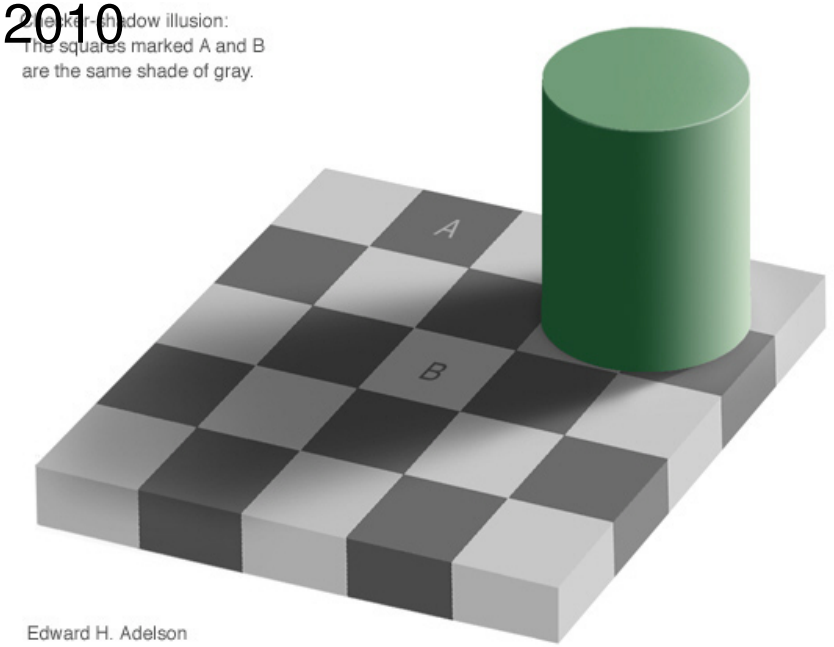
Chapter 2

Image Processing

Digital Color Images

Lecture *Sistemi intelligenti naturali ed artificiali (SINA)* from 15. Oct. 2010



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Program for today

1. **What is Color**
   - Colors and the Human Visual System (HVS)
   - Additive / Subtractive Color
2. **What are Color Space**
   - RGB Color Space
   - HIS Color Space
   - YUV Color Space
   - Why Different Color Spaces?
3. **Pseudo Color**
4. **Concluding Remarks**

What is Color?

What is Color

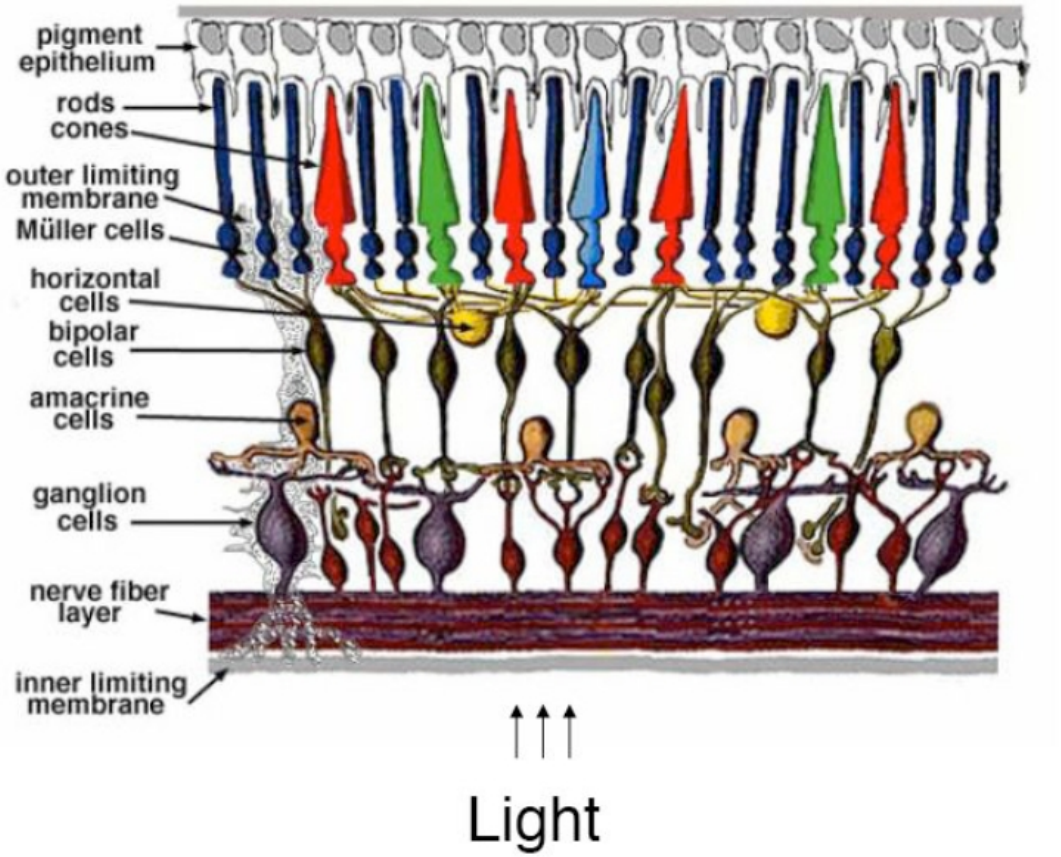
- The colors that humans perceive are determined by the nature of the light reflected from an object! Green objects reflect “green” light!
- Achromatic: Only *intensities* (amount of light). Achromatic information ranges from black to white

Example: Gray levels as seen on black/white TV screens.

