

Světlo a barvy v počítačové grafice

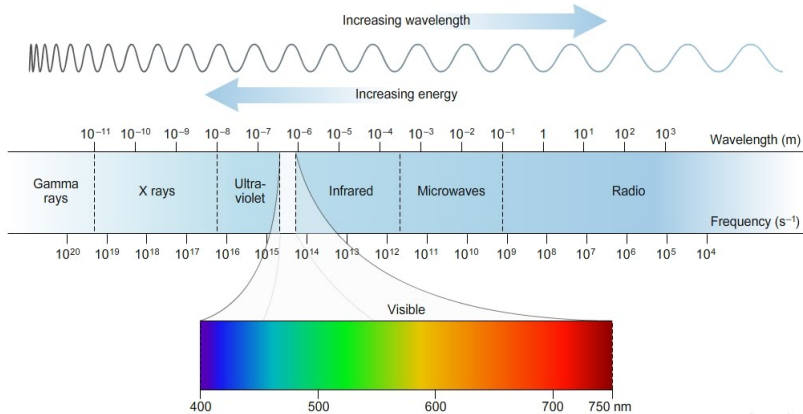
Počítačová grafika

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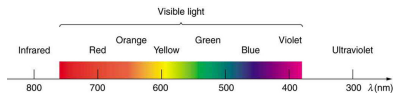
Palacký University, Olomouc

EM spektrum

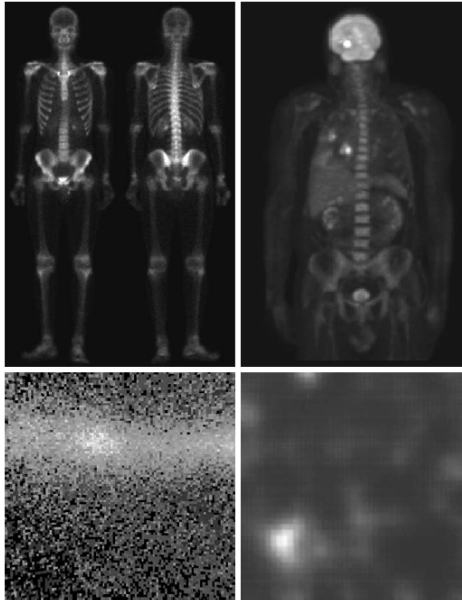


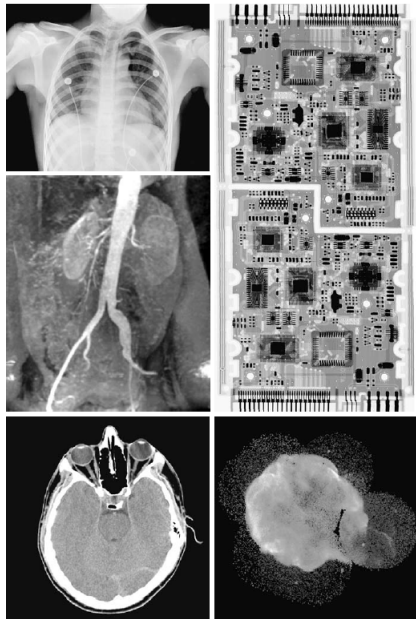
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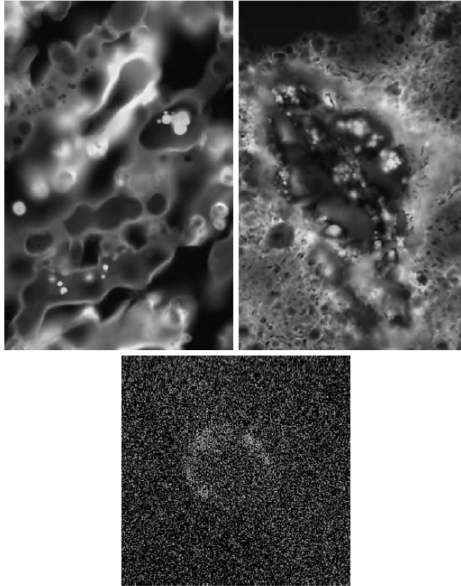
- $\lambda = \frac{c}{f}$, $E = h * f$
- c ... rychlost světla (300000 km/s)
- h ... Planckova konstanta ($6.6252 * 10^{-34}$ J*s)

