Brief Introduction to Color Spaces

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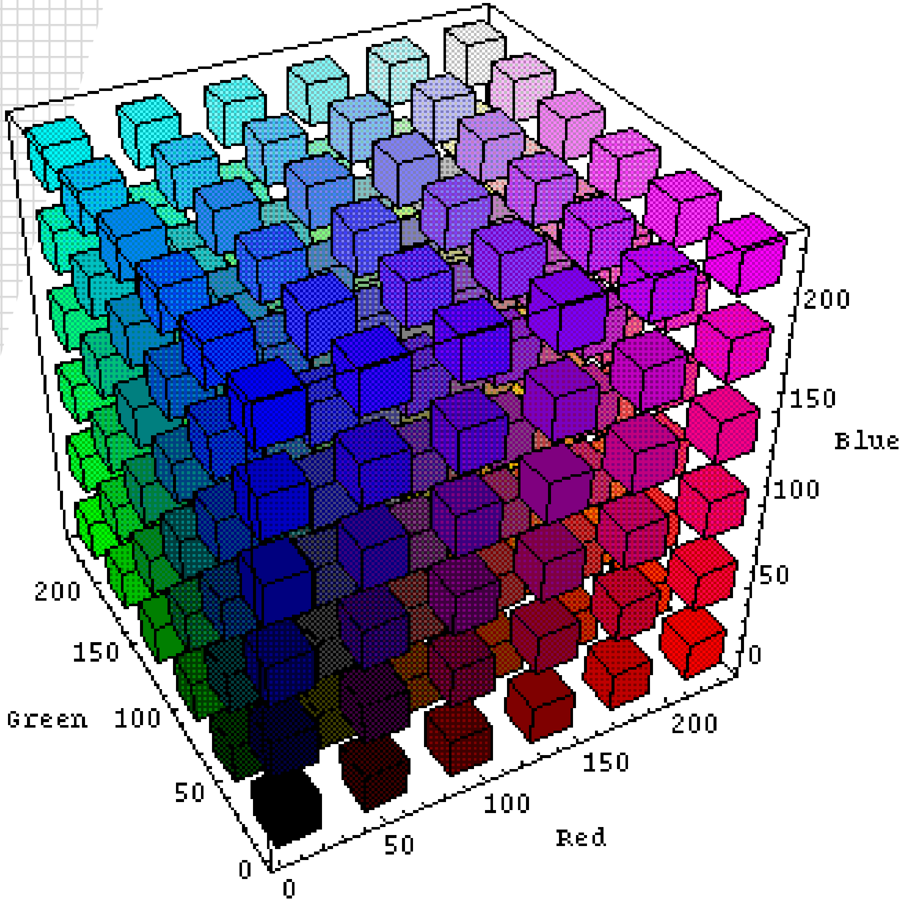
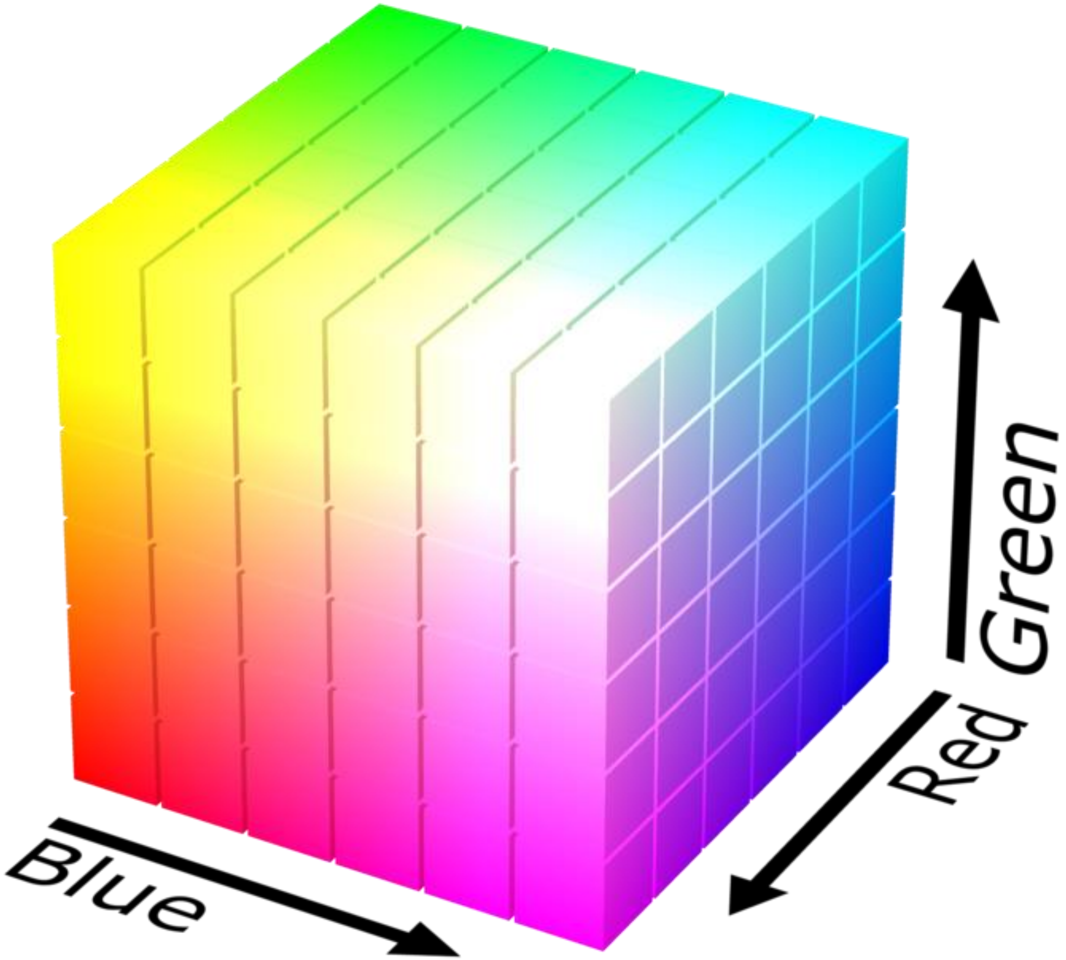
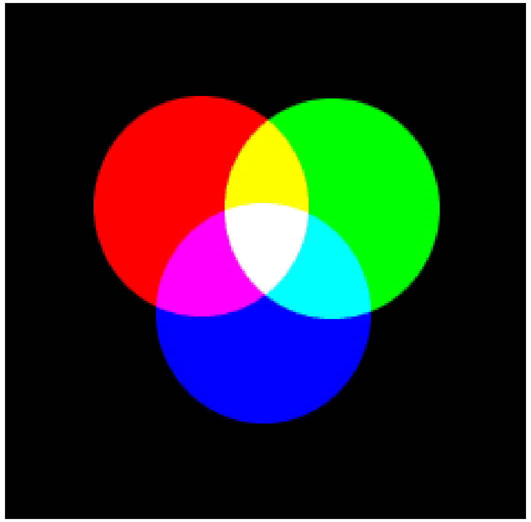
RGB color space