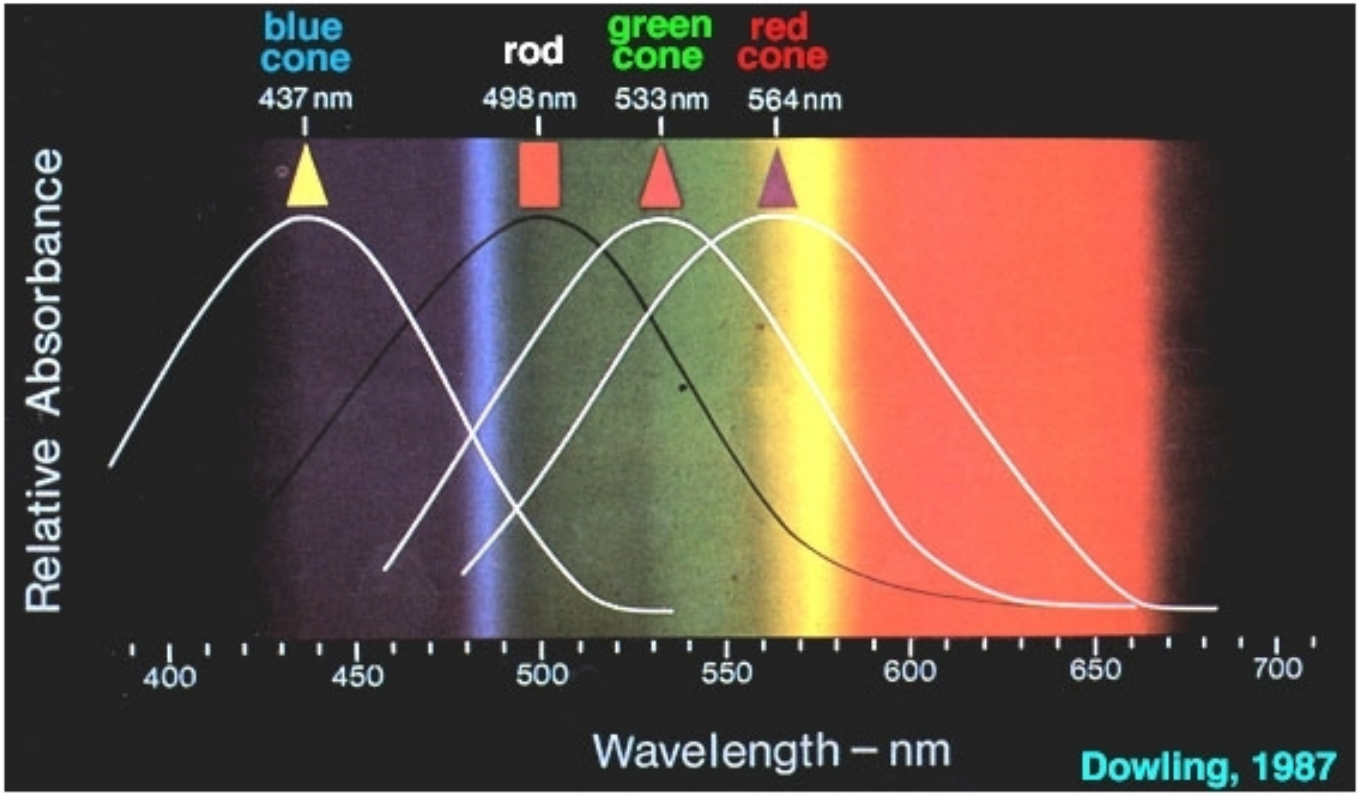
- Chromatic: Lightwaves; Visual range: 400nm-700nm

Red, Green,Blue

- R,G,B are called Primary Colors
- R,G,B are used in cameras
- R,G,B were chosen due to the structue of the human eye



Receptivity of the Eye Cells



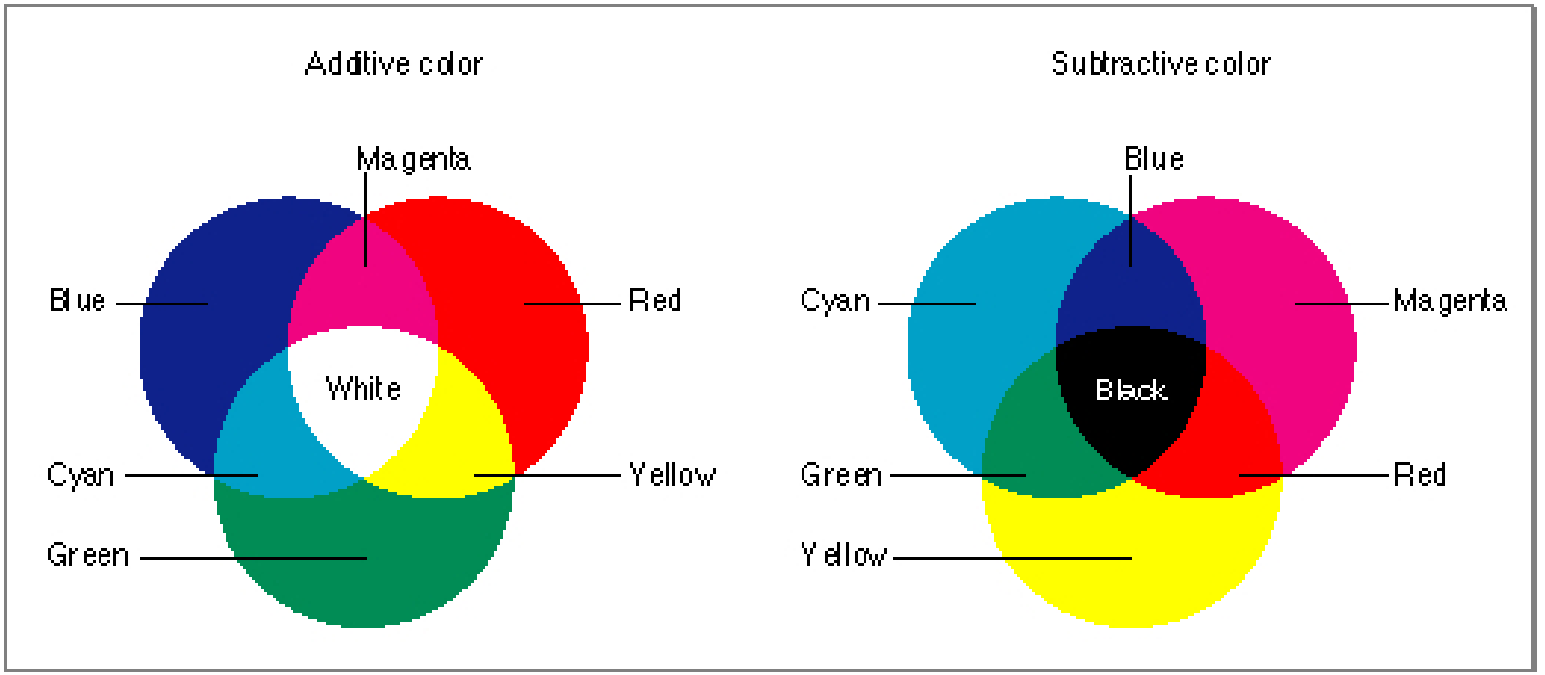
Red, Green,Blue=White? Really???

