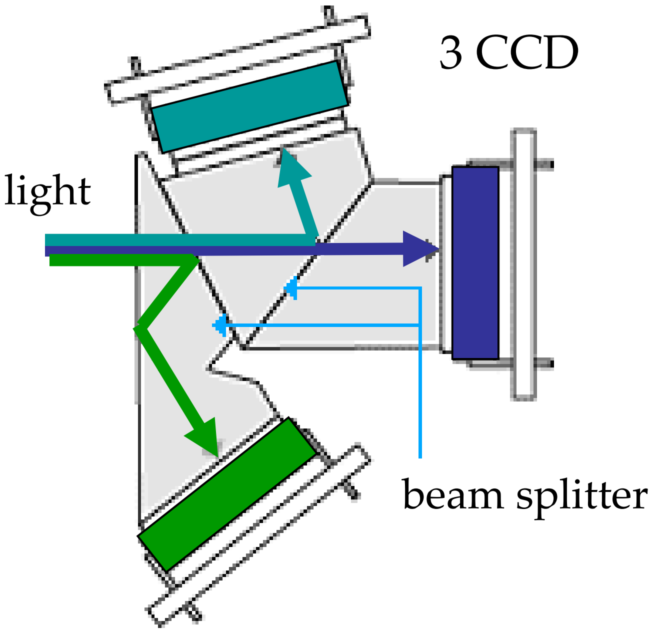
$$I_R = k \int_{-\infty}^{\infty} h_R(\lambda) p(\lambda) d\lambda$$

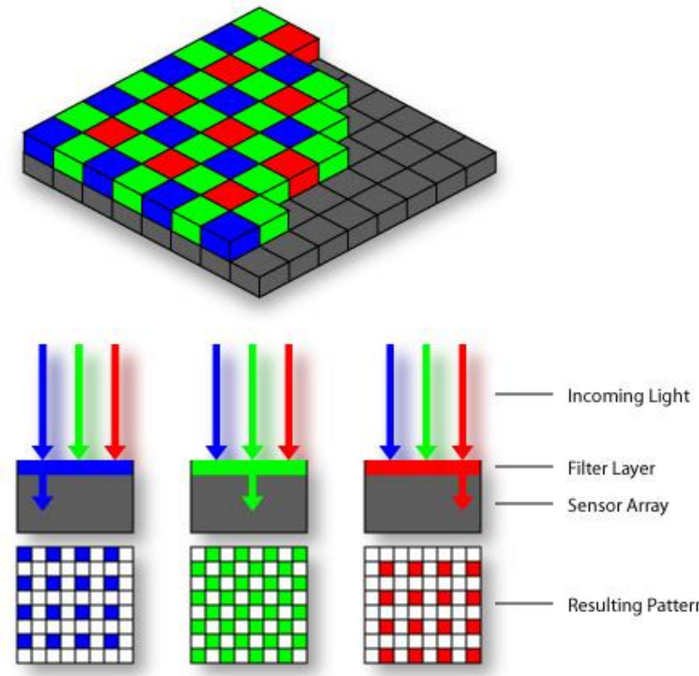
$$I_G = k \int_{-\infty}^{\infty} h_G(\lambda) p(\lambda) d\lambda$$