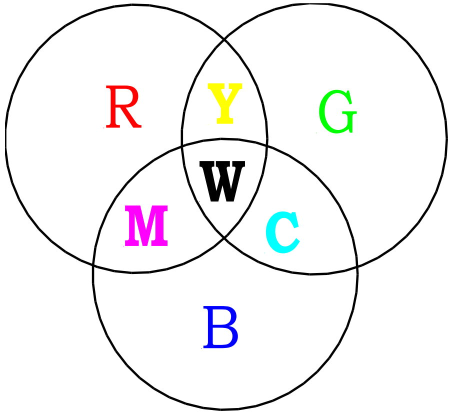


Additive Synthesis



RGB

Additive color composition starting from the three RGB primary colors.
From their overlapping we get white (W), from the overlapping of two lights we get yellow (*Y*), *magenta* (*M*) and *cyan* (*C*).



The operation of TV monitors and screens is based on this principle.

The complementary colors

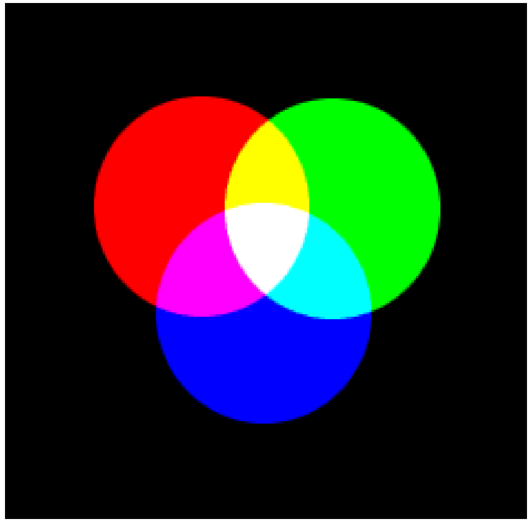
Complementary Color = when the sum of a given color to another gives White (W)

$R + G + B = W$

$R + G = W - B = Y$

$R + B = W - G = M$

$B + G = W - R = C$



Yellow is complementary to **Blue**
Magenta is complementary to **Green**
Cyan is complementary to **Red**

Color can also be obtained as a mixture of <u>colored substances</u> (pigments, dyes, etc.) whose behavior can be simulated by considering color filters.

Subtractive synthesis

Colored Optical Filter = a medium with flat, parallel faces that when crossed by white light selectively absorbs a portion of it.

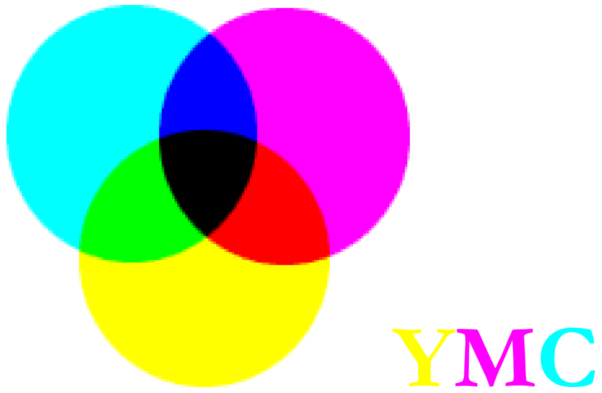
The filter takes on the color produced by the complementary radiation of that which is absorbed as happens to colored substances.

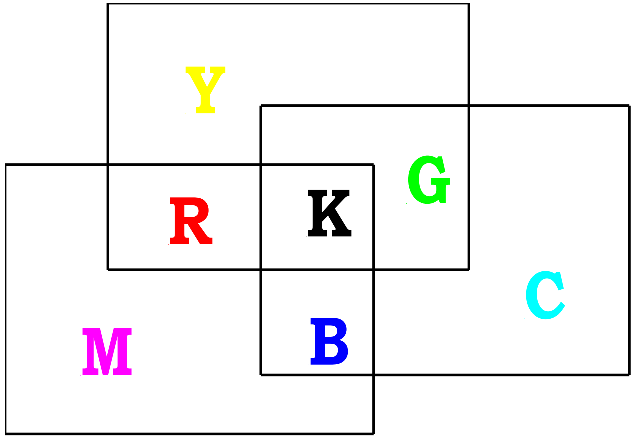
By overlaying three filters of yellow (Y), magenta (M) and cyan (C) on a white light visor, colors are obtained for Subtractive Synthesis

Overlaying all three filters absorbs all visible radiation so you get Black (K).

Overlaying two filters gives the color corresponding to the light component that is not absorbed by either filter.

Subtractive synthesis





Subtractive color composition starting with the three primary YMC colors obtained by placing the three filters in the path of a white light beam.

From their superposition we obtain black (K), from the superposition of two filters we obtain red (R), green (G) and blue (B).

Sintesi Sottrattiva = aggiunge un filtro viene "sottratta" una componente che modifica il colore della luce.

Images in subtractive synthesis

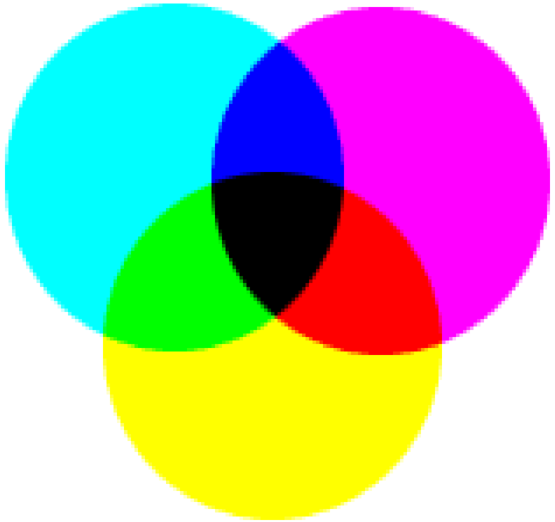
In subtractive synthesis, the following color combinations are obtained (+ = superposition of filters) :