- So why don't we get white, when we use paint?

  Subtractive Color!!

- But why does it work for the TV?

  Additive Color!!



Additive / Subtractive Color

- Additive Color: Sum of light of different wave lengths. That light reaches our eye directly.

Example

- TV, Video Projectors, LCD Monitors

- Subtractive Color: White Color is emitted by the sun and is only partially reflected from an object!

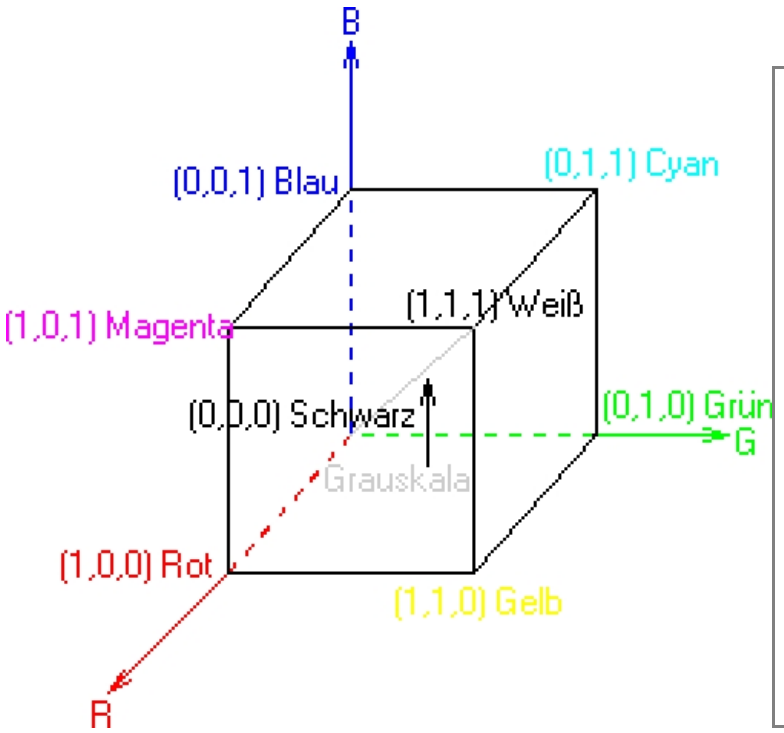
Example

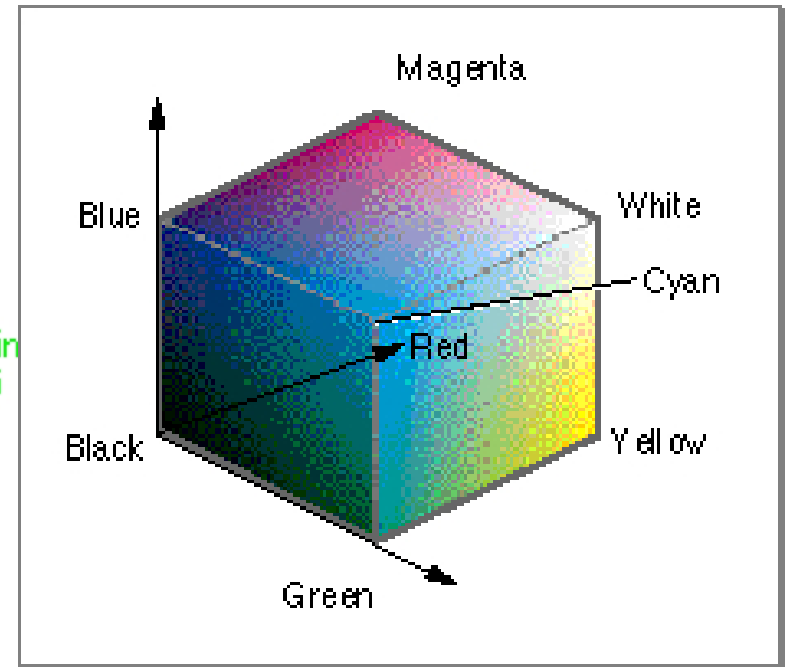
- Red paint filters all light except red!
- Yellow paint absorbs blue, but reflects red and grean

What are Color Spaces?

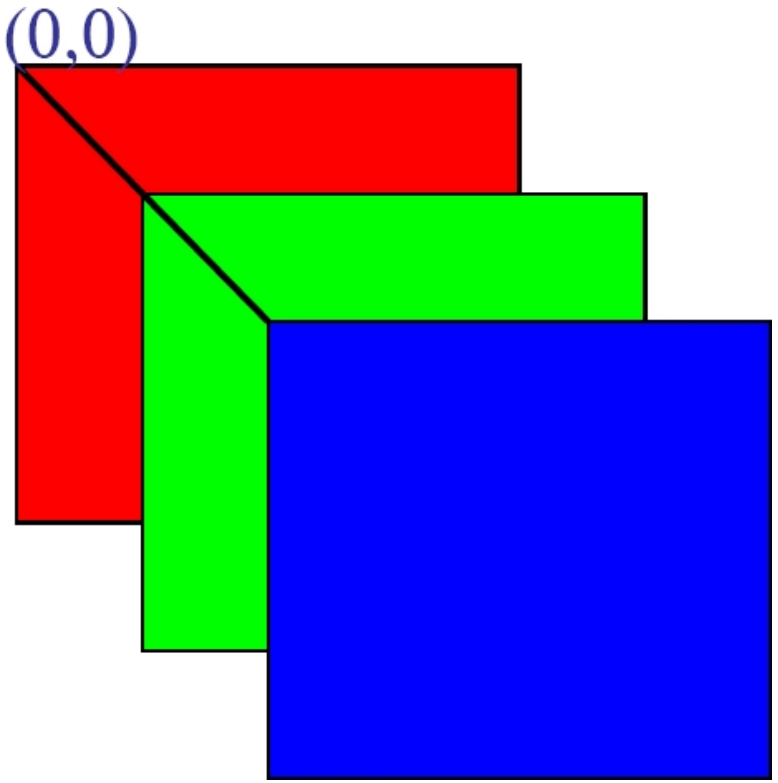
RGB Color Space

- the *classical* Computer Color space
- 3 different colors: Red, Green, Blue.
- Similar to the human visual system
- If R,G,B have the same energy we perceive a shade of white (gray, black).





