Application 1
Vision & Color

Human Vision
LGN: Lateral Geniculate Nucleus

Human Eye
- Cornea: a transparent, bumpy surface is smooth
- Vitreous Body: surrounds all ganglion cells as they pass through the optic disc and to the brain; has no photoreceptors.
- Aqueous: water, a jellylike substance between the cornea and lens
- Lens: a transparent, bumpy structure
- Retina: a membrane
- Fovea: small area
- Pupil: the hole
- Iris: a pinkish, circular object

Accommodation
- Changes in the lens shape and position with accommodation.
- Eyes can change the shape of the lens to alter the focal length of the eye, allowing for near vision and far point.
- Distance of the object from the eye is the range of accommodation.
- The range of accommodation is constant, but changes with age.
- Range of accommodation decreases with age.
Myopia and Hyperopia

- Myopia 近視
- Hyperopia 遠視

Retina

- Retina：網膜，影像形成之處，主要是感光細胞組成 light sensitive cells，rods and cones

Rods and Cones

- Rods：感光度較高，在low light levels時作用，在fovea(小凹)附近密度最高，可以約100個rods的訊號匯集一起送到神經細胞，所以極敏感，但解析度差。
- Cones：解析度高，但感光性較差(大於1lux)，有色彩分析能力，有三種感光cones，其波長 peak sensitivity 分別在420(S)、534(M)及564(L)nm。在夜間，沒有色彩，因cones不感光→黃昏的浪漫夜。
Rods and Cones

- The relative sensitivity of rods and cones as a function of wavelength.

![Graph showing the relative sensitivity of rods and cones.](image)

Rods and Cones

- Spectral Response of Rods and S-, M-, L-Cones
  - 498 (Rods) nm
  - 420 (S-Cones), 534 (M-Cones), 564 (L-Cones) nm

- Density of Rods and Cones
  - Fovea: only M- and L-Cones; no S-Cones and Rods

![Graph showing normalized absorbance and wavelength](image)

Color Deficiency

- Color Deficiency

![Graphs showing normal trichromat, anomalous trichromat, and dichromat](image)
Mixing Colored Light
Color Addition

- Additive Primary Colors:
  - Red
  - Green
  - Blue

The beams of red, green, and blue flashlights mixed together create other colors. All three together create white. This is the basis for RGB color systems.

Mixing Colored Pigments
Color Subtraction

- Subtractive Primary Colors:
  - Cyan
  - Magenta
  - Yellow
  - Black (optional)

Mixing Color

- Why blue + yellow pigment yields green color?

![Graph showing wavelength and reflection](image)

Primary Colors

- White
- Red
- Green
- Blue
- Yellow
- Cyan
- Magenta
Complementary Colors

- Complementary Colors - any two colors that add together to produce white
  e.g. magenta + green = white

CIE Color Matching Function

CIE: Commission Internationale d’Eclairage

CIE x(λ), y(λ), z(λ)
Tristimulus values of color: XYZ

\[ S(\lambda) \]

\[ R(\lambda) \]

\[ \bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda) \]

\[ X = \sum_{\lambda=400nm}^{700nm} S(\lambda) R(\lambda) \bar{x}(\lambda) \]

\[ Y = \sum_{\lambda=400nm}^{700nm} S(\lambda) R(\lambda) \bar{y}(\lambda) \]

\[ Z = \sum_{\lambda=400nm}^{700nm} S(\lambda) R(\lambda) \bar{z}(\lambda) \]

CIE Chromaticity Chart

\[ x = \frac{X}{X+Y+Z} \]

\[ y = \frac{Y}{X+Y+Z} \]

\[ z = 1 - x - y \]

Color Mixing

- Color Mixing: any given color can be reproduced by mixing any combination of colors on the chromaticity chart.

Color Temperature

![Diagram of color temperature and color mixing](image)