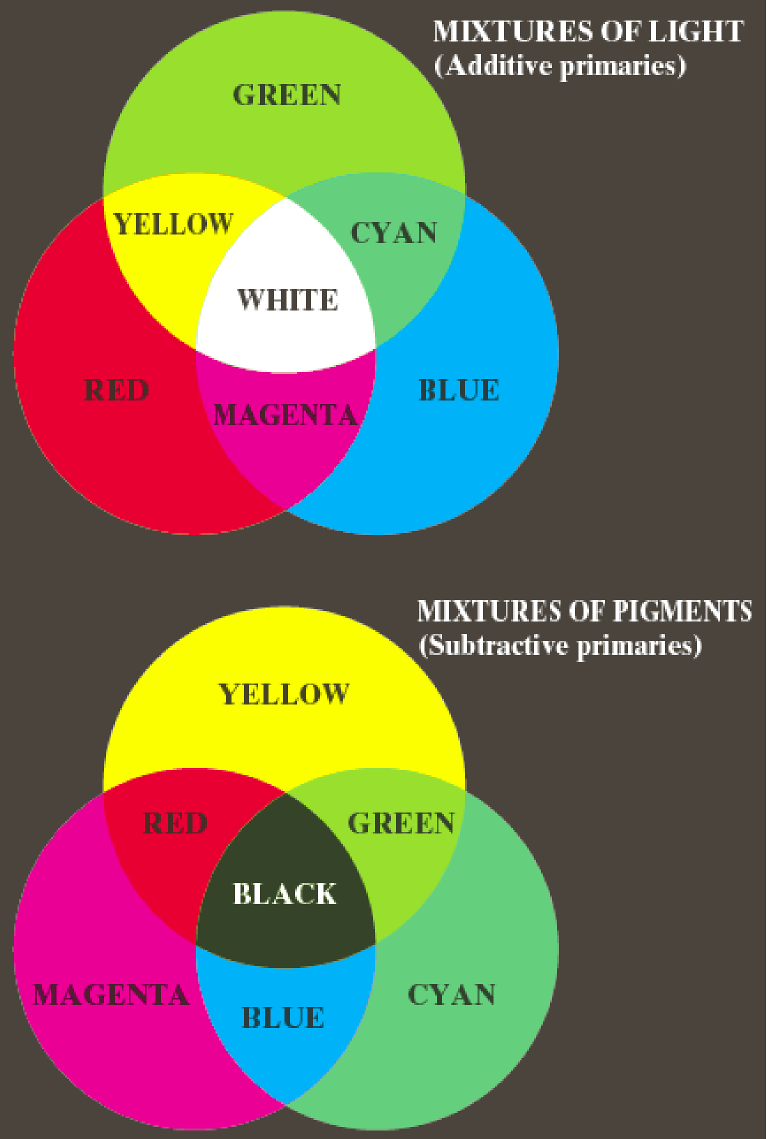
Y + **M** = **R**

Y + **C** = **G**

M + **C** = **B**

Y + **M** + **C** = **K**





PRIMARY AND SECONDARY COLORS
OF LIGHT AND PIGMENT

Primary and secondary colors

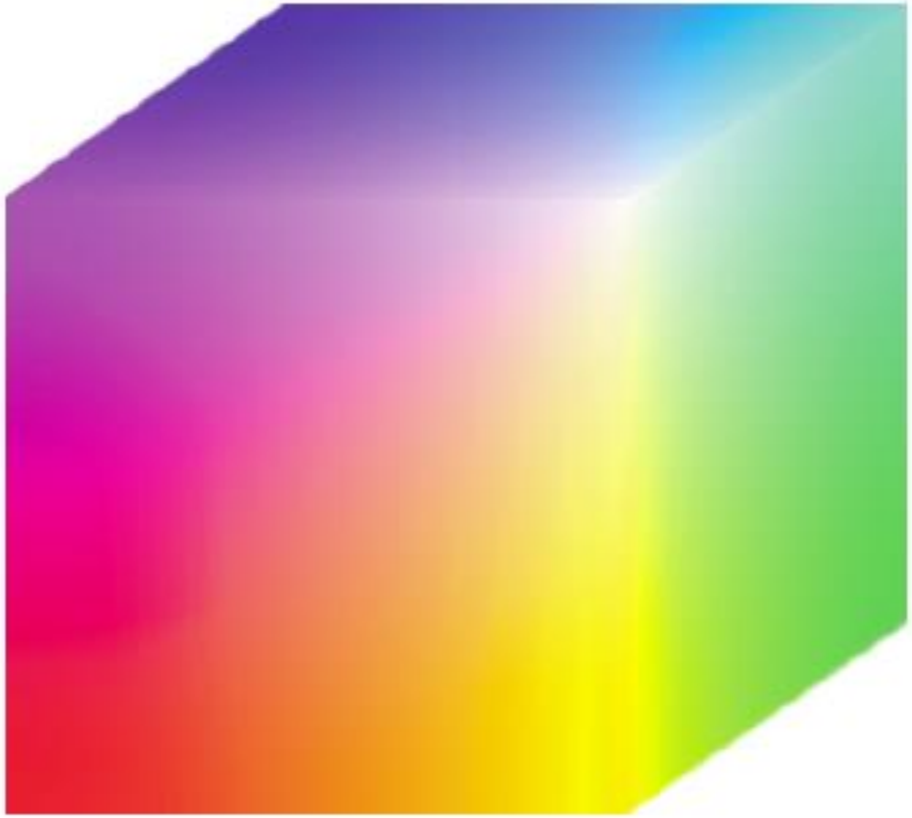
In the **RGB model** with additive synthesis:

- The colors Red R, Green G and Blue B are called **primary colors**.
- Combining them with each other does NOT result in all visible colors.
- Combining them two by two yields the **secondary colors**: Magenta M, Yellow Y and Cyan C.