RGB Color Space



A single pixel consists of three components: $[0, 255]$. Each pixel is a vector.

128	251	60	=

Pixel-vector in the computer memory

Final pixel color in the image

Caution

Sometimes pixels are not stored as vectors but in Image Bands. First, the complete red-component is stored, then the complete green, then blue.

Example RGB

Original Image

Red Band

Green Band

Blue Band

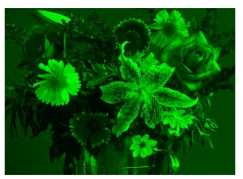
Convert Color to Grayscale Images

RGB to Gray Conversion

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

$= \left(\right.$

$+$

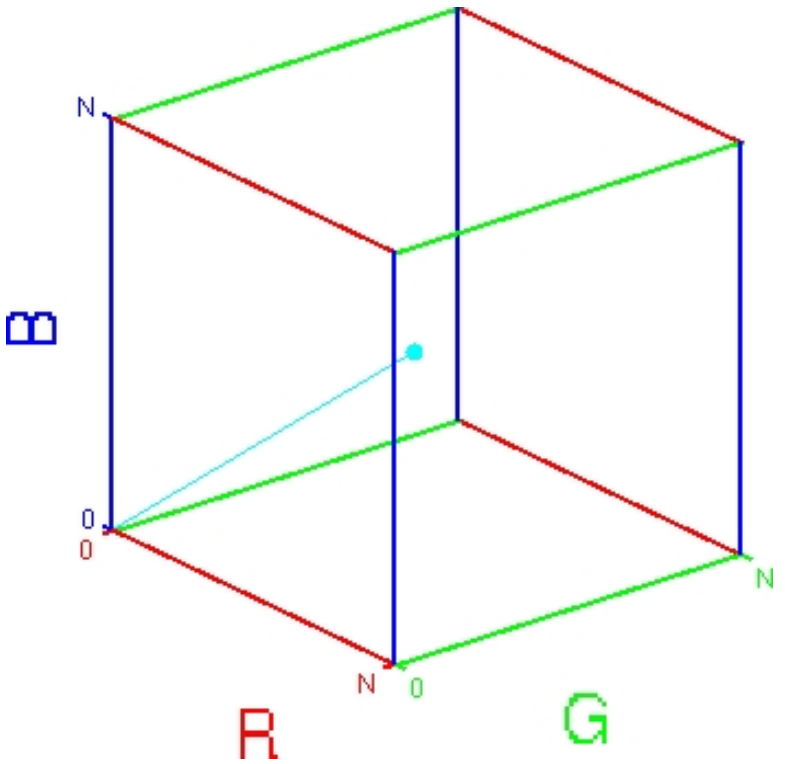


$+$

$\left. \right) \frac{1}{3}$

Color and Intensity are mixed in RGB

- Same Color,



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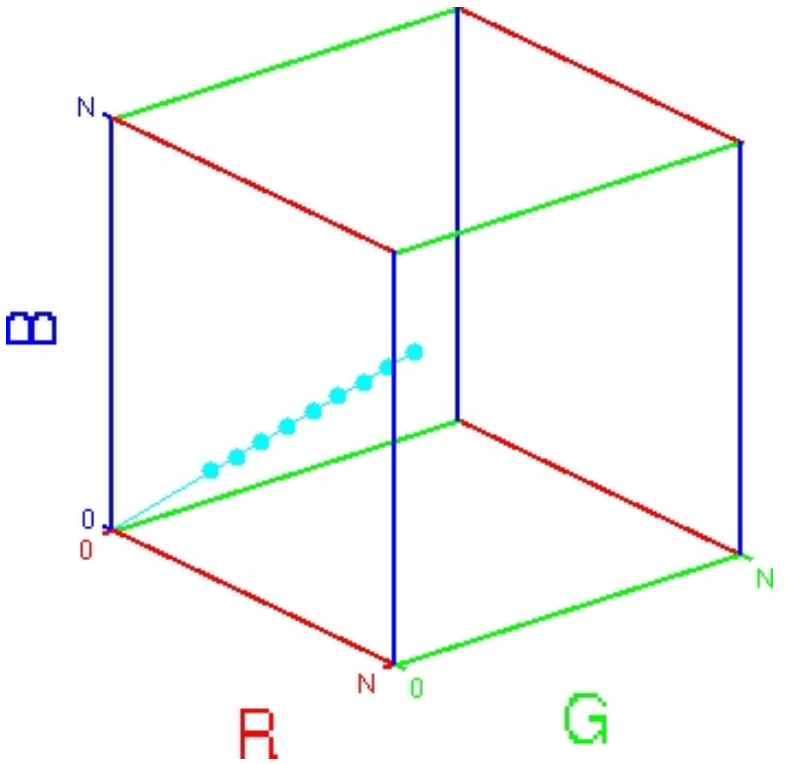
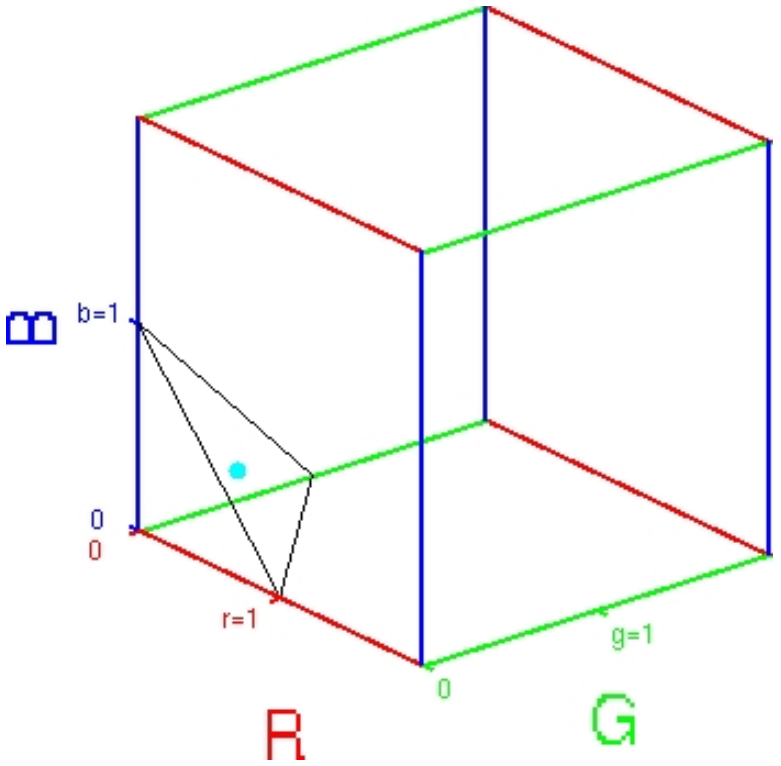


