Exercise II
Image Formation

Digital Photography

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Image Formation

$$C = \int_{\lambda} E(\lambda)S(\lambda)R(\lambda)\mathrm{d}\lambda$$

Image Formation

$$C = \int_\lambda E(\lambda) S(\lambda) R(\lambda) \mathrm{d}\lambda$$

color

illuminant

reflectance

sensor

Image Formation

$$C = \int_\lambda E(\lambda) S(\lambda) R(\lambda) \mathrm{d}\lambda$$

color

illuminant

reflectance

sensor

The value of **one** pixel with **one** sensor.

Image Formation
(Multiple Sensors)

Example: color imaging

$$\text{Red} = \int_\lambda E(\lambda)S(\lambda)R_{\text{red}}(\lambda)\mathrm{d}\lambda$$

$$\text{Green} = \int_\lambda E(\lambda)S(\lambda)R_{\text{green}}(\lambda)\mathrm{d}\lambda$$

$$\text{Blue} = \int_\lambda E(\lambda)S(\lambda)R_{\text{blue}}(\lambda)\mathrm{d}\lambda$$

Image Formation
(Simulation in Computer)

Image Formation
(Simulation in Computer)

Discretize the electromagnetic spectrum

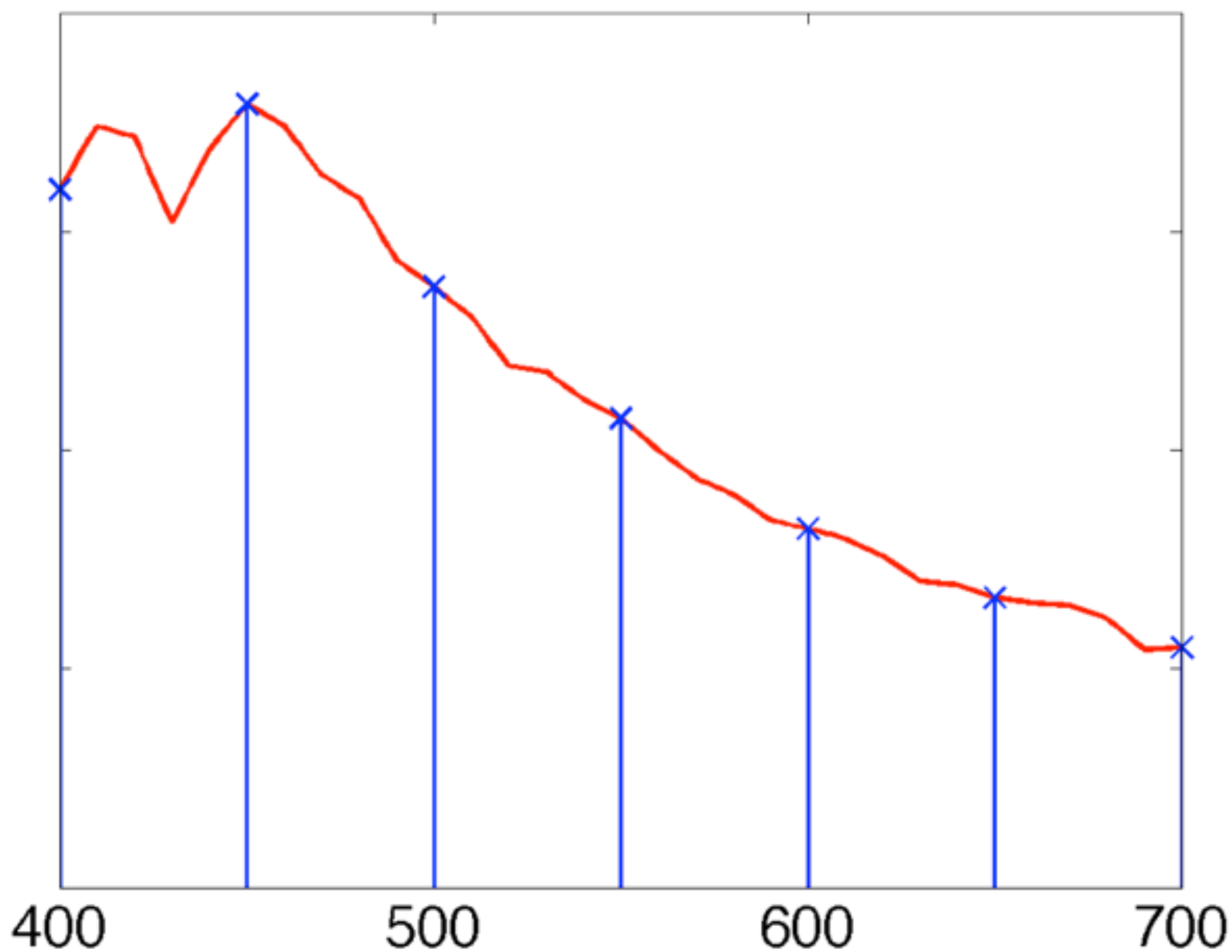


Image Formation
(Simulation in Computer)

$$C = \int_{\lambda} E(\lambda)S(\lambda)R(\lambda)\mathrm{d}\lambda$$

$$\downarrow$$

$$C = \sum_{i=1}^{n} E(\lambda_i)S(\lambda_i)R(\lambda_i)$$

Image Formation
(Implementation in MATLAB)

Data available in k wavelengths

Image Formation
(Implementation in MATLAB)

Data available in k wavelengths

N sensors (in color imaging: N=3)