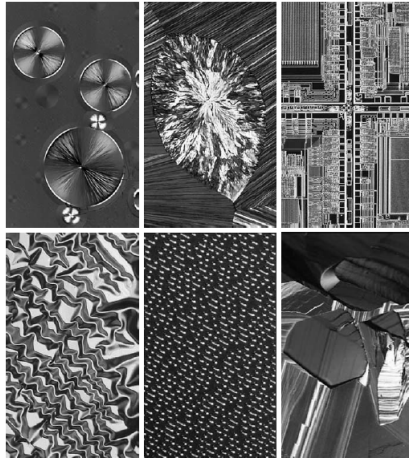


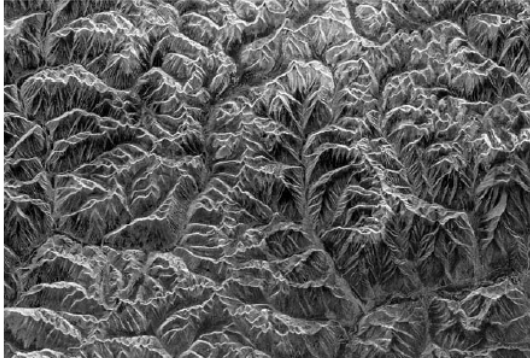
- $380nm$ fialová
- $760nm$ červená

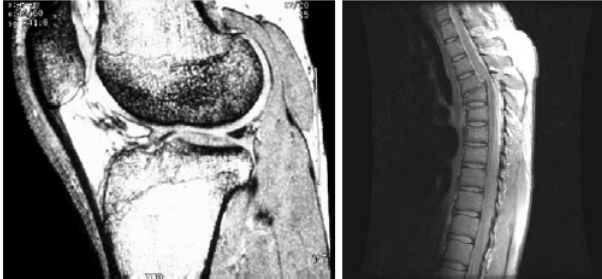




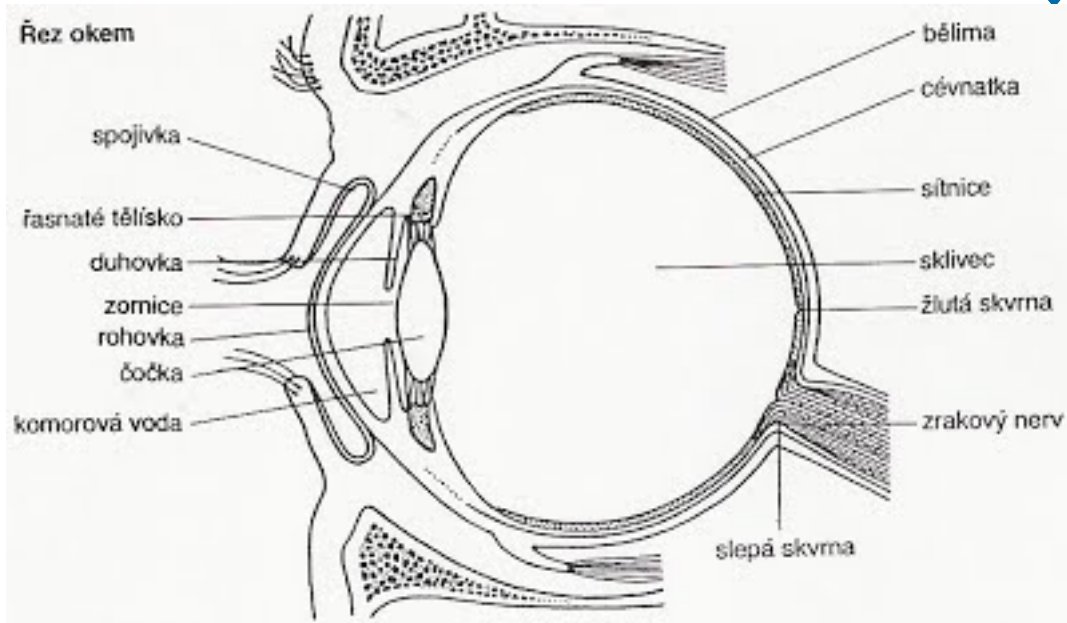


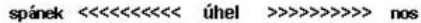


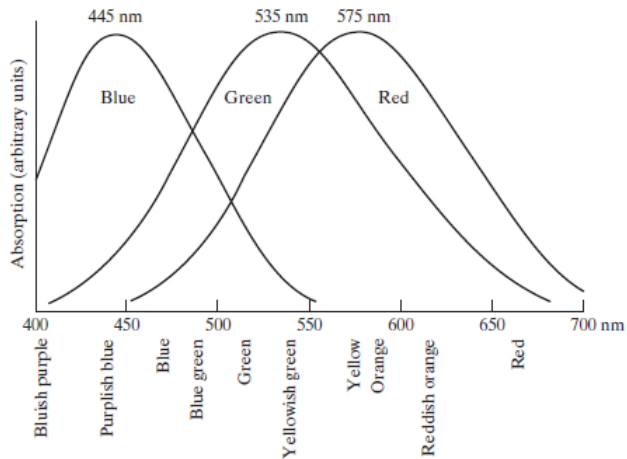


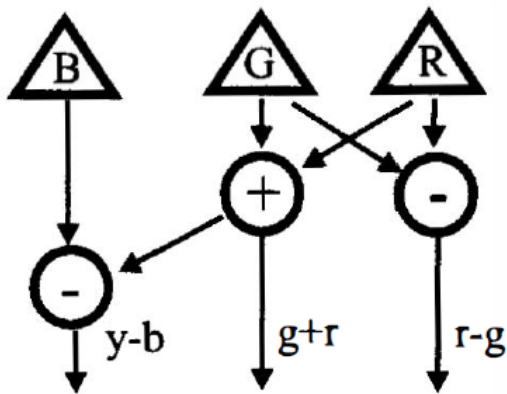


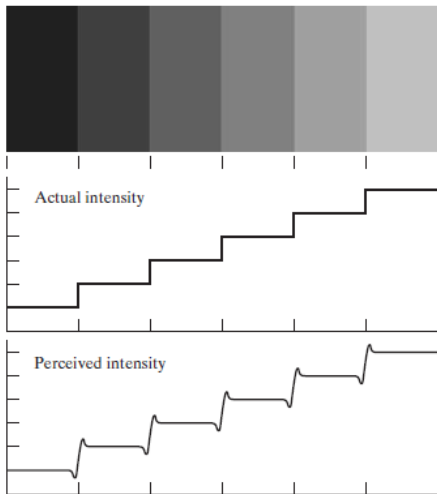
- **Jas** – intensity
- **Sytost** – saturation
- **Světlost** – brightness