Color and Intensity are mixed in RGB

- Same Color,
- different intensities
- Chromaticiy Plane



Color and Intensity are mixed in RGB

- Same Color,
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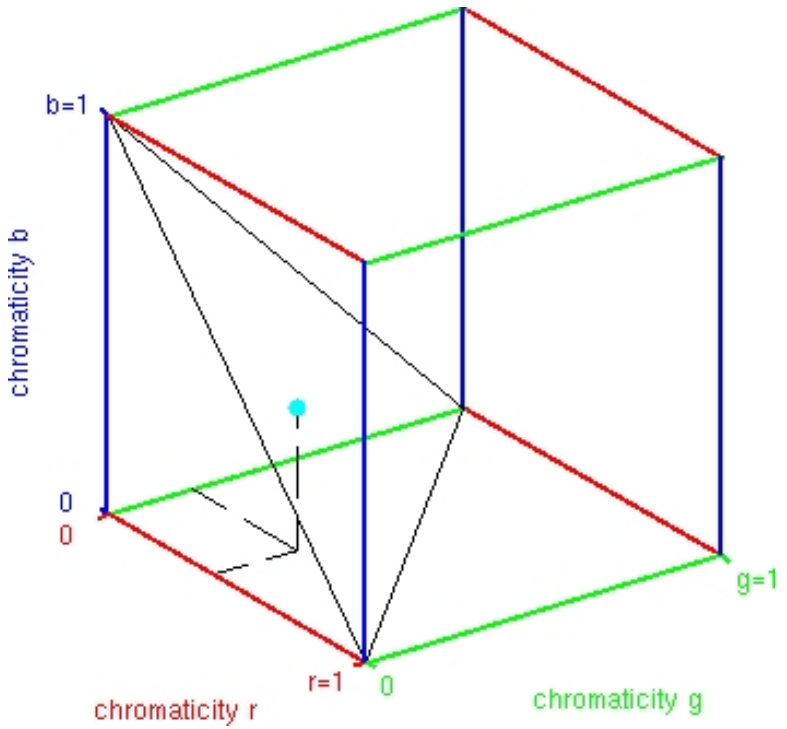
- Chromaticiy Plane
- $r + g + b = 1$



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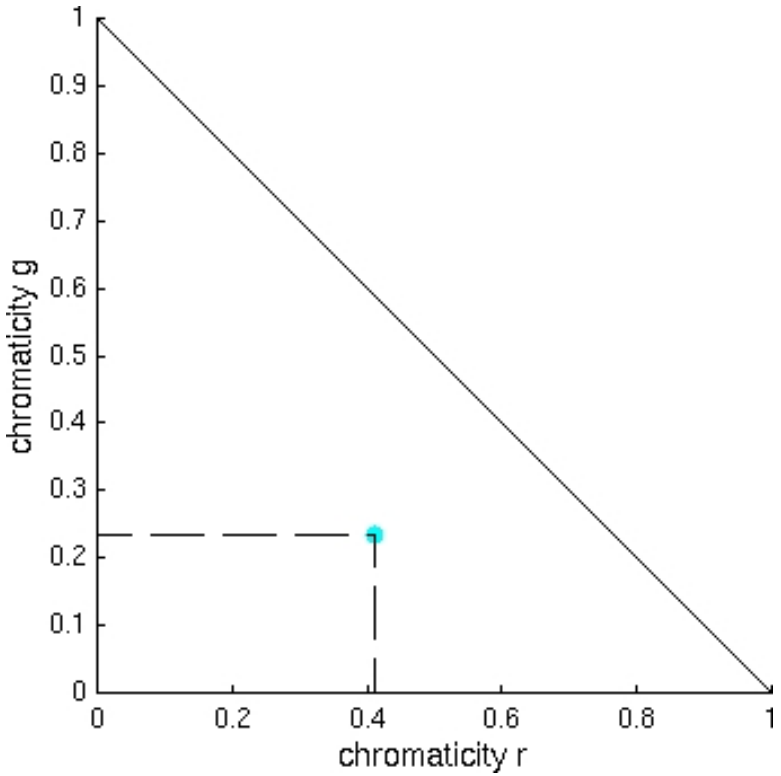

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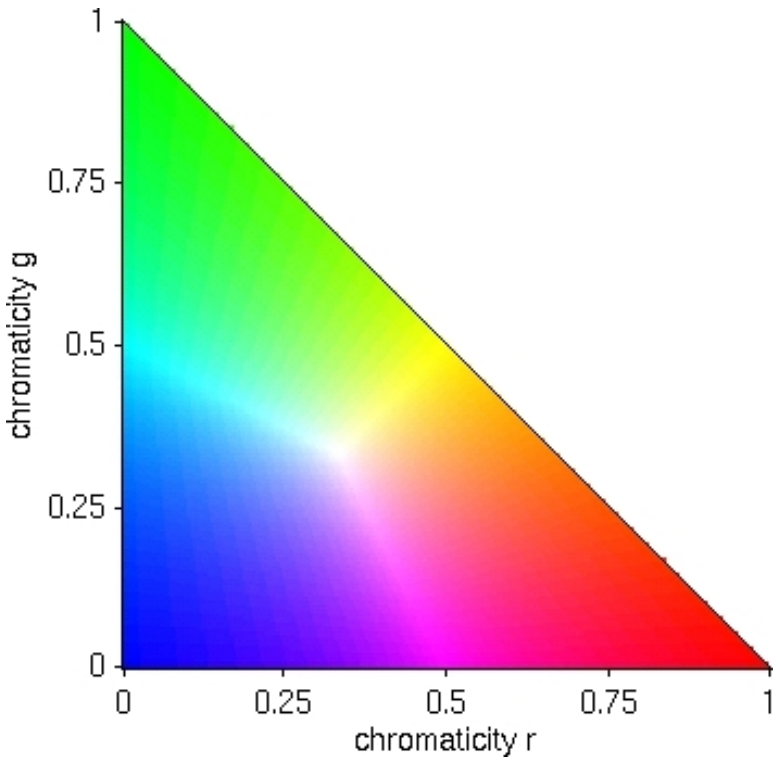