$$\text{Sensor sensitivities} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1N} \\ r_{21} & r_{22} & \cdots & r_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ r_{k1} & r_{k2} & \cdots & r_{kN} \end{bmatrix}_{k \times N}$$

Image Formation
(Implementation in MATLAB)

Data available in **k** wavelengths

N sensors (in color imaging: N=3)

Illuminant with **k** samples

$$\text{Illuminant} = \begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_k \end{bmatrix}_{k \times 1}$$

Image Formation
(Implementation in MATLAB)

Data available in **k** wavelengths

N sensors (in color imaging: N=3)

Illuminant with **k** samples

Reflectances for **p** pixels

$$\text{Reflectance} = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1p} \\ s_{21} & s_{22} & \cdots & s_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ s_{k1} & s_{k2} & \cdots & s_{kp} \end{bmatrix}_{k \times p}$$

Image Formation
(Implementation in MATLAB)

$$C = \sum_{i=1}^{n} E(\lambda_i) S(\lambda_i) R(\lambda_i)$$

$$C = S^T \times \mathrm{diag}(E) \times R$$

$$\mathrm{diag}(E) = \begin{pmatrix} e_1 & 0 & \cdots & 0 \\ 0 & e_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & e_k \end{pmatrix}$$

Image Formation
(Implementation in MATLAB)

$$C = \sum_{i=1}^{n} E(\lambda_i) S(\lambda_i) R(\lambda_i)$$

$$C = S^T \times \mathrm{diag}(E) \times R$$

$$\mathrm{diag}(E) = \begin{pmatrix} e_1 & 0 & \cdots & 0 \\ 0 & e_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & e_k \end{pmatrix}$$