$$I_B = k \int_{-\infty}^{\infty} h_B(\lambda) p(\lambda) d\lambda$$

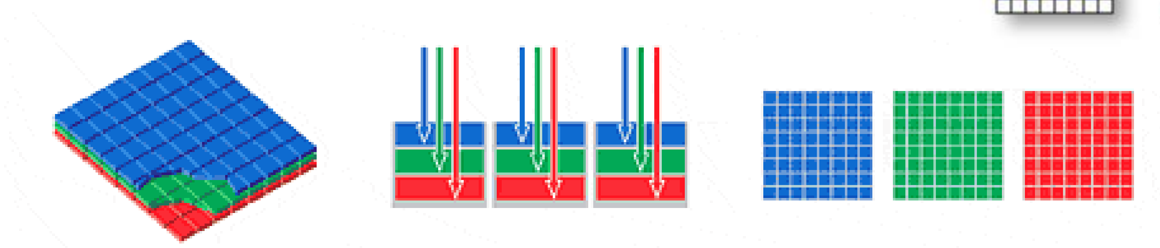
Sensing Colour

3 CCD





Bayer pattern



Foveon X3™

Colour Space

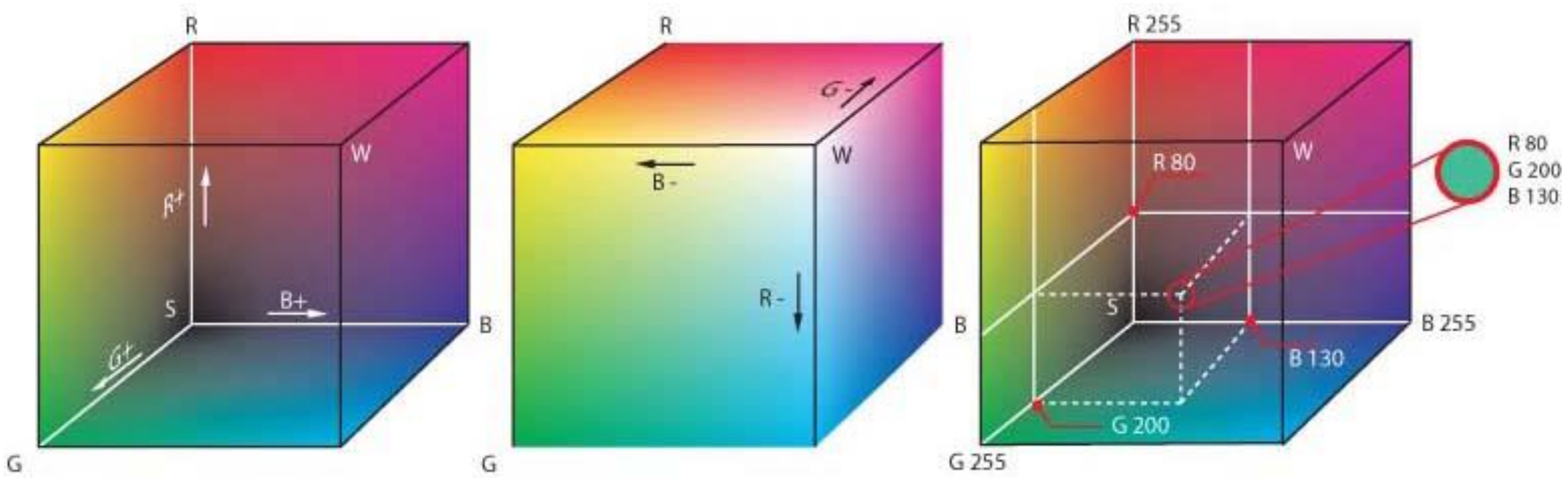
- “The purpose of a color model is to facilitate the specification of colours in some standard, generally accepted way”

  Gonzalez & Woods

- Colour space
  - Coordinate system
  - Subspace: One colour -> One point

RGB

- Red Green Blue
- Defines a colour cube.
- Additive components.
- Great for image capture.
- Great for image projection.
- Poor colour description.

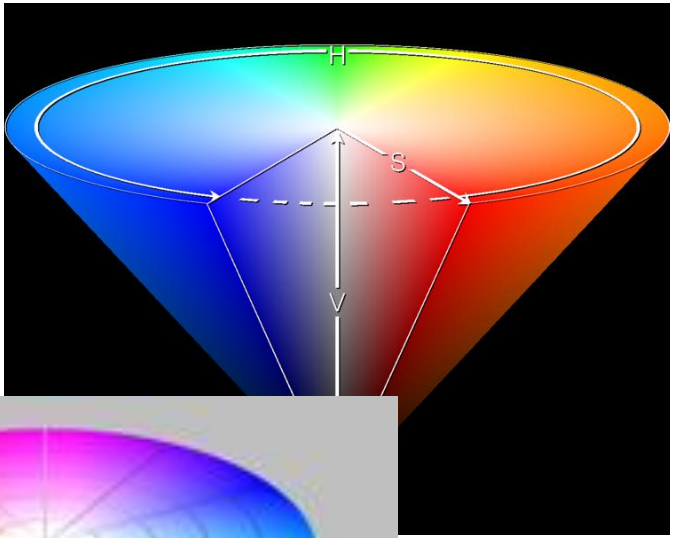


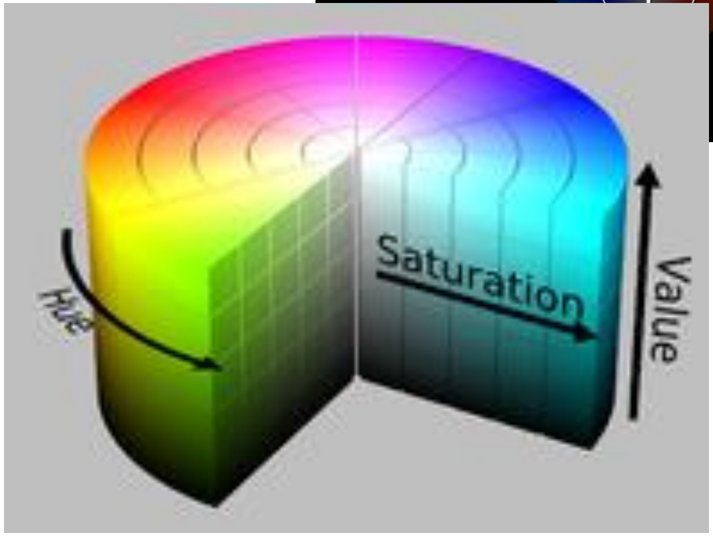
CMYK

- Cyan Magenta Yellow Key.
- Variation of RGB.
- Technological reasons: great for printers.

