Lec 2 Colour

Outline

- [ ] Colour Physics
- [ ] Colour Perception and Colour matching

Colour Physics

Simplified rendering models:

illumination * reflectance = colour signal

- The colour signal we see or capture is a product of the interaction between the illumination (lighting conditions) and the reflectance (how the light reflects) properties of the object/material.
-

Illumination * transmittance = colour signal

- The colour signal we see or capture is a product of the interaction between the illumination (lighting conditions) and the transmittance (how light passes through) properties of the object/material.

The human vision can be optimised for spectrum from the sun → greatest intensity at ~500 nm

Reflectance spectra: reflectance (0 to 1) as a function of wavelength. Eyes (and cameras) simplify this signal by reducing it to intensity detected via three types of sensors and hence, objects with different spectral albedoes may be perceived as having the same colour (metamerism).

Additive colour mixing:

- Colours are combined by ***adding*** the colour spectra → CRT phosphors, multiple projectors aimed at a screen, Polachrome slide film
- Red + Green = Yellow

Subtractive colour mixing:

- Colours combine by ***multiplying*** the colour spectra → photographic films, paint, cascaded optical filters, crayons
- Cyan + Yellow = Green

Colour Perception and Colour Matching

The Human Eye

- **Spectral Resolution** → 400(violet) - 700 nm (red)
- **Dynamic Range** → ~10^8 : 1
- **Spatial Resolution** → ~1-3 cm @ 20 m
- **Radiometric Resolution** → ~ 16-32 shades B&W, ~ 100 colours

Physiology

Light enters eye → focused by cornea and lens → strikes retina (back of eye)

- Retina includes 2 types of cells → simulated by visible light
    - Rods
    - Cones

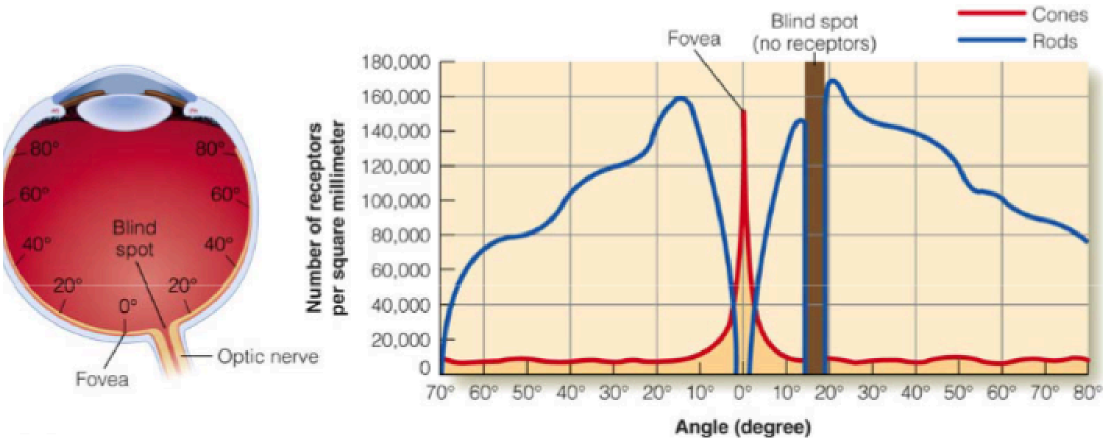
Cones

- **See** colour → 74% Red, 10% Green & 16% Blue
- ~6.5 Million

- High resolution → closely packed
- Cones dominate in **light-adapted** (daylight) vision, known as **photopic** vision
- Not sensitive to intensity compared to rods → they responds to visible wavelengths → perception of colour
- Shorter and thicker than rods

Rods

- **Don't see** colour
- ~100 Million
- Excited by single photon and respond to higher frequencies (blue/green)
- Peripheral & night vision
- Rods cominate in **dark-adapted** (night) vision, known as **scotopic**.
- Scotopic is most active in short wavelengths → reason for things appearing blue in the dark
- Long and slender receptors