S : Reflectances

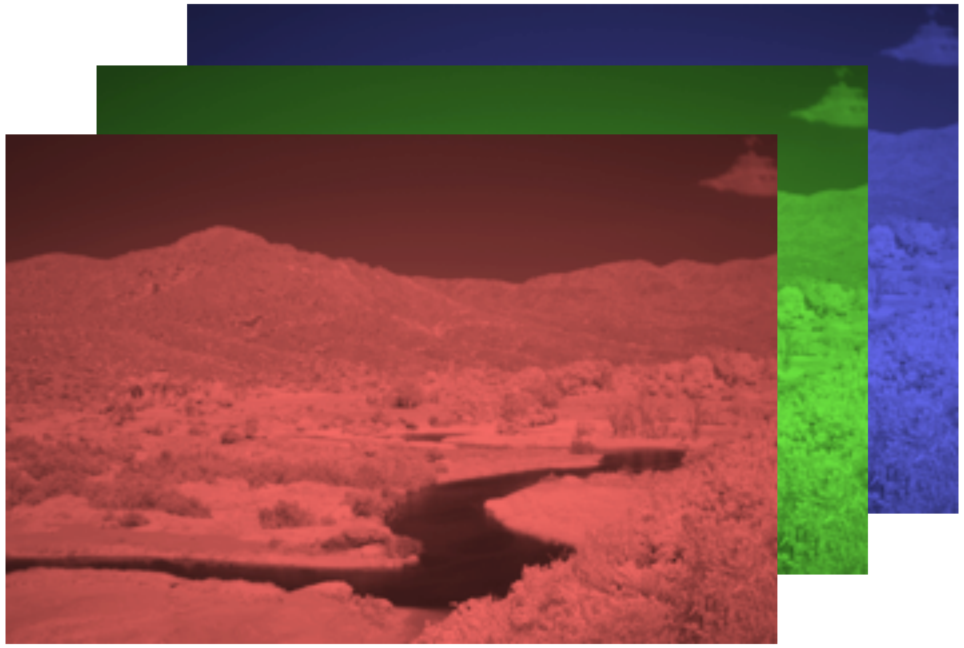
E : Illuminant

R : Sensor Sensitivities

What are you supposed to do?