HSI

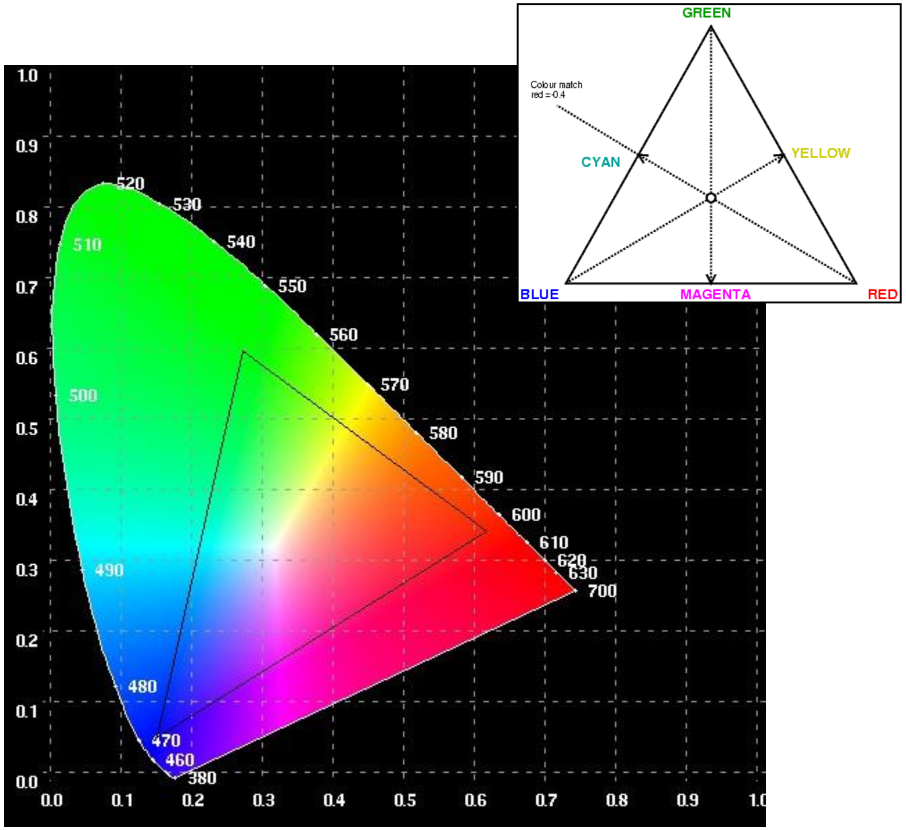
- Hue Saturation Intensity
- Defines a colour cone
- Great for colour description.





Chromaticity Diagram

- Axis:
  - Hue
  - Saturation
- Outer line represents our visible spectrum.
- No three primaries can create all colours!

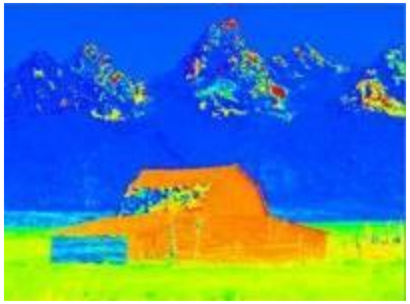


http://www.cs.rit.edu/~ncs/color/a_chroma.html

RGB to HSI

Hue:

$$H = \begin{cases} \theta & \Leftarrow B \le G \\ 360 - \theta & \Leftarrow B > G \end{cases}$$



$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\left[(R-G)^2+(R-B)(G-B)\right]^{1/2}} \right\}$$

Saturation

$$S = 1 - \frac{3}{(R+G+B)}\left[\min(R,G,B)\right]$$

Intensity

$$I = \frac{1}{3}(R+G+B)$$

HSI to RGB

- Depends on the 'sector' of H

0 <= H < 120

$$B = I(1-S)$$

$$R = I\left[1+\frac{S\cos H}{\cos(60^{o}-H)}\right]$$

$$G = 3I-(R+B)$$

120 <= H < 240

$$H = H - 120^{o}$$

$$R = I(1-S)$$

$$G = I\left[1+\frac{S\cos H}{\cos(60^{o}-H)}\right]$$

$$B = 3I-(R+B)$$

240 <= H < 360

$$H = H - 240^{o}$$

$$G = I(1-S)$$

$$B = I\left[1+\frac{S\cos H}{\cos(60^{o}-H)}\right]$$

$$R = 3I-(R+B)$$

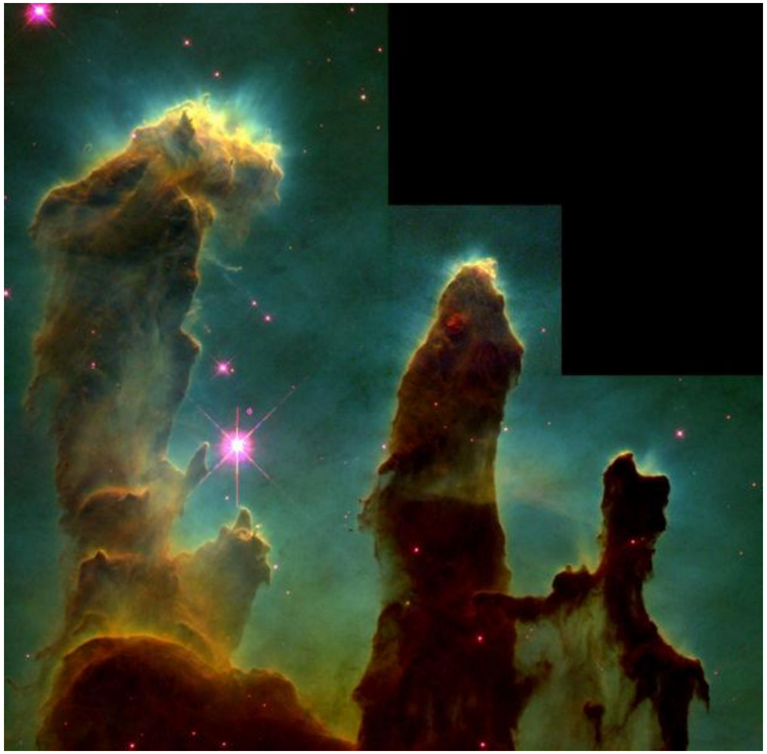
Topic: Colour processing

- Colour spaces
- Colour processing
- Noise

A WFPC2 image of a small region of the Tarantula Nebula in the Large Magellanic Cloud [NASA/ESA]