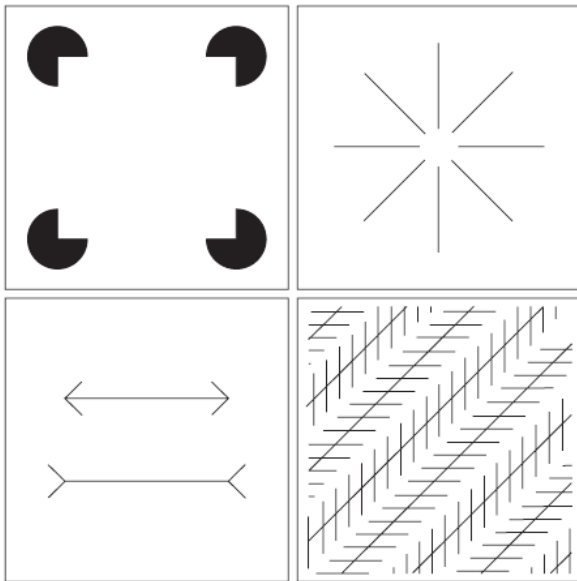


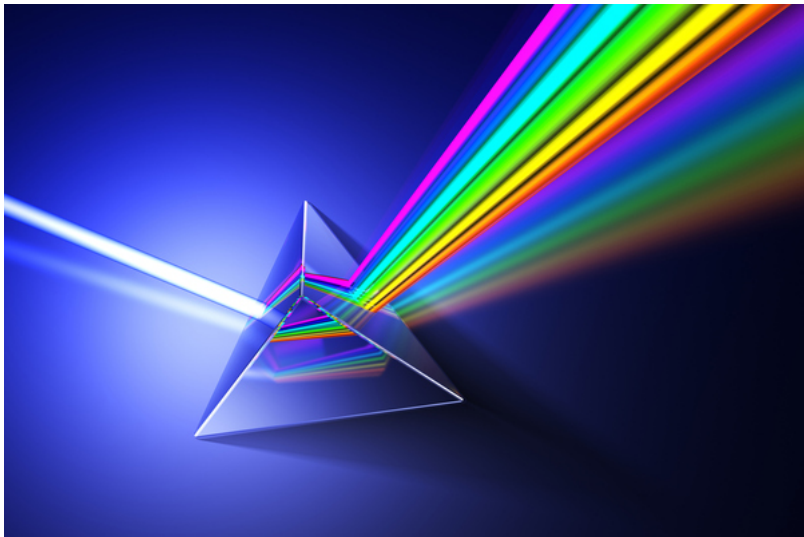


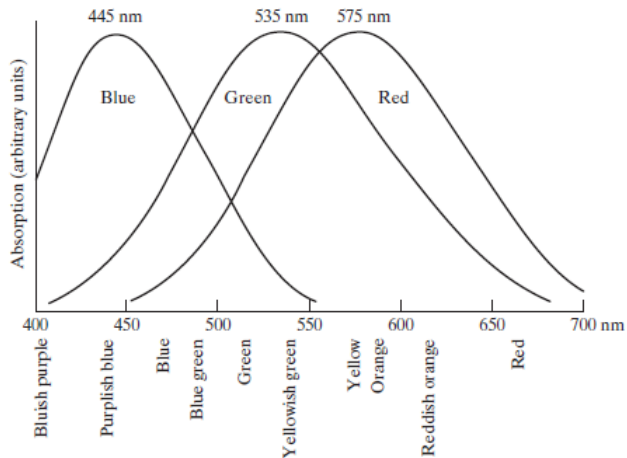






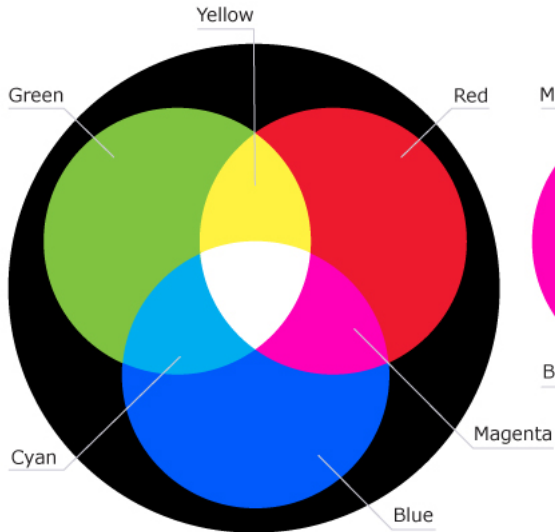




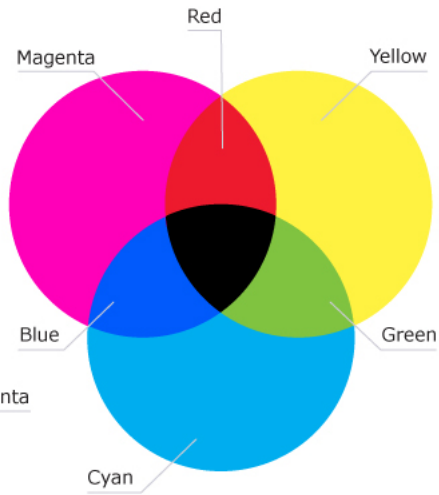


- Červená - 700 nm
- Zelená - 546,1 nm
- Modrá - 435,8 nm

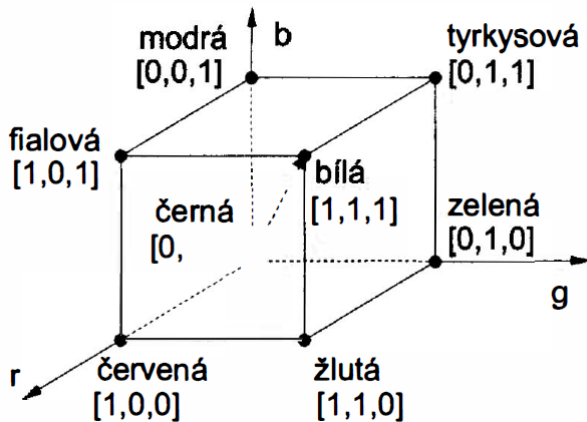
Additive
(combining lights)



Subtractive
(mixing paints or inks)



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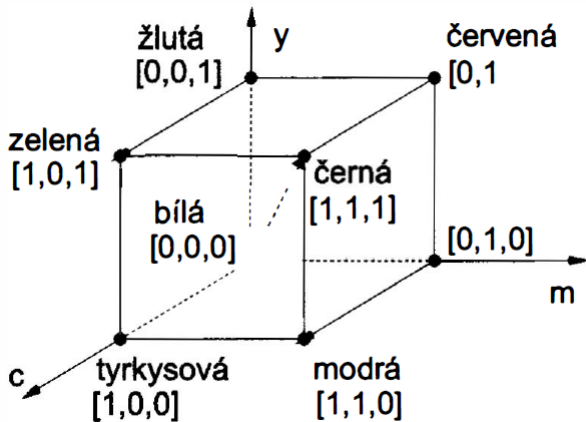


$$I = 0.299R + 0.587G + 0.114B$$

Matlab:

$$I = \text{rgb2gray}(A)$$

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



RGB → CMY

$$\begin{bmatrix} c \\ m \\ y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

$$I_{cmy} = 1 - I_{rgb}$$

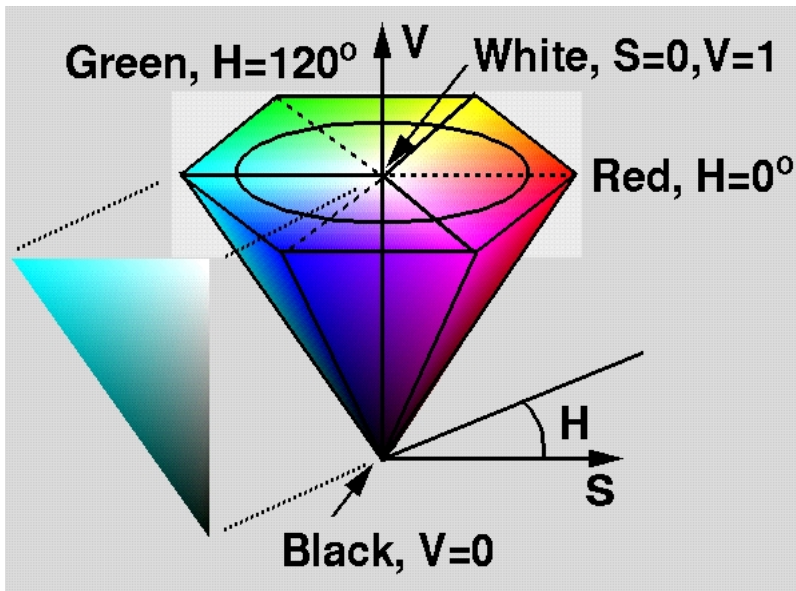
$$I_{cmy} = \text{imcomplement}(I_{rgb})$$

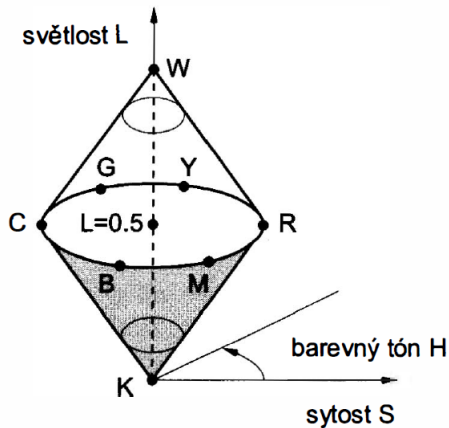
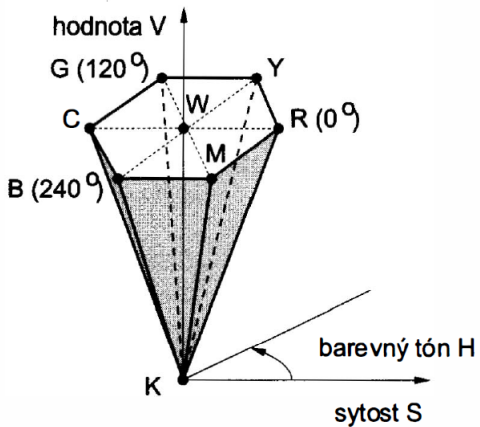
CMY → RGB

$$\begin{bmatrix} r \\ g \\ b \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} c \\ m \\ y \end{bmatrix}$$