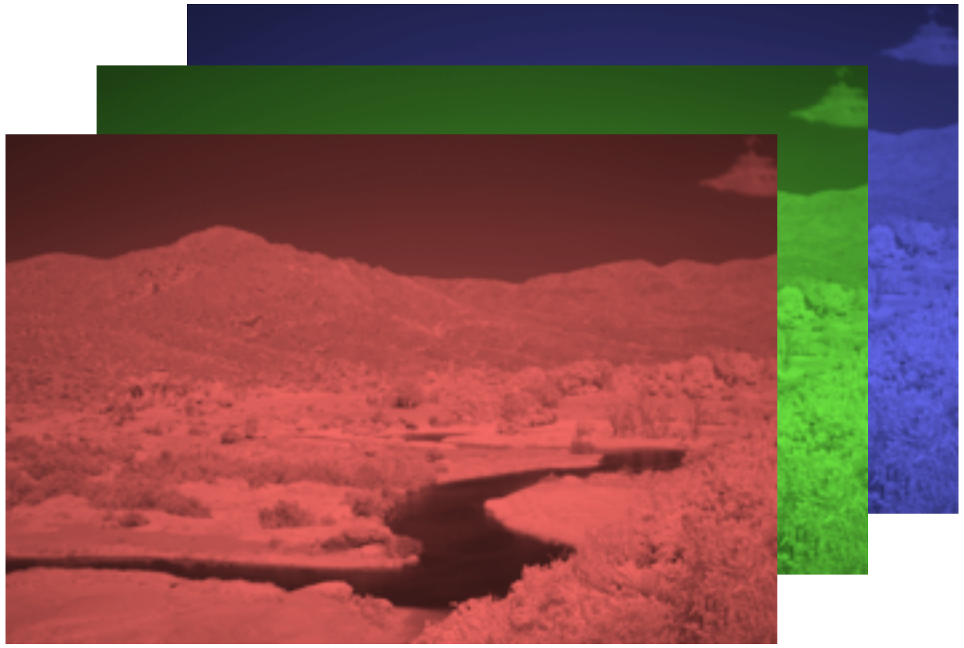
Form Three-channel Images

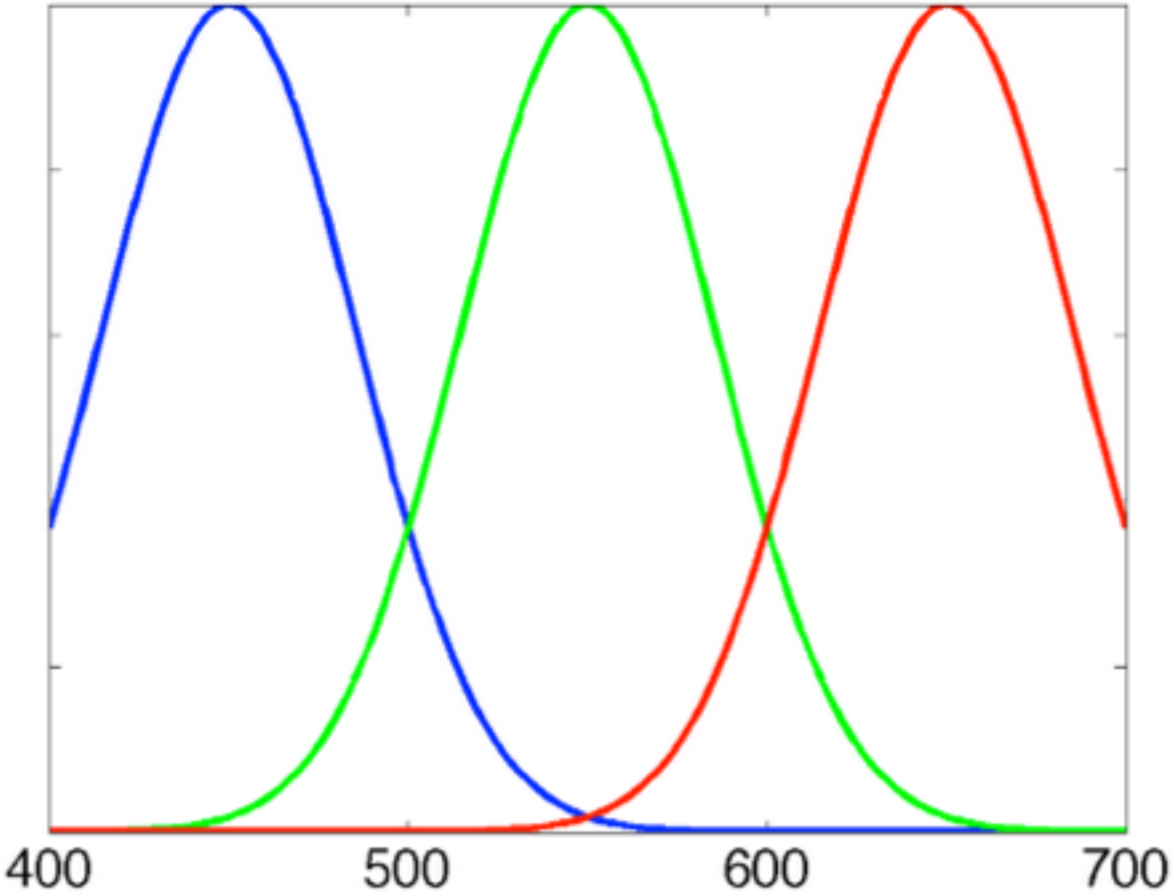
Three channels:
Red, Green, Blue



Form Three-channel Images

Three channels:
Red, Green, Blue





Ex.
Sensor sensitivities