Pseudocolour

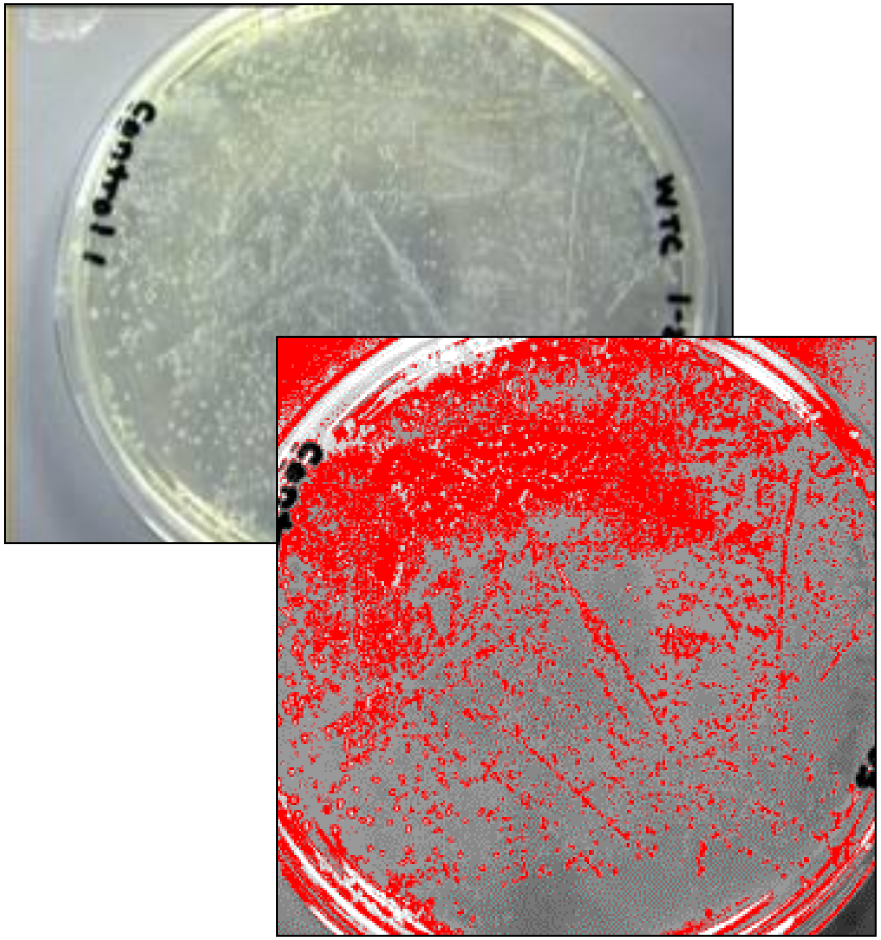
- Also called *False Colour*.
- Opposed to *True Colour* images.
- The colours of a pseudocolour image do not attempt to approximate the real colours of the subject.