- Rods and Cones are not distributed evenly around the retina.
    - Density of cones is greatest at the fovea → for sharp vision
    - Brown bar contains no receptors → where the ganglion cells leave the eye to form optic nerve
- The eye indicates the locations in degrees relative to the fovea

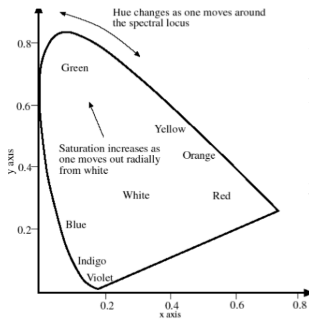
Brain and Processing

- LGN (part of the thalamus) → relays signals from left visual field of each eye to the visual cortex and vice-versa
- Optic nerve bundle contains 800,000 nerve fibres → 100 millions are receptors in the retina → rods and cones interconnected to nerve fibres on many-to-one basis

Colour Spaces

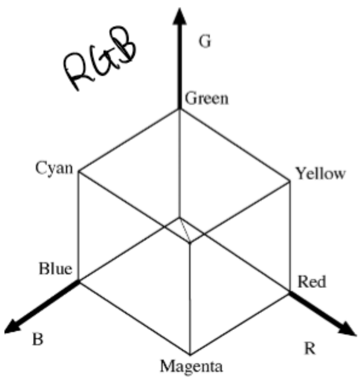
CIE XYZ Colour Space

- All colour sensations that are visible to a person's eyesight
- Do not describe the way light interacts in reality → but simplify it according to humans eye perceives
- Mathematical model that represents colours using X,Y,Z
- Y → luminance (brightness), X & Z capture chromaticity (colour information) of the light
- Not suitable for computer vision



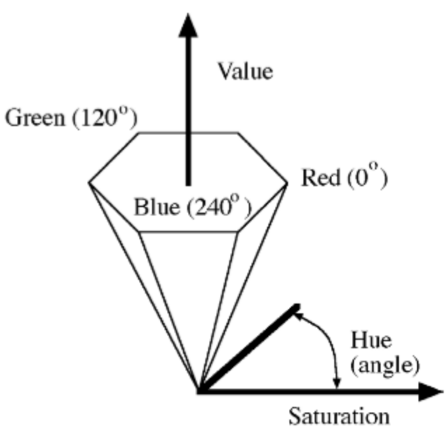
RGB Colour Space

- R (red), G (Green), B (Blue) → primary additive colours used in digital display & imaging systems
- Additive model where different intensities of red, green & blue light are combined to create wide range of colours
- RGB colour space is **device-dependent** → representation can vary between different devices (i.e. monitors, camera, printers)



HSV Colour Space

- HSV (Hue, Saturation, Value)
- Hexcone:
    - Hue form circle around central axis
    - Saturation varies along radius
    - Value changes along vertical axis
- Intuitive for **colour selection and manipulation** → allow users to adjust hue for different colours → saturation for vividness → value for brightness
- Used in graphics software and colour picker; for artists and designers



Past Exam Questions:

- How do pixels in a camera differ from the photoreceptors in the human retina in terms of colour space and the distribution of colour, sensitivity, and resolution? (Use diagrams in your answer)

- **Spectral Resolution.** Humans can perceive 10 octaves of sound frequencies, from 20Hz to 20kHz. State the approximate spectral resolution (wavelength in nm) that humans can perceive

- **Dynamic Range.** The difference in intensity between the softest perceivable sound and the loudest sound that can be tolerated without pain is a ratio of 109 :1. State the approximate visual dynamic range (as a ratio) that humans can perceive in regards to the difference between the lowest perceptible light intensity and the highest intensity we can tolerate without glare.

- **Spatial Resolution.** State the approximate number of centimetres spatial resolution that humans can perceive at 20 metres.

- **Radiometric Resolution.** Regardless of our spectral resolution and dynamic range, most humans can only reliably distinguish between a limited number of colours and shades of grey. State the approximate number of colours and the approximate number of shades of grey that humans can reliably distinguish between (when placed in a graduated scale on the same page).

- Describe the three colour spaces, CIE, RGB and HSV, using diagrams and explain their respective strengths and weaknesses and where and how they are most commonly used.