Form Three-channel Images

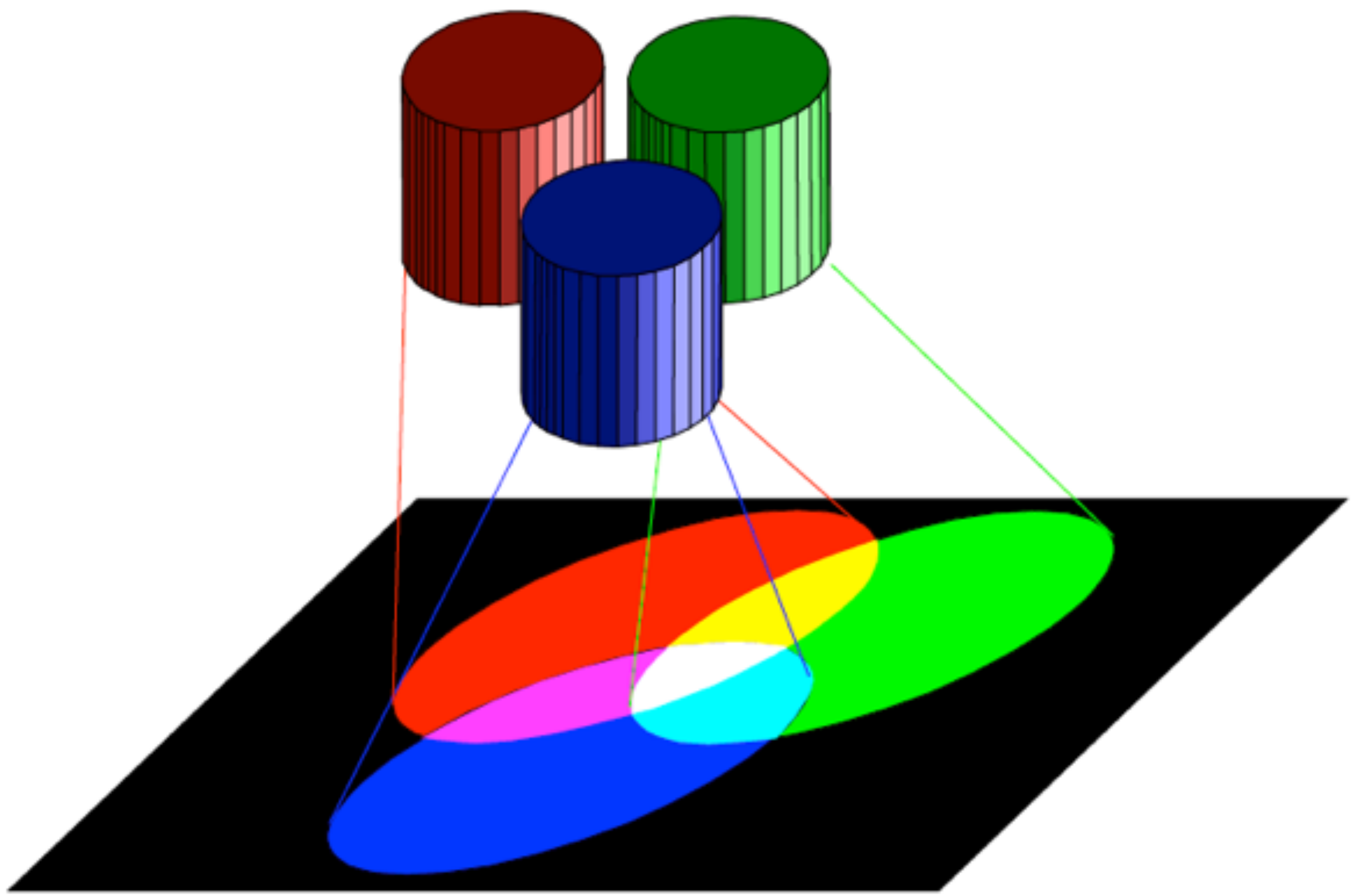
Different illuminants

Color Spaces

Trichromatic Color Theory

Additive Color Representation

Red, Green, Blue



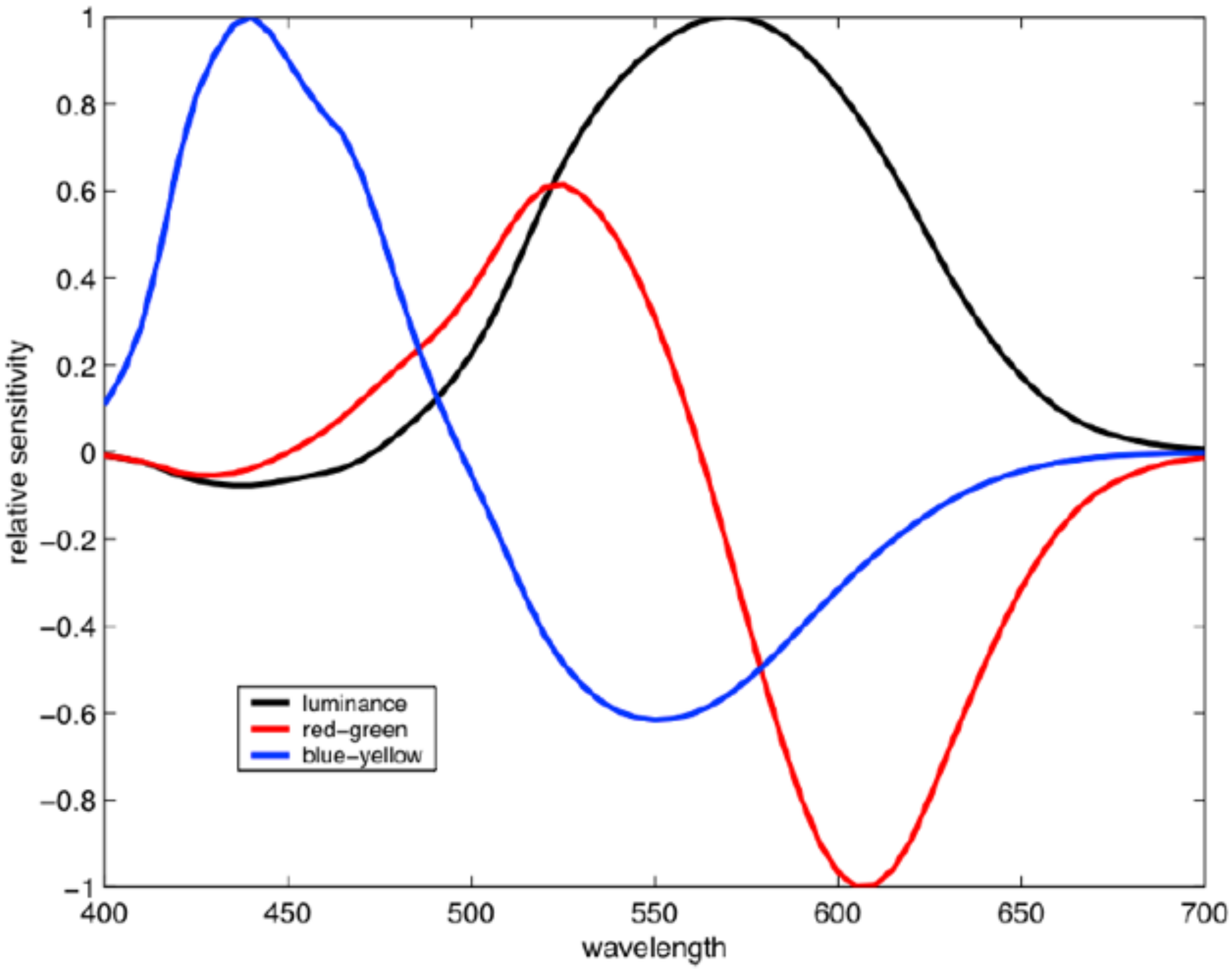
Opponent Color

- The four fundamental colors of the visible spectrum are red, yellow, green, and blue.
- While there are combinations of red and blue (purple) and red and yellow (orange), there are no combinations of red and green or blue and yellow.