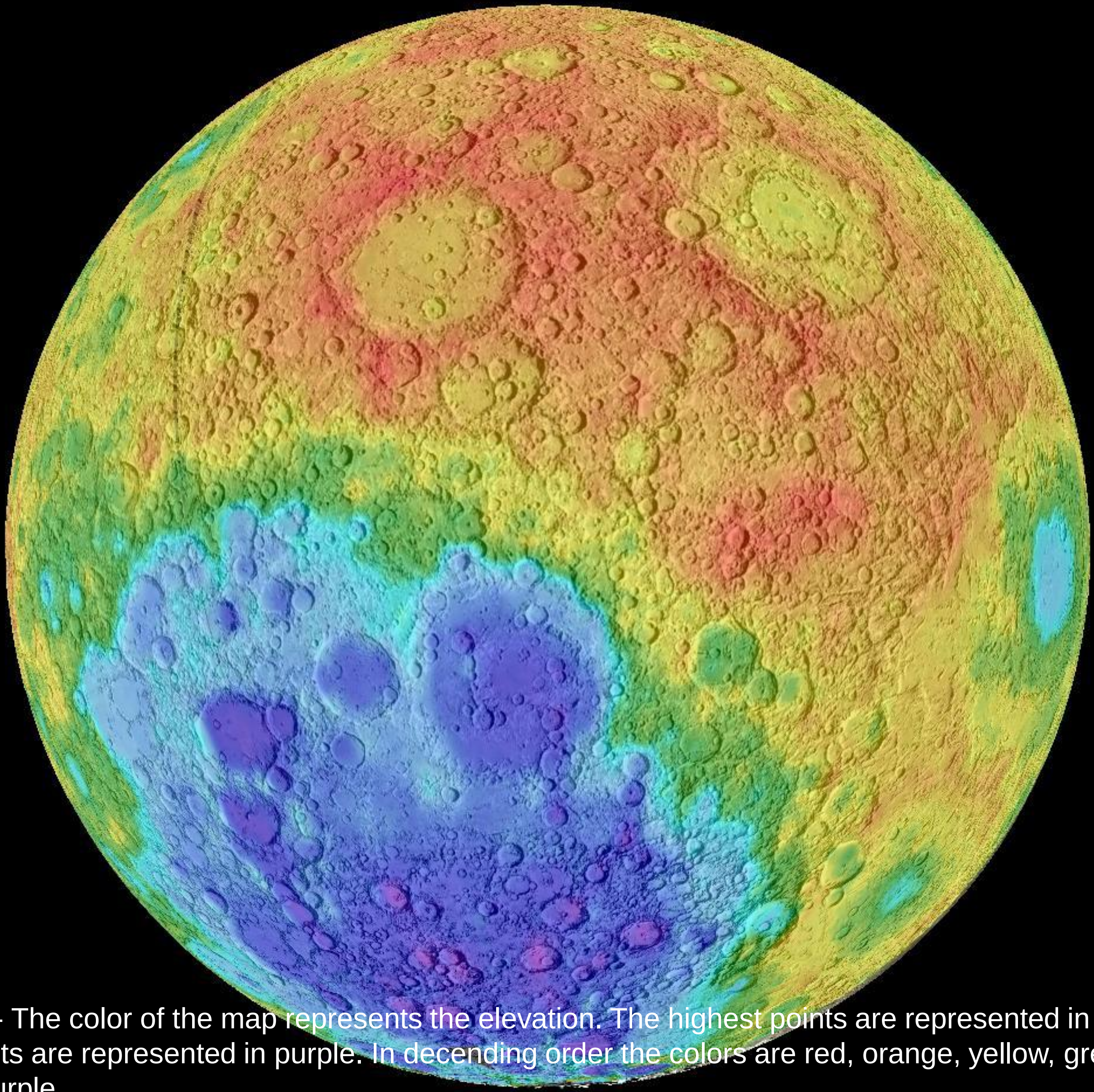


One of Hubble's most famous images: “pillars of creation” where stars are forming in the Eagle Nebula. [NASA/ESA]

Intensity Slicing

- Quantize pixel intensity to a specific number of values (*slices*).
- Map one colour to each *slice*.
- Loss of information.
- Enhanced human visibility.

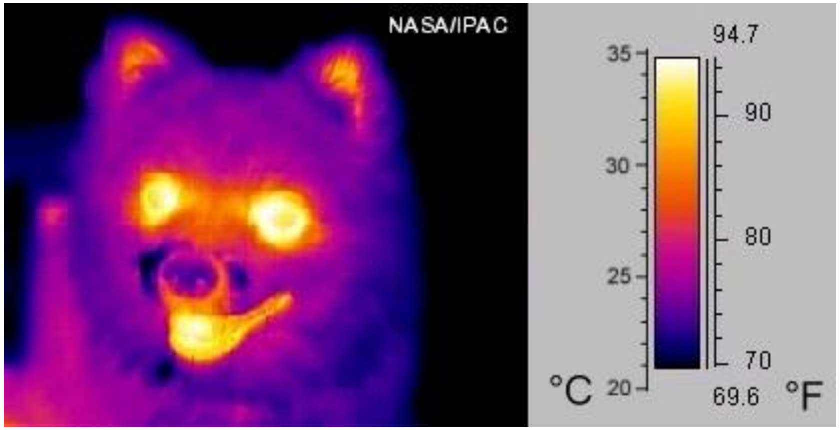


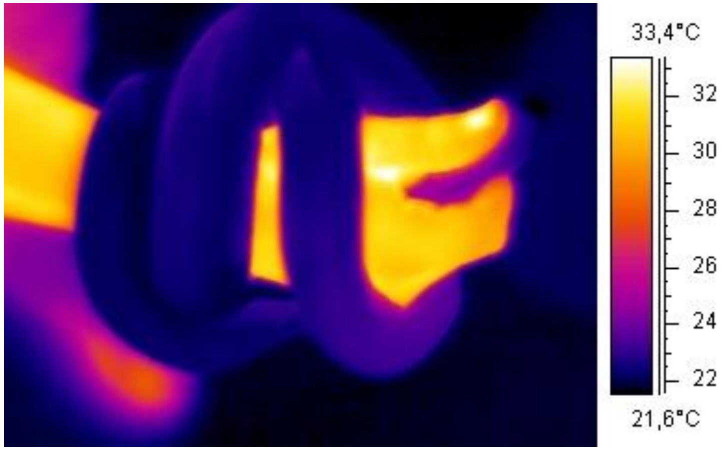


The Moon - The color of the map represents the elevation. The highest points are represented in red. The lowest points are represented in purple. In decending order the colors are red, orange, yellow, green, cyan, blue and purple.

Intensity to Colour Transformation

- Each colour component is calculated using a transformation function.
- Viewed as an Intensity to Colour map.
- Does not need to use RGB space!





$$f(x,y) \Rightarrow \begin{cases} f_R(x,y) = T_R\left[f(x,y)\right] \\ f_G(x,y) = T_G\left[f(x,y)\right] \\ f_B(x,y) = T_B\left[f(x,y)\right] \end{cases}$$

A supernova remnant created from the death of a massive star about 2,000 years ago.

http://chandra.harvard.edu/photo/false_color.html

http://landsat.gsfc.nasa.gov/education/compositor/

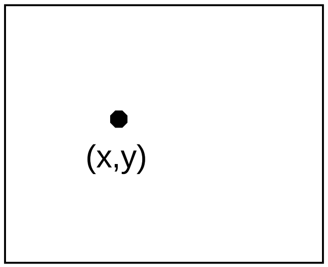
Colour Image Processing

- Grey-scale image
  - One value per position.

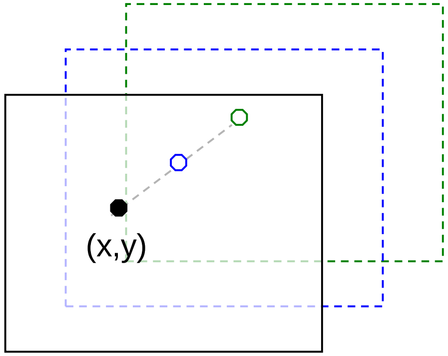
    $f(x,y) = I$

- Colour image
  - One vector per position.

    $f(x,y) = [R\ G\ B]^T$



Grey-scale image



RGB Colour image

Colour Transformations

- Consider single-point operations:

  T_i: Transformation function for colour component *i*

  s_i, r_i: Components of *g* and *f*

$$g(x,y) = T\left[f(x,y)\right]$$

$$s_i = T_i(r_1, r_2, \ldots, r_n)$$

$$i = 1,2,\ldots,n$$

- Simple example:
  - Increase Brightness of an RGB image

$$s_R = r_R + 20$$

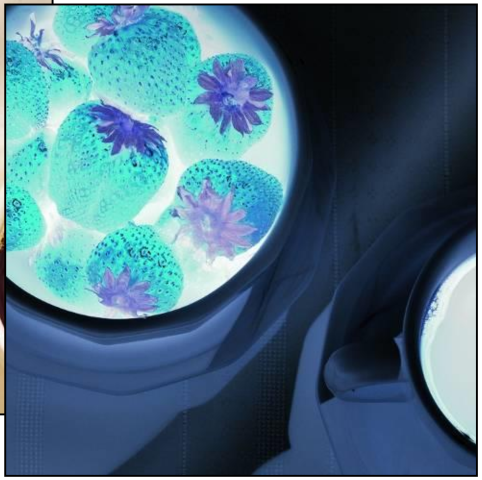
$$s_G = r_G + 20$$

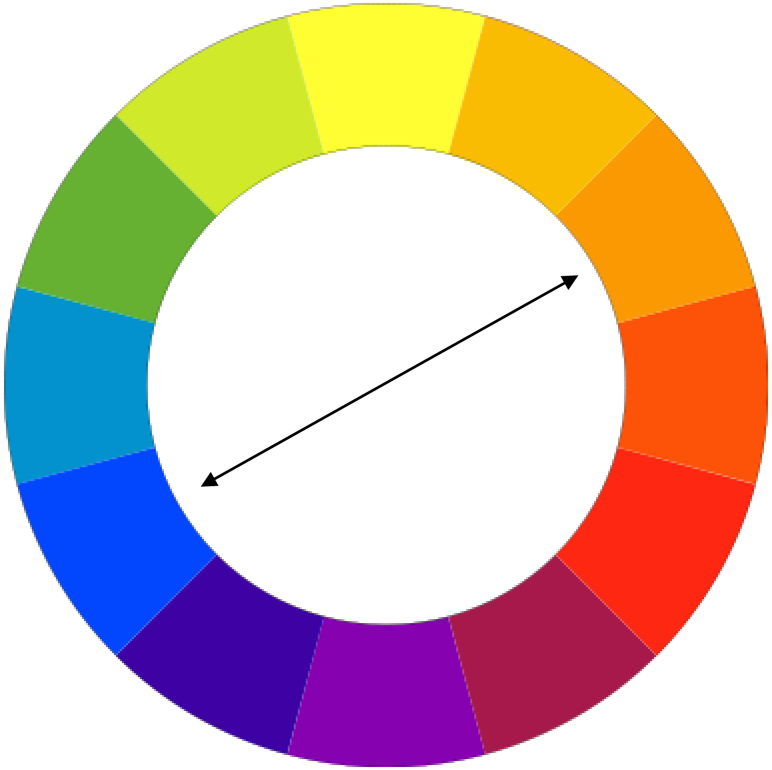
$$s_B = r_B + 20$$

What about an image negative?

Colour Complements

- Colour equivalent of an image negative.





Complementary Colours

Colour Slicing

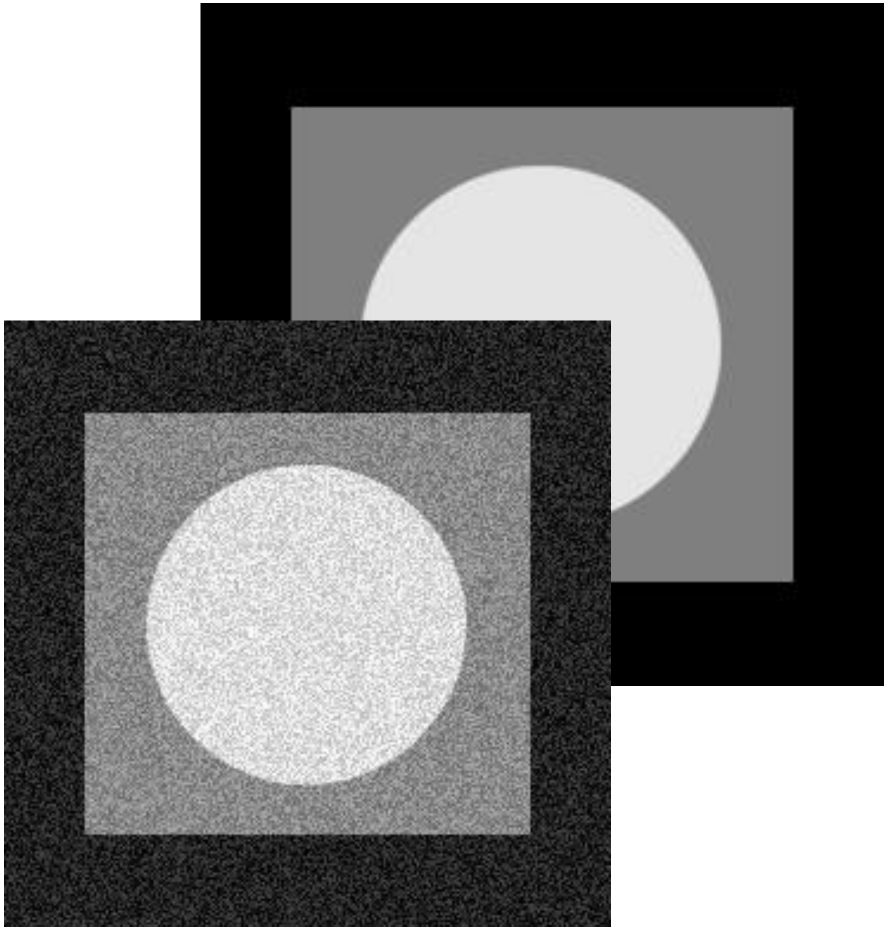
- Define a hyper-volume of interest inside my colour space.
- Keep colours if inside the hyper-volume.
- Change the others to a neutral colour.

Topic: Noise

- Colour spaces
- Colour processing
- Noise

Bring the Noise

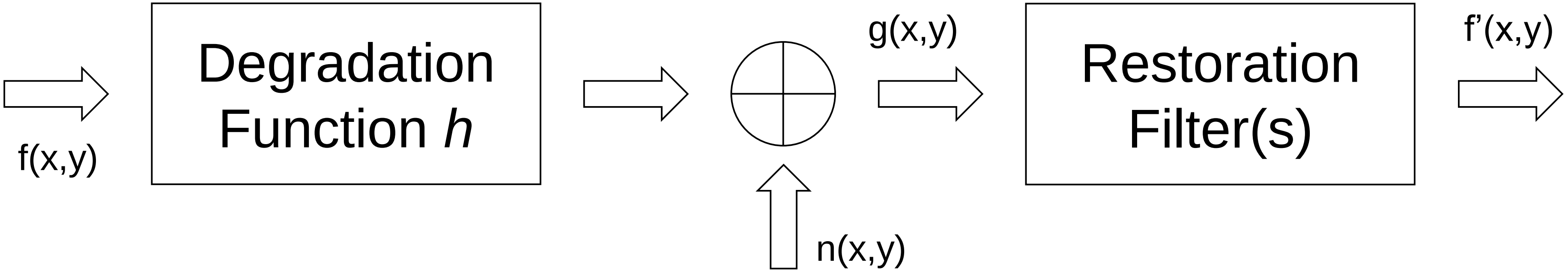
- Noise is a distortion of the measured signal.
- Every physical system has noise.
- Images:
  - The importance of noise is affected by our human visual perception
  - Ex: Digital TV ‘block effect’ due to noise.



Where does it come from?

- ‘Universal’ noise sources:
  - Thermal, sampling, quantization, measurement.
- Specific for digital images:
  - The number of photons hitting each images sensor is governed by quantum physics: *Photon Noise.*
  - Noise generated by electronic components of image sensors:
    - *On-Chip Noise*, *KTC Noise*, *Amplifier Noise*, etc.