RGB to Chromaticity concersion

$$r = \frac{R}{R+G+B} \; g = \frac{G}{R+G+B} \; b = \frac{B}{R+G+B}$$

Another way of separating color and intensity: HSI

- *H*=Hue, *S*=Saturation, *I*=intensity
- intensity *I*: 
- H and S may characterize a color: Chromatics

Hue 

- associated with the dominant wavelength in the mixture of light waves, as perceived by an observer.
- is the color attribute that describes a pure color

Saturation 

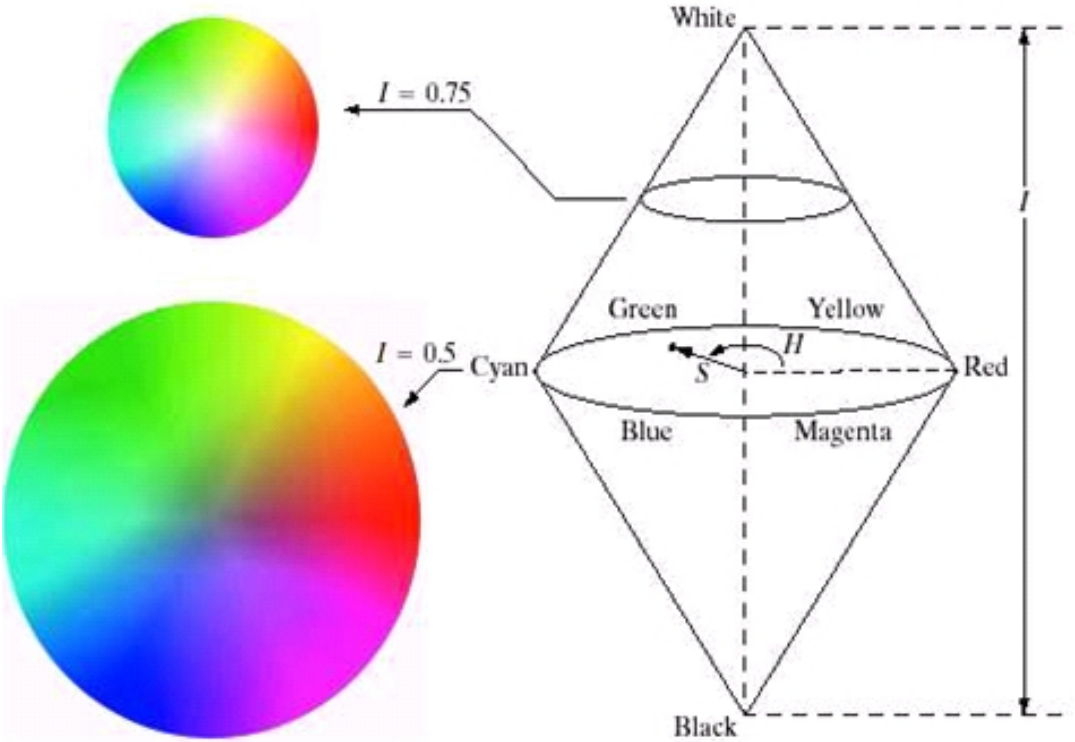
- relative purity
- amount of white light in the color
- mixed with hue

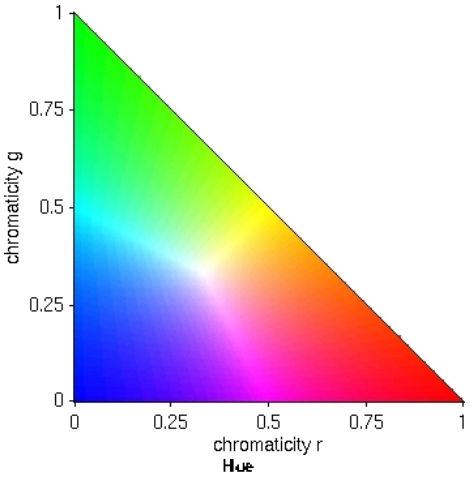
Example

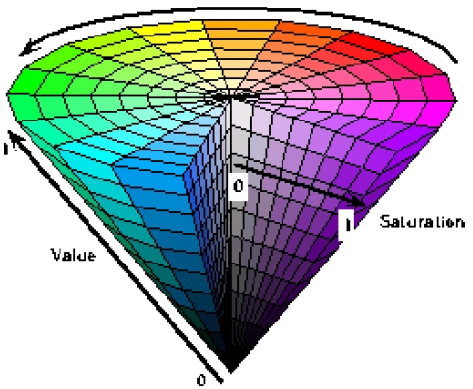
Pure colors are fully saturated. Not saturated is, e.g., pink (red+white).

HSI Color Space

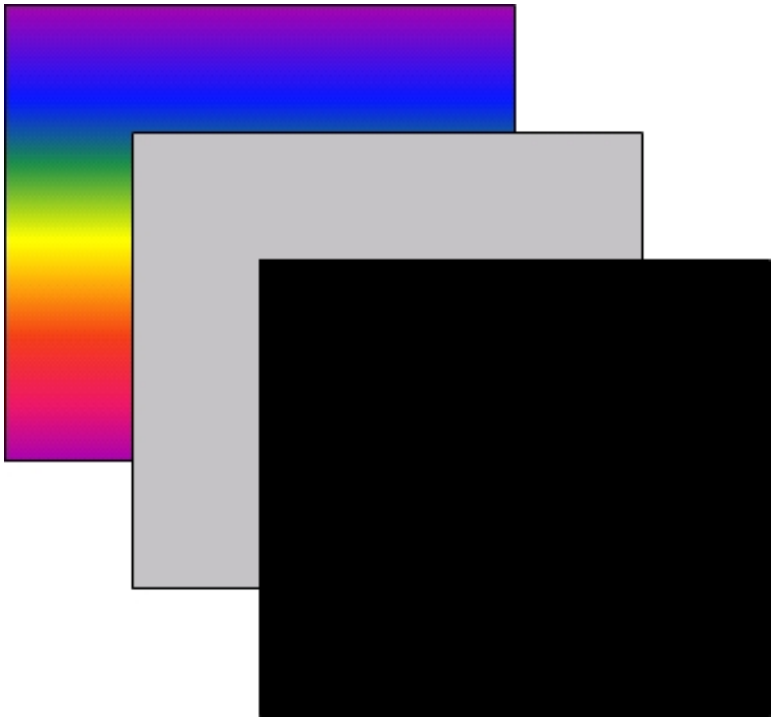
- Perhaps the most intuitive color representation
- Used in Computer Graphics and Computer Vision