Opponent Color Modelling

- In imaging:
  - Luma, lightness: $\alpha R' + \beta G' + \gamma B'$
  - Red - green: $\alpha R' - \beta G'$ ($+/- \gamma B'$)
  - Blue - yellow: $\gamma B' - (\alpha R' + \beta G')$

Normalized Color Opponent Sensitivities



Camera to sRGB

Provided in the .mat file

Camera RGB → Camera RGB to Linear sRGB → Linear sRGB → Non-linear Function → sRGB

$$C_{\text{srgb}} = \begin{cases} 12.92 C_{\text{linear}}, & C_{\text{linear}} \leq 0.0031308 \\ (1+a) C_{\text{linear}}^{1/2.4} - a & C_{\text{linear}} > 0.0031308 \end{cases}$$

One sRGB Image

sRGB to YCbCr

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1140 \\ -0.1687 & -0.3313 & 0.5000 \\ 0.5000 & -0.4187 & -0.0813 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix}$$

$$\boxed{\text{sRGB}} \longrightarrow \text{sRGB to YCbCr} \longrightarrow \boxed{\text{YCbCr}}$$

YCbCr Channels

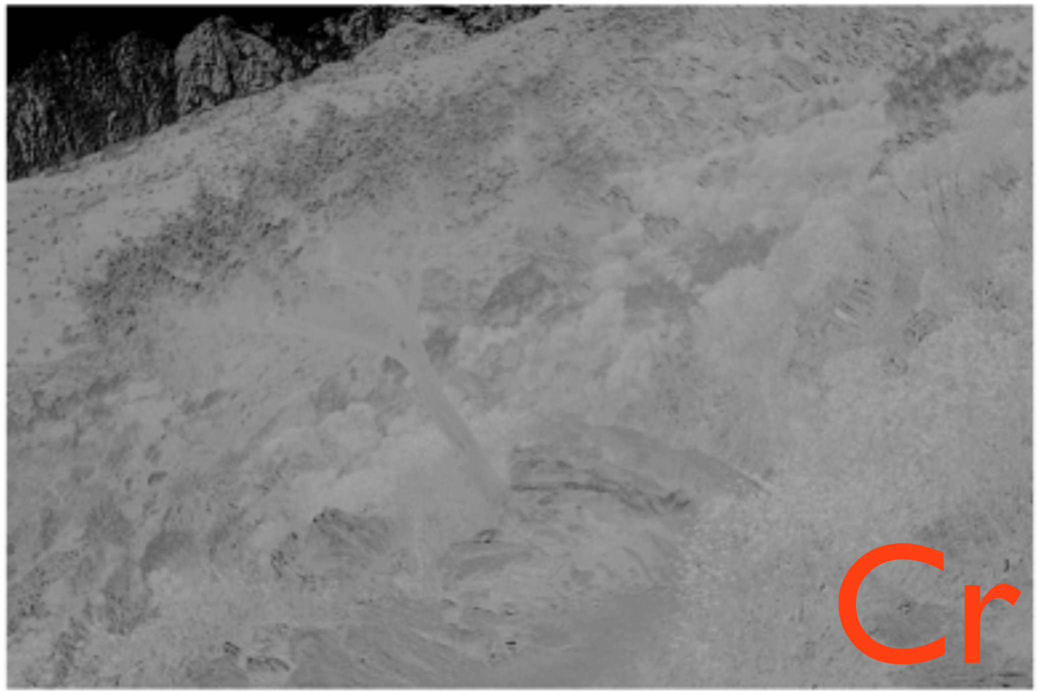


Image Filtering

- Apply the following filters

-1	0	+1
-2	0	+2
-1	0	+1

Gx

$* \mathbf{I}$

-1	-2	-1
0	0	0
+1	+2	+1

Gy

$* \mathbf{I}$

Filter the Image

Image Filtering

- Magnitude response: $G = \sqrt{G_x^2 + G_y^2}$

What does this filter do?

Image Saliency

Original Image

Saliency map

General Remarks

- Zero tolerance for **plagiarism**.
- Do ask questions in office hours.