$$I_{rgb} = 1 - I_{cmy}$$

$$I_{rgb} = \text{imcomplement}(I_{cmy})$$





$r, g, b \dots$ jednotlivé barevné složky

$$max = \max(r, g, b)$$

$$min = \min(r, g, b)$$

$$h = \begin{cases} \text{undef} & \text{if } max = min \\ 60^\circ \frac{g-b}{max-min} + 0^\circ & \text{if } max = r \text{ and } g \geq b \\ 60^\circ \frac{g-b}{max-min} + 360^\circ & \text{if } max = r \text{ and } g < b \\ 60^\circ \frac{b-r}{max-min} + 120^\circ & \text{if } max = g \\ 60^\circ \frac{r-g}{max-min} + 240^\circ & \text{if } max = b \end{cases}$$

$$s = \begin{cases} 0 & \text{if } max = 0 \\ \frac{max-min}{max} & \text{else} \end{cases}$$

$$v = max$$

$$I_{hsv} = \text{rgb2hsv}(I_{rgb})$$

r, g, b ... jednotlivé barevné složky

$$\max = \max(r, g, b)$$

$$\min = \min(r, g, b)$$

$$l = \frac{1}{2}(\max + \min)$$

$$s = \begin{cases} 0 & \text{if } l = 0 \text{ or } \max = \min \\ \frac{\max - \min}{\max + \min} & \text{if } 0 < l \leq \frac{1}{2} \\ \frac{\max - \min}{2 - (\max + \min)} & \text{if } l > \frac{1}{2} \end{cases}$$

HSV → RGB



$$h_i = \frac{h}{60} \bmod 6$$

$$f = \frac{h}{60} - h_i$$

$$p = v \cdot (1 - s)$$

$$q = v \cdot (1 - f \cdot s)$$

$$t = v \cdot (1 - (1 - f) \cdot s)$$

$$(r, g, b) = \begin{cases} (v, t, p) & \text{if } h_i = 0 \\ (q, v, p) & \text{if } h_i = 1 \\ (p, v, t) & \text{if } h_i = 2 \\ (p, q, v) & \text{if } h_i = 3 \\ (t, p, v) & \text{if } h_i = 4 \\ (v, p, q) & \text{if } h_i = 5 \end{cases}$$

$$\text{Irgb} = \text{hsv2rgb}(\text{Ihsv})$$

$$\begin{bmatrix} y \\ u \\ v \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.141 & -0.289 & 0.437 \\ 0.615 & -0.515 & -0.1 \end{bmatrix} \cdot \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

RGB \rightarrow YCbCr

$$\begin{bmatrix} y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.1687 & -0.3313 & 0.5 \\ 0.5 & -0.4187 & -0.0813 \end{bmatrix} \cdot \begin{bmatrix} r \\ g \\ b \end{bmatrix}$$