HSI Color Space



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Example HSI

Original Image

Hue

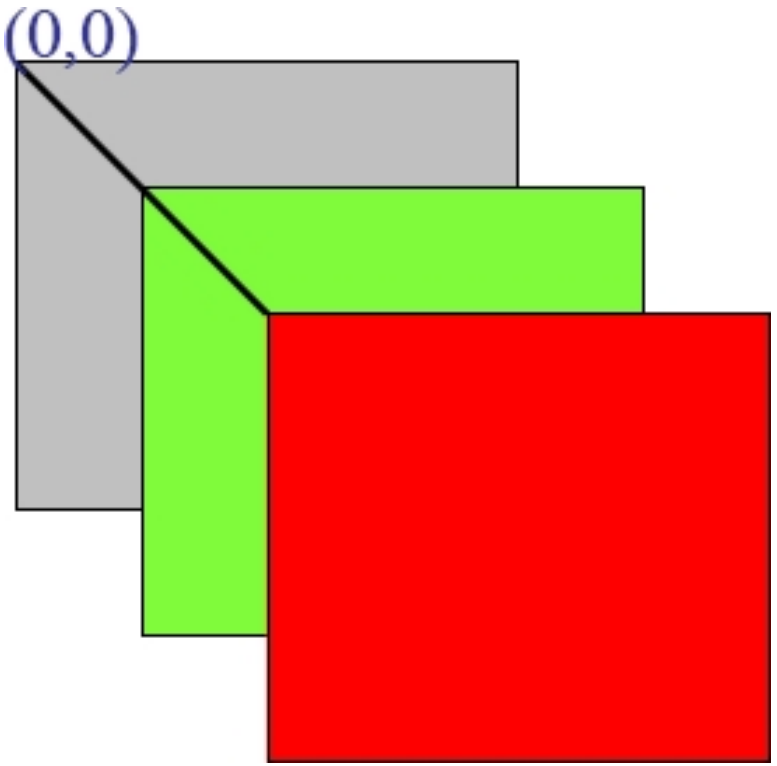
Saturation

Intensity

YUV Color Space

- YUV: used in commercial color TV broadcasting and video signals
- backwards compatible to the old B/W TV.
- We need a format that decouples grayscale and color: HSI
- “Poor-man’s” HSI because it is much easier to compute from RGB than HSI

YUV Color Space



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Example YUV

Original Image

Y-band

U-Band

V-Band

So Why Different Color Spaces

RGB Color space

- \+ works like Human Visual System (HVS)
- − difficult to decouble color from intensity

HSI Color space

- \+ a more physically motivated description of color
- \+ decoubles color, intensity and saturity
- − difficult to compute

YUV Color space

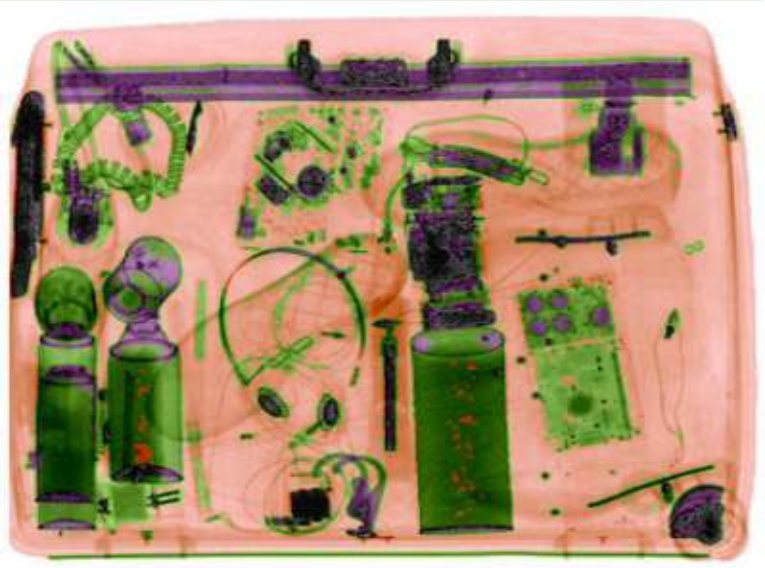
- \+ Simple to compute
- \+ similar to HSI
- \+ motivated by broadcasting technology
- \+ saves memory through biological arguments
- − hardly used in Computer Vision and Computer Graphics

What is Pseudo Color?

Full Color / Pseudo Color

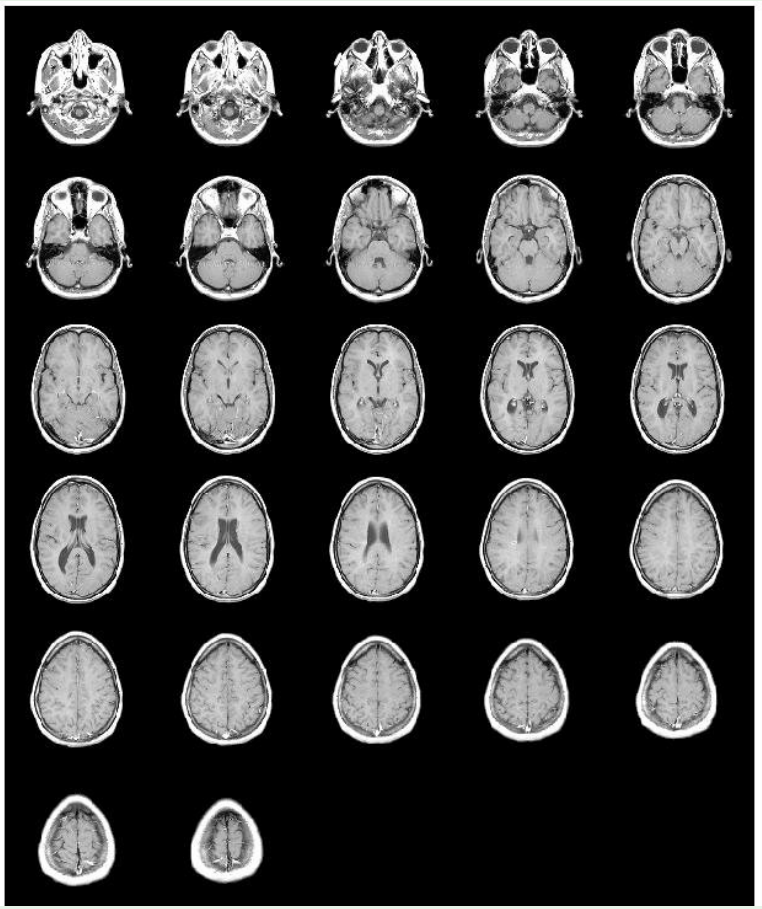
- Full Color Images: Acquired by a (TV/DV) camera, digital camer or scanner
- Pseudo Color Images: Assigned a shade of color to a monochrome intensity or range of intensities

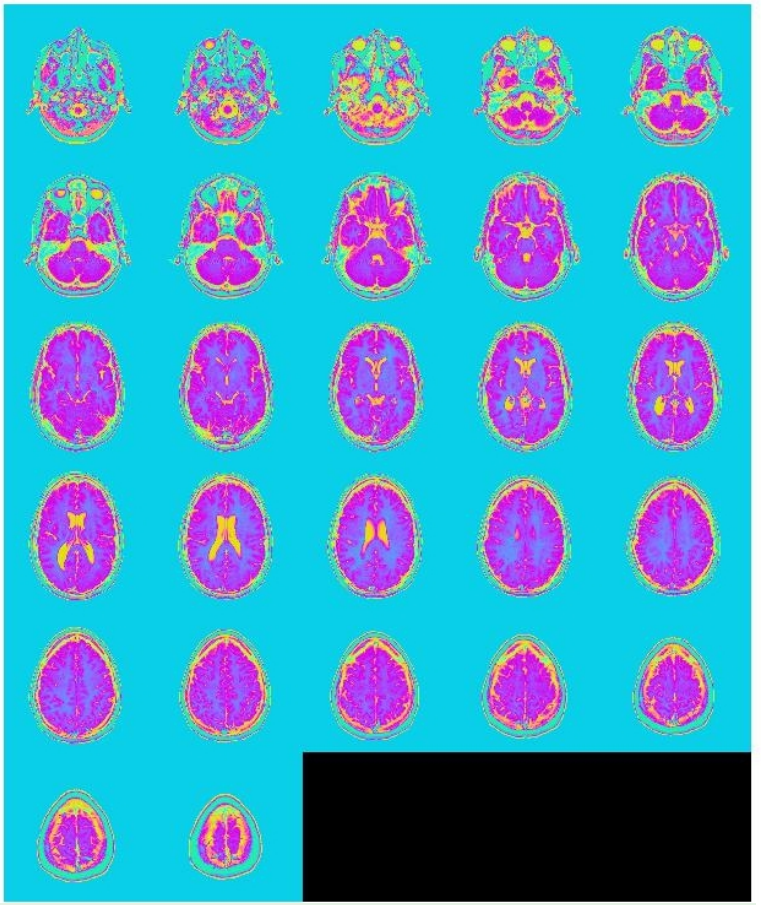
Example



Full Color / Pseudo Color

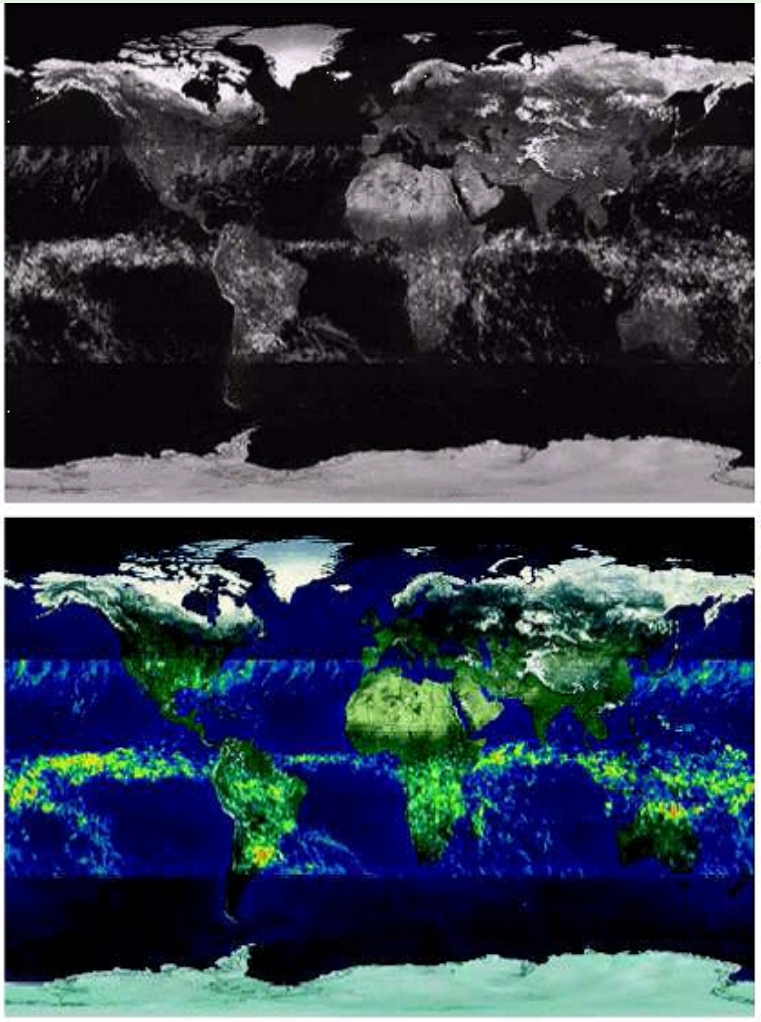
Example