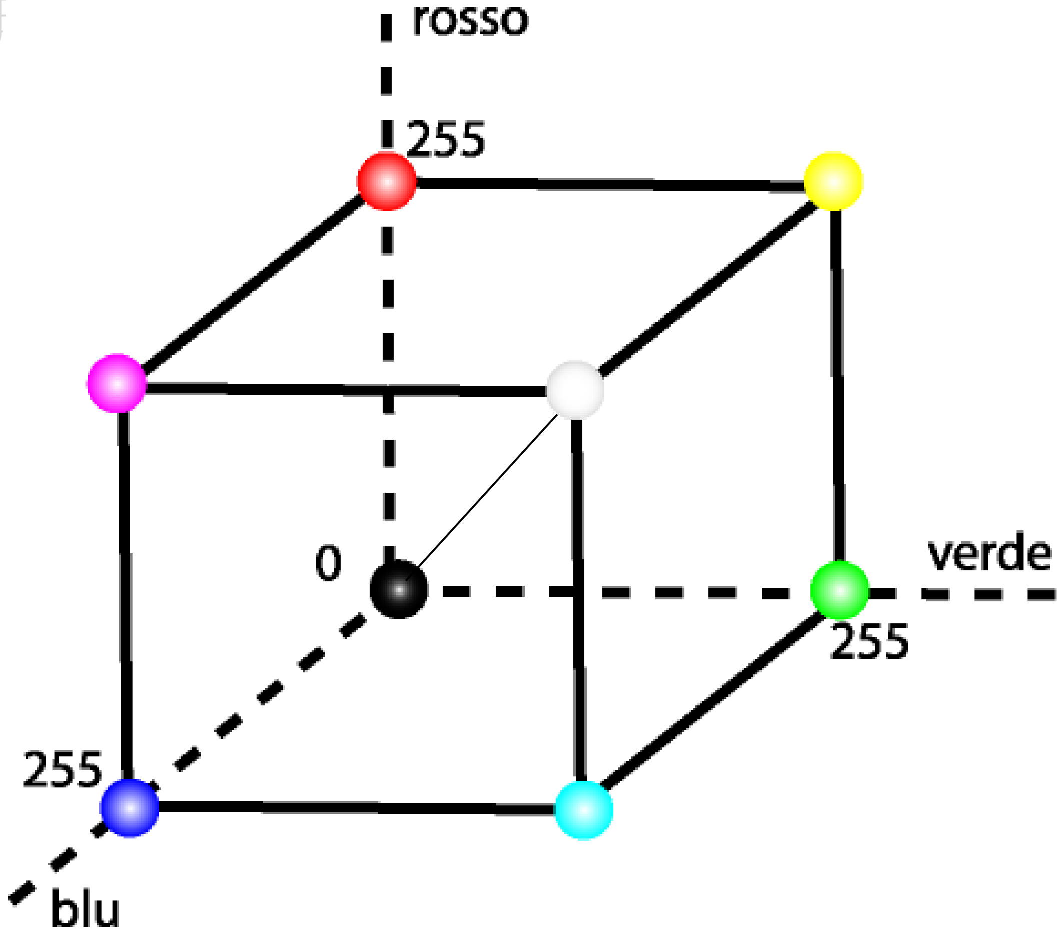
RGB

- In the RGB model each color is obtained by mixing the three basic colors.

- If each color component is understood as a Cartesian coordinate, then the RGB model can be graphically described by a cube.



Descrizione geometrica



The contributions of RED, GREEN and BLUE are assumed independent of each other (and thus represented by directions perpendicular to each other).

Each color is a point contained within the cube.

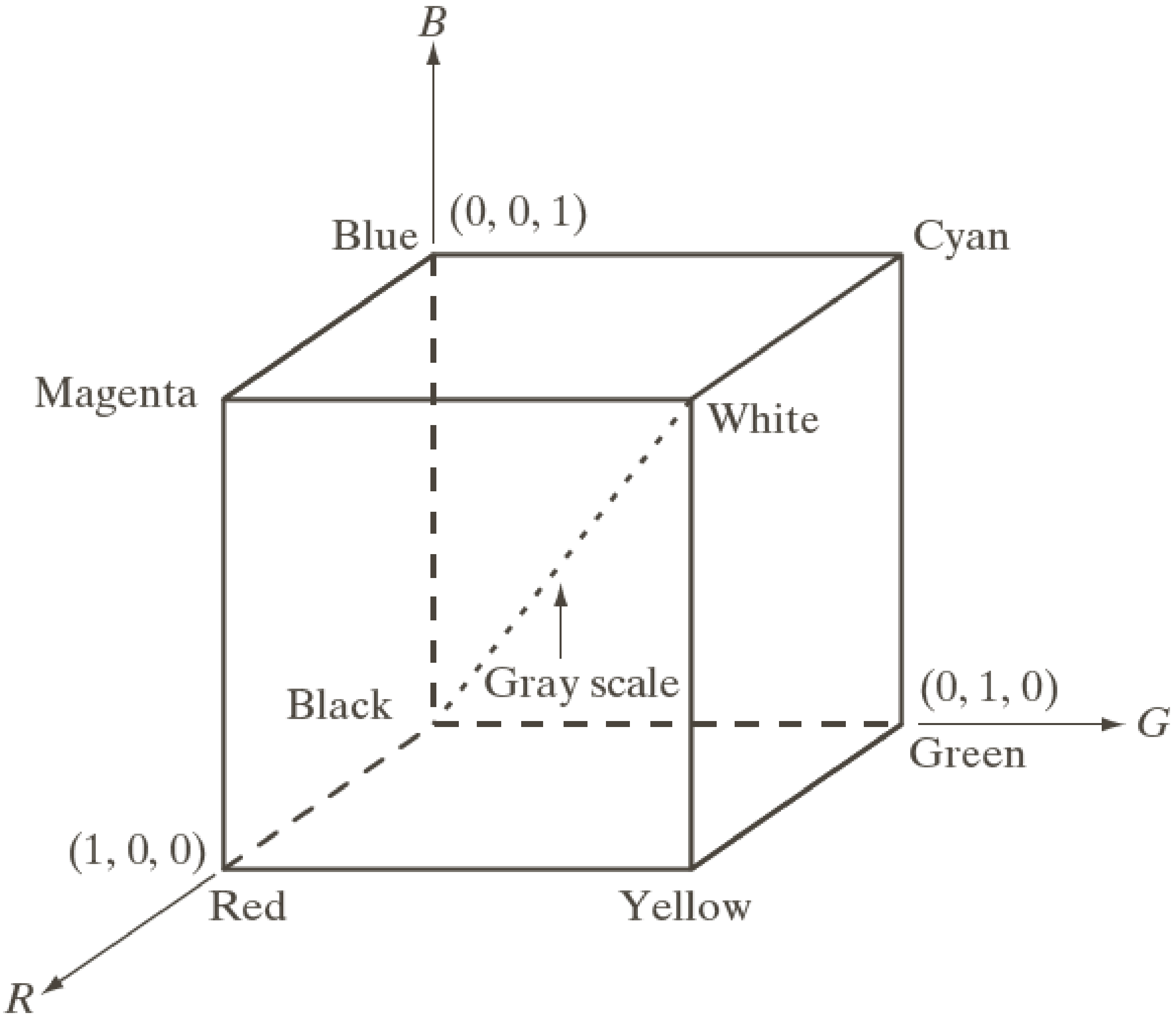
The line joining black and white is the line of grays.