`Iycbcr = rgb2ycbcr(Irgb)`

YCbCr \rightarrow RGB

`Irgb = ycbcr2rgb(Iycbcr)`

$R = 700\text{nm}$

$G = 541.1\text{nm}$

$B = 435.8\text{nm}$

monochromatická barva

$$C = r \cdot R + g \cdot G + b \cdot B$$

barevné srovnávací funkce

$r(\lambda)$, $g(\lambda)$, $b(\lambda)$

monochromatická barva o vlnové délce λ

$$C(\lambda) = r(\lambda) + g(\lambda) + b(\lambda)$$

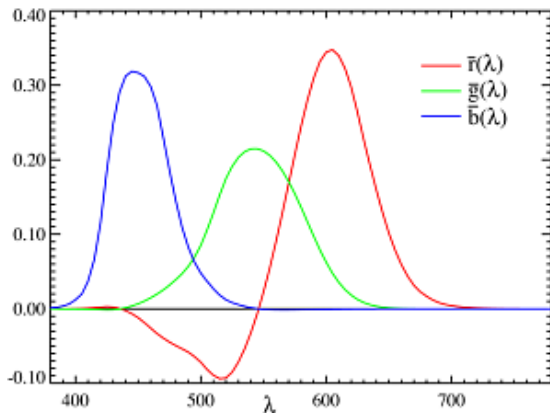
souřadnice obecné barvy

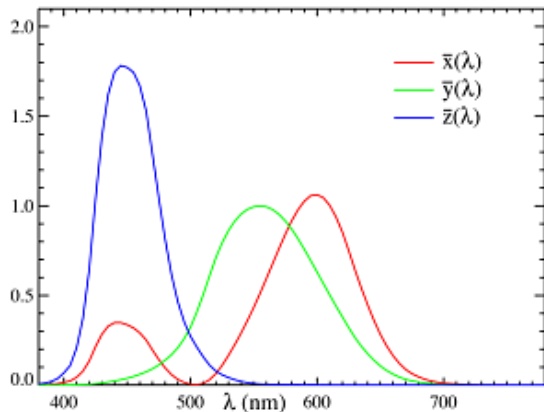
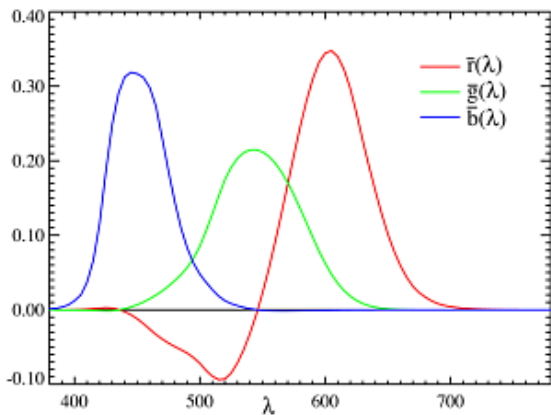
spektrální rozložení $p(\lambda)$

$$r = \int_{\lambda} p(\lambda) \cdot r(\lambda) d\lambda$$

$$g = \int_{\lambda} p(\lambda) \cdot g(\lambda) d\lambda$$

$$b = \int_{\lambda} p(\lambda) \cdot b(\lambda) d\lambda$$





souřadnice barvy

spektrální rozložení $p(\lambda)$

$$x = \int_{\lambda} p(\lambda) \cdot x(\lambda) d\lambda$$

$$y = \int_{\lambda} p(\lambda) \cdot y(\lambda) d\lambda$$

$$z = \int_{\lambda} p(\lambda) \cdot z(\lambda) d\lambda$$

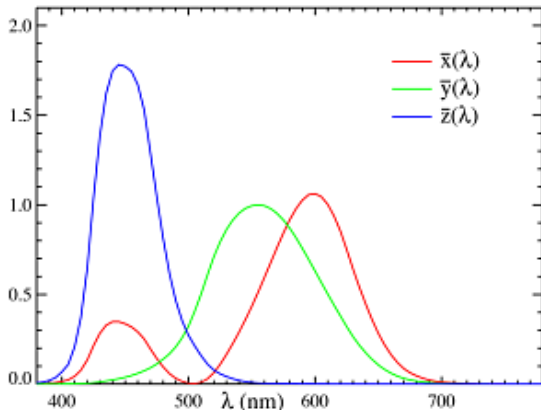
normalizovaný tvar

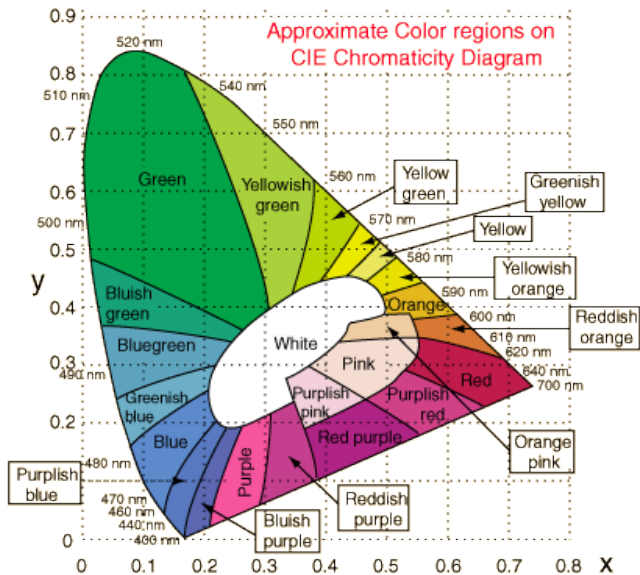
$$x = \frac{x}{x+y+z}$$

$$y = \frac{y}{x+y+z}$$

$$z = \frac{z}{x+y+z}$$

jelikož $x + y + z = 1$ stačí 2 souřadnice