Degradation / Restoration



$$g(x,y) = h(x,y) * f(x,y) + n(x,y)$$

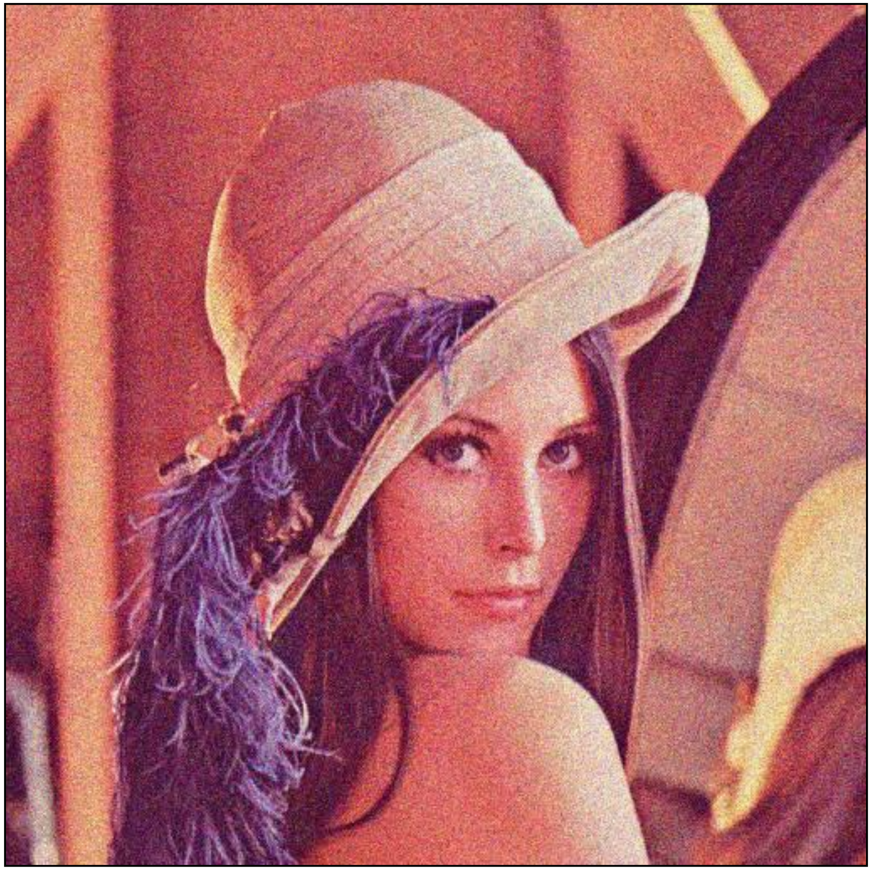
$$G(u,v) = H(u,v)F(u,v) + N(u,v)$$

Noise Models

- Noise models
  - We need to mathematically handle noise.
  - Spatial and frequency properties.
  - Probability theory helps!
- Advantages:
  - Easier to filter noise.
  - Easier to measure its importance.
  - More robust systems!

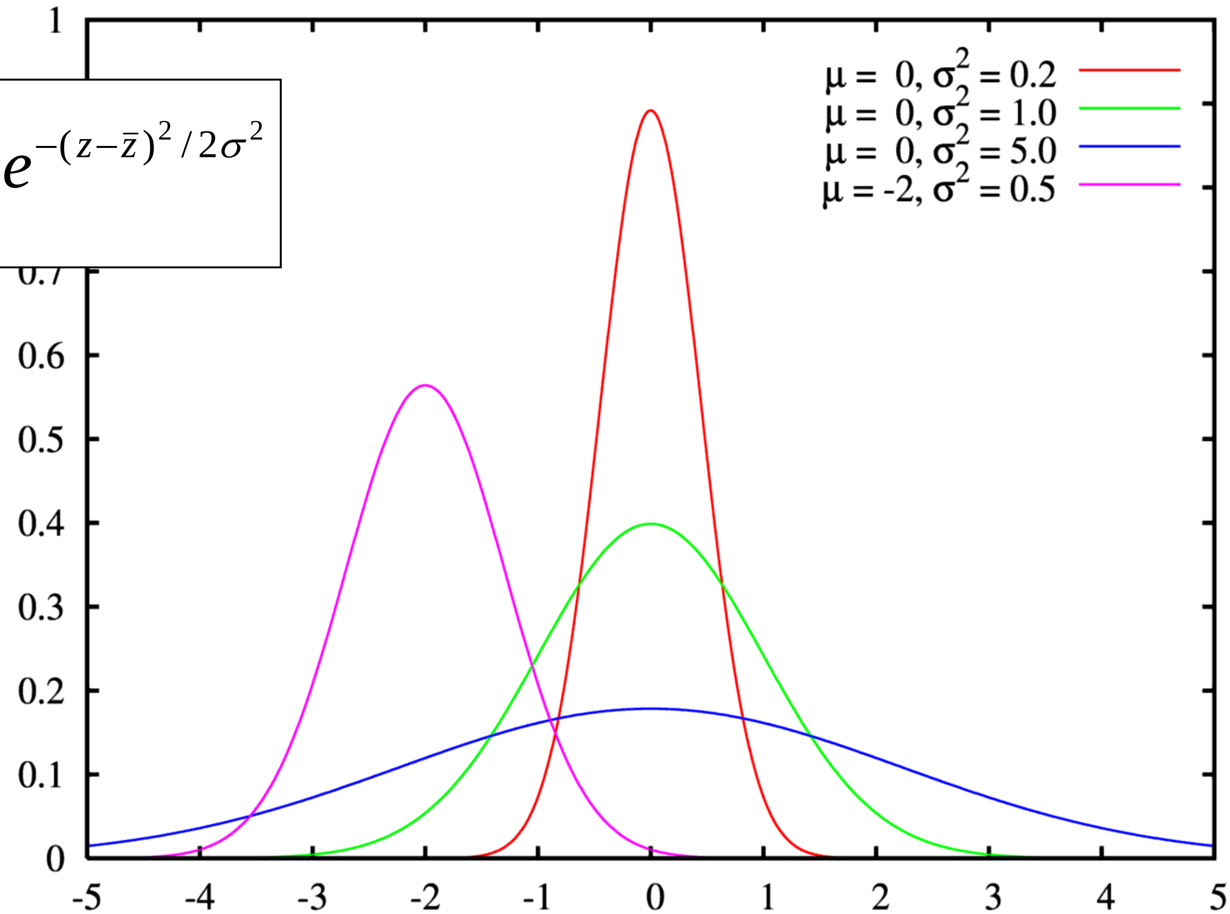
Model: Gaussian Noise

- Gaussian PDF (Probability Density Function).
- Great approximation of reality.
  - Models noise as a sum of various small noise sources, which is indeed what happens in reality.



Model: Gaussian Noise

$$p(z) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(z-\bar{z})^2/2\sigma^2}$$



Model: Salt and Pepper Noise

- Considers that a value can randomly assume the MAX or MIN value for that sensor.
  - Happens in reality due to the malfunction of isolated image sensors.

How do we handle it?

- Not always trivial!
  - Frequency filters.
  - Estimate the degradation function.
  - Inverse filtering.
  - ...

One of the greatest challenges of signal processing!

Resources

- Gonzalez & Woods – Chapters 5 and 6
- http://www.howstuffworks.com/