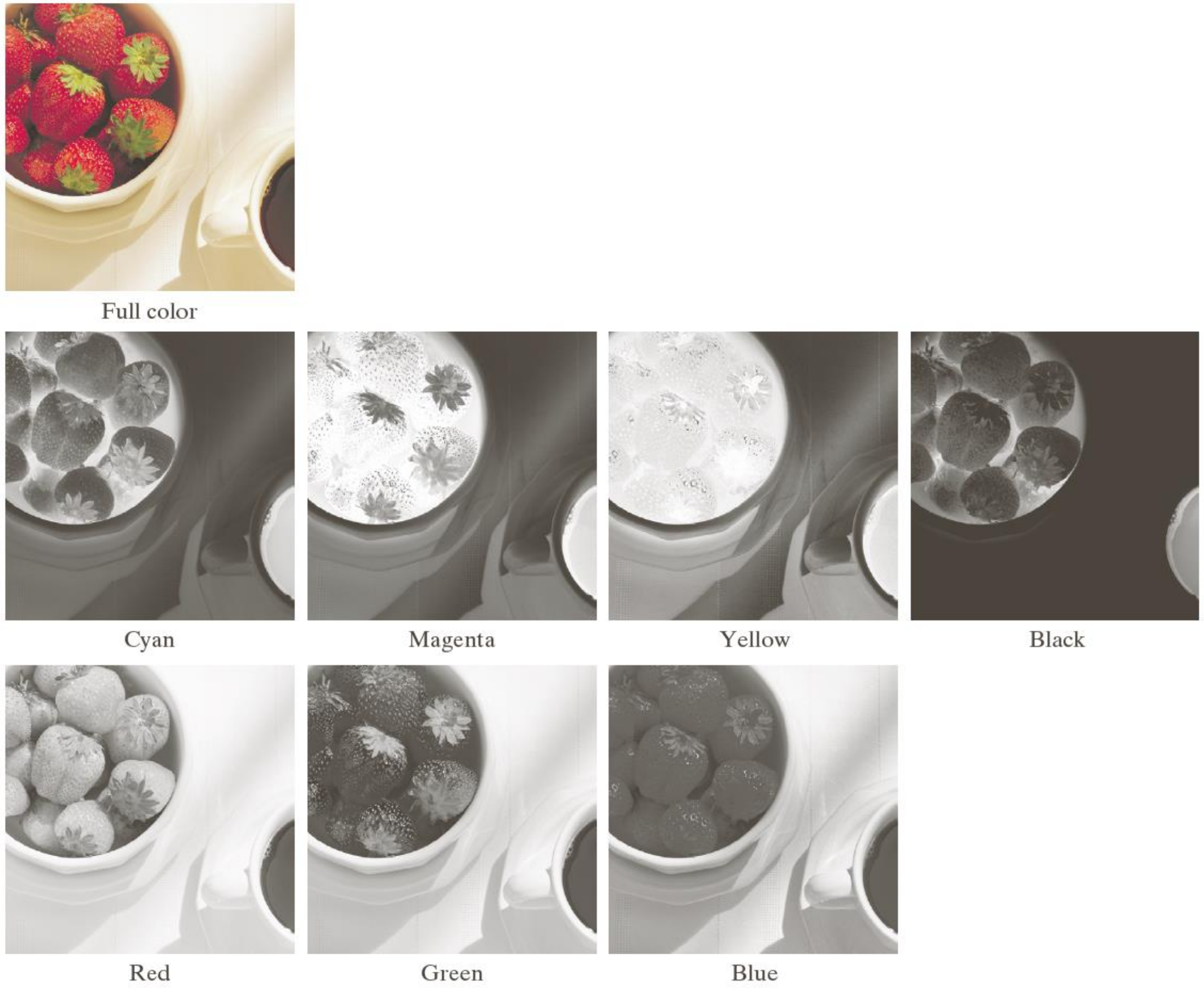
Discussion

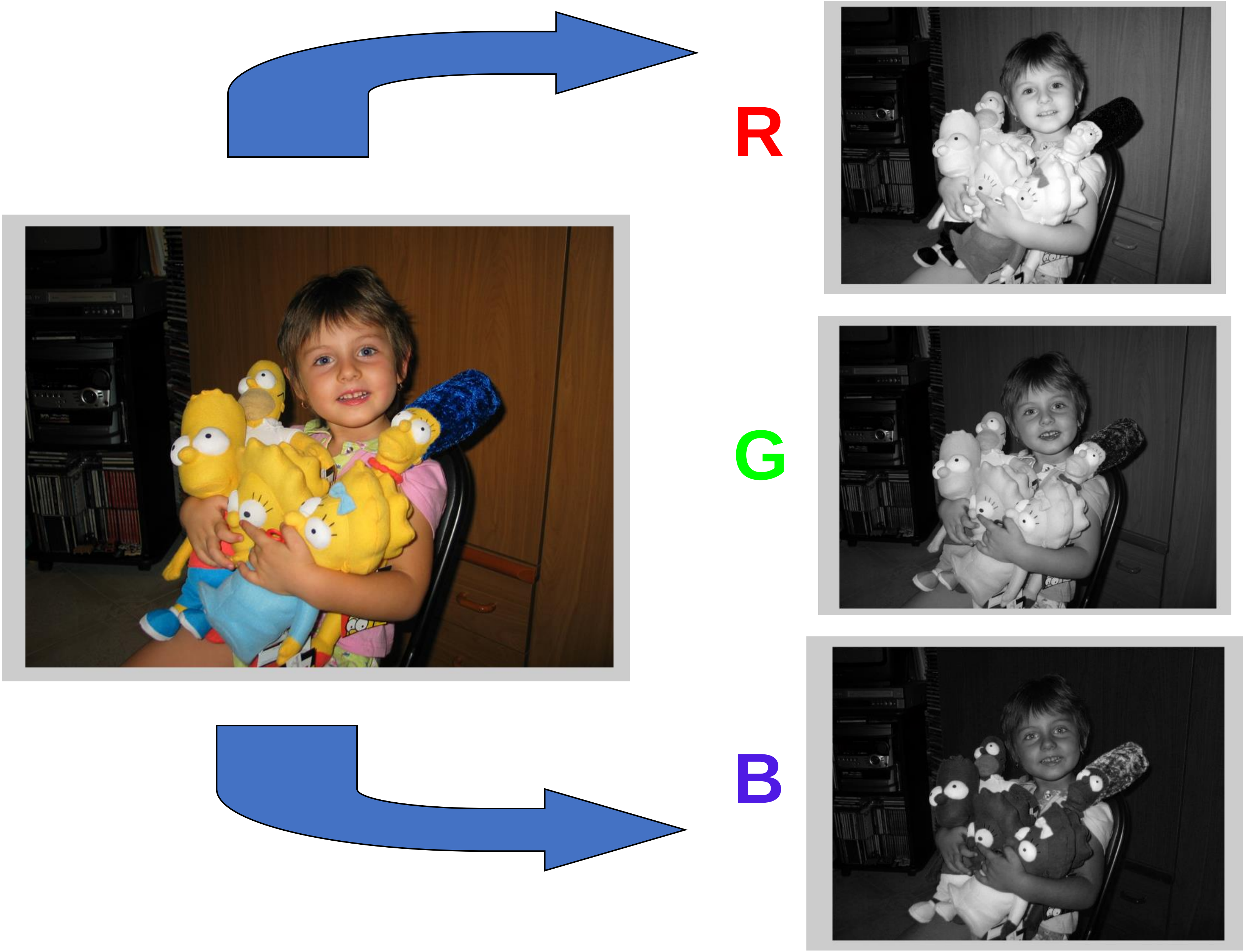
- **PRO: simple to use and implement in software and hardware: a STANDARD.**
- **CON: perceptually uncomfortable: difficult to tell by looking at a color in nature in what proportion R, G and B contribute to it.**