doplněné o jasovou hodnotu Y

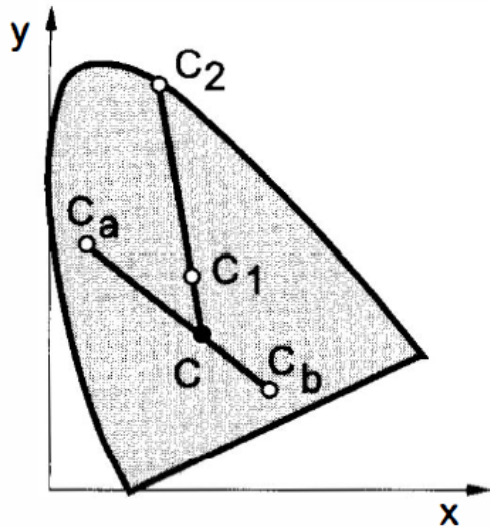




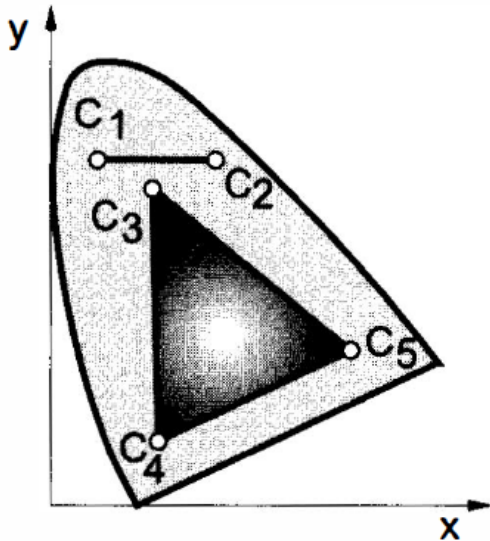
sytost barvy – relativní vzdálenost C_1 od standardního bílého světla C cca 25%

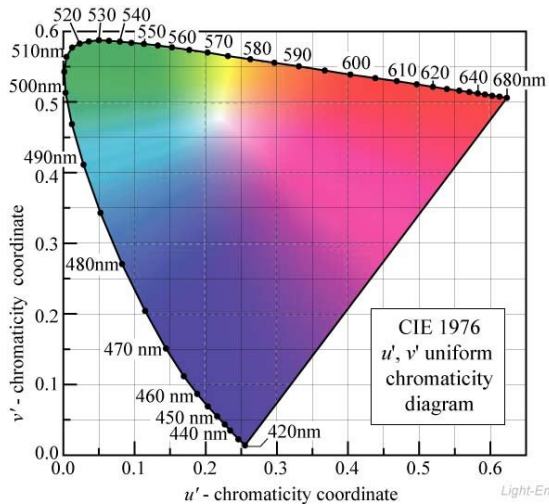
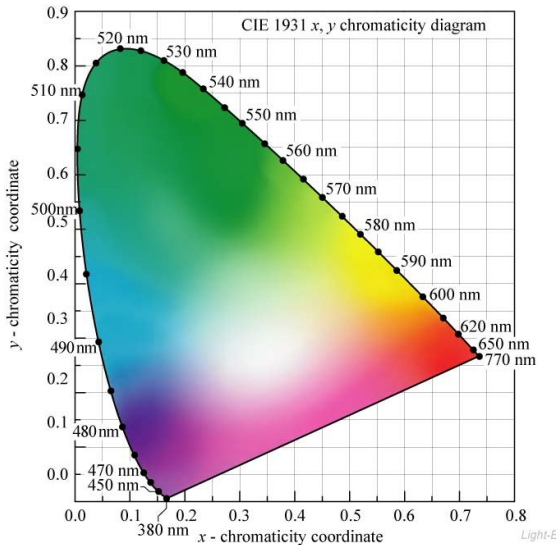
dominantní vlnová délka pro bod C_1 je bod C_2

doplňkové barvy C_a a C_b



Barevné rozsahy – color gamut
konvexní množiny





Převod CIE 1931 → CIE 1976

$$u = \frac{2x}{6y-x+1.5}$$

$$v = \frac{4.5y}{6y-x+1.5}$$

Převod CIE 1976 → CIE 1931

$$x = \frac{27u}{4 \cdot (4.5u - 12v + 9)}$$

$$y = \frac{3v}{4.5u - 12v + 9}$$