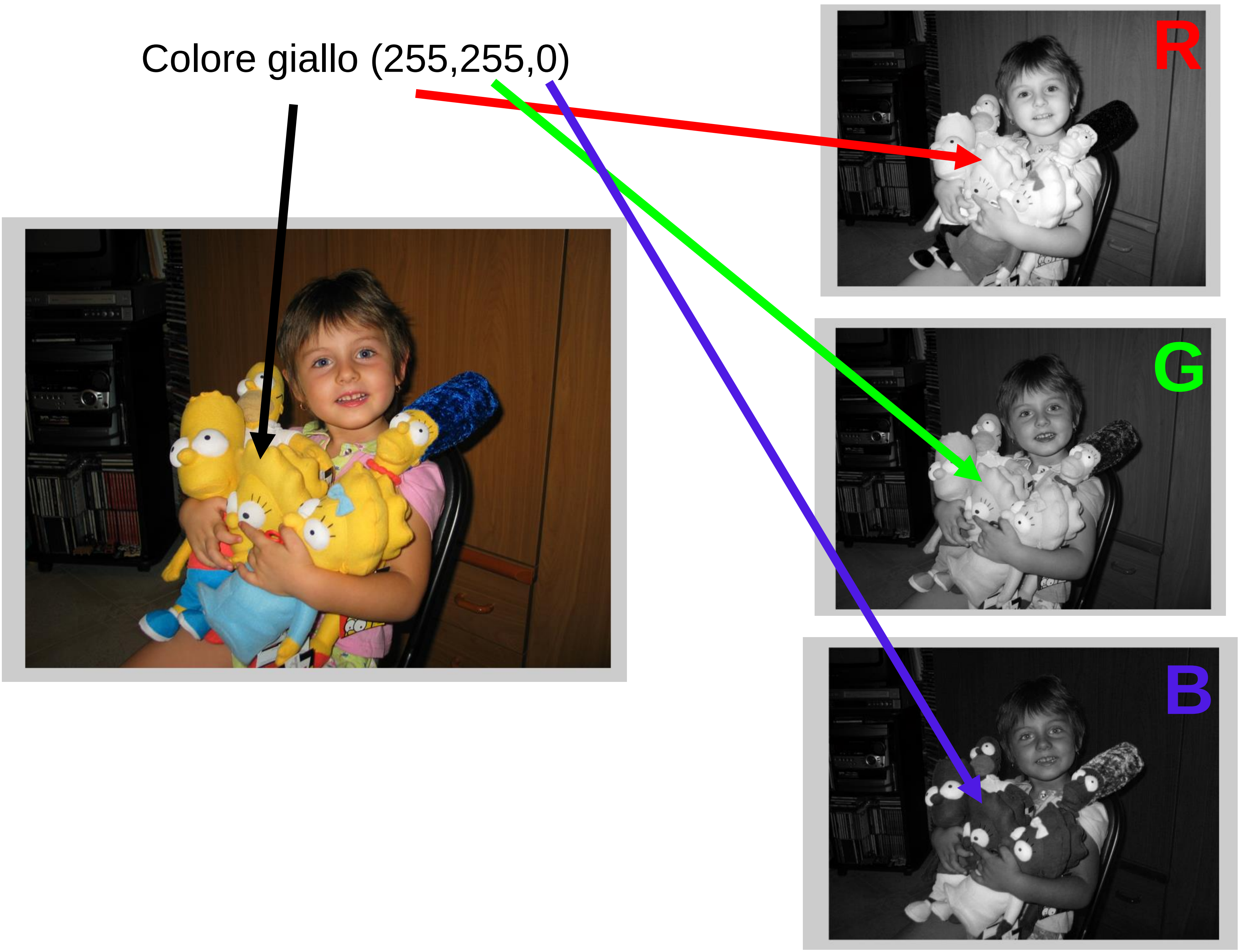
CMY

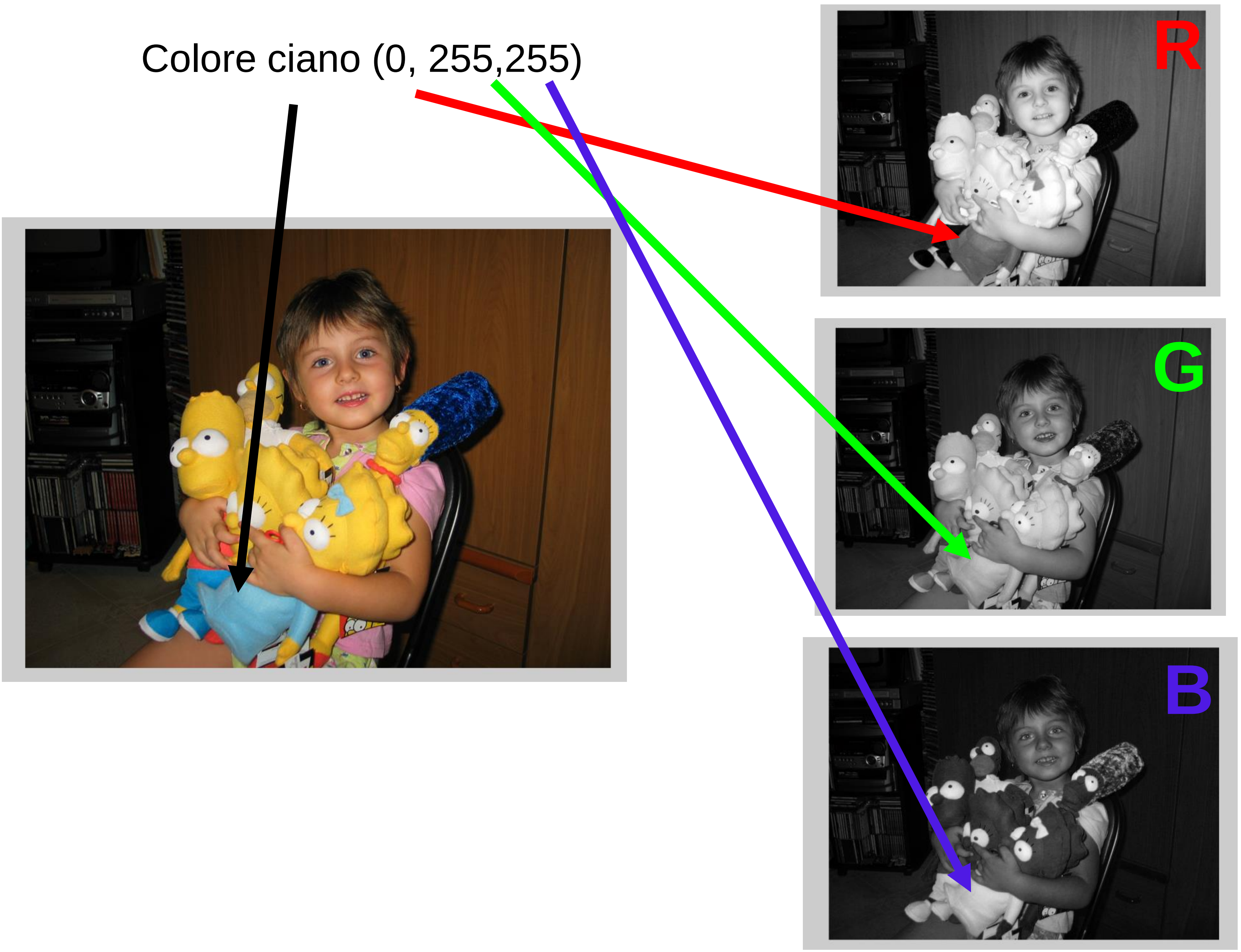
The complementary model to RGB is CMY, Cyan, Magenta and Yellow.

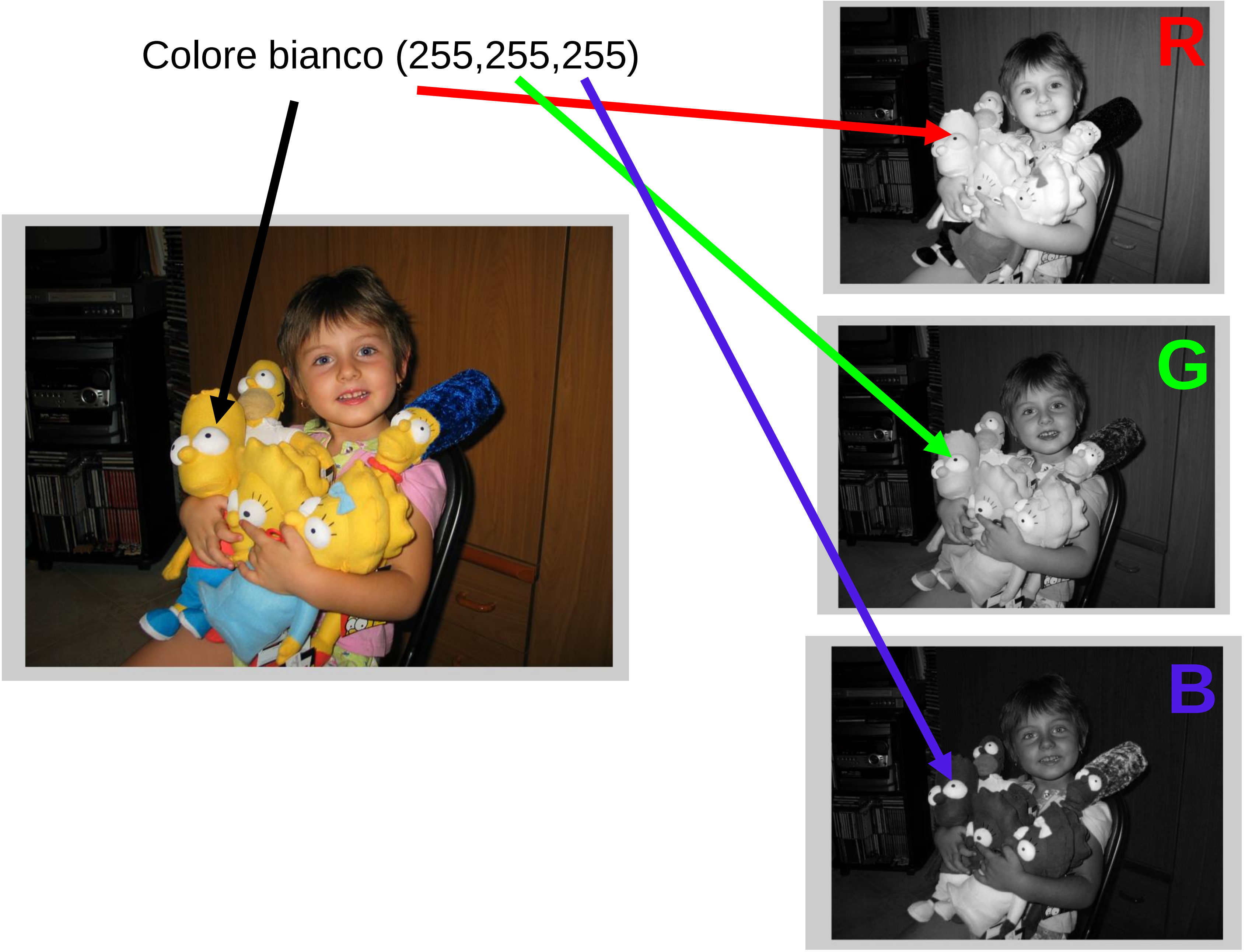



Full color
Cyan
Magenta
Yellow
Black
Red
Green
Blue


R
G
B


Colore giallo (255,255,0)
R
G
B


Colore ciano (0, 255,255)
R
G
B


Colore bianco (255,255,255)
R
G
B

Python!

- Write a Python program that:
  - Shows the input image
  - Shows the RGB channels
  - Calculates the new representation of the image in CMY
  - Show CMY channels

$$R + G + B = W$$

$$R + G = W - B = Y$$

$$R + B = W - G = M$$

$$B + G = W - R = C$$

Luminance-chrominance representations

- Color spaces, in which one component is **luminance** and **the other two components are related to chrominance**, are called **luminance-chrominance representations**.

- Luminance provides a grayscale version of the image while chrominance provides the "extra" information that transforms the grayscale image into a color image.

- **Luminance-chrominance representations are particularly important in image compression.**

The human eye is more sensitive to luminance than to color. I can therefore "spend" many bits to record luminance and save some on chrominance.

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The YUV space

- **YUV space** is often used for encoding analog images or video, keeping luminance and chrominance separate.

- **WARNING**. **YUV refers NOT to a specific space, but to a family of spaces with the above-mentioned characteristics**. As an example we report the YUV space defined in the ITU-R BT.601-4 standard.

- Possible digital counterparts of YUV spaces include **YC_bC_r spaces**.

From RGB to YUV

- **Luminance** can be obtained by a li**near combination of the light intensities of the red, green and blue channels of RGB**. A fairly faithful approximation of "Y" luminance is obtained through weighted addition:

$$\boldsymbol{Y = 0.299R + 0.587G + 0.114B}$$

- The term **chrominance** is defined as the **difference between the color and an appropriately weighted reference white at the same luminance**:

$$\boldsymbol{U = 0.564(B - Y) \rightarrow U = -0.169R - 0.331G + 0.5B}$$

$$\boldsymbol{V = 0.713(R - Y) \rightarrow V = +0.5R - 0.419G - 0.081B}$$

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Luminance

RGB image

$$Y = a\,R + b\,G + c\,B$$

$a = .3$

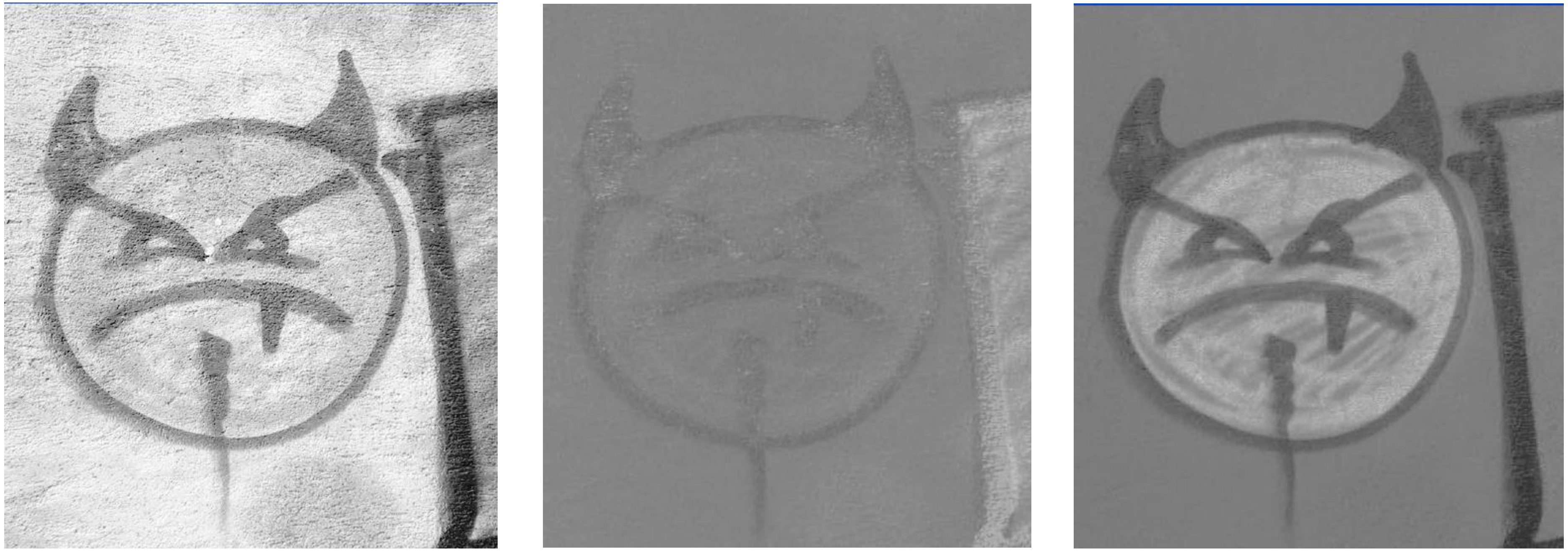
$b = .6$

$c = .1$

Luminance channel

The three RGB channels do not make equal contributions to luminance. The value of "luminance" is maximally maintained in the G channel.

The YUV space



From YUV to YC_bC_r

- YC_bC_r spaces can be easily obtained by **normalizing and possibly quantizing the YUV channels**.

- In the case where R, G and B are integers between 0 and 255, C_b and C_r can be obtained by shifting U and V. Y is the same as YUV. In this way, all 3 channels Y, C_b and C_r will be between 0 and 255.

$$Y = 0.299R + 0.587G + 0.114B$$
$$C_b = U + 128$$
$$C_r = V + 128$$

- **The YC_bC_r space is widely used in compression. We will find it in the JPEG format.**

da RGB a Y C_b C_r

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Y is luminance, the other two channels encode colours.

This is a reversible transformation.

The Y C_b and C_r is a colour model that takes advantage of the ‘weakness’ of the human visual system.

The YC_bC_r space

YC_bC_r :

Y represents luminance while C_b and C_r represent chrominance of blue and red

Homework

- Write a python program able to transform an image into YUV color space and then into YCbCr. Show the results at each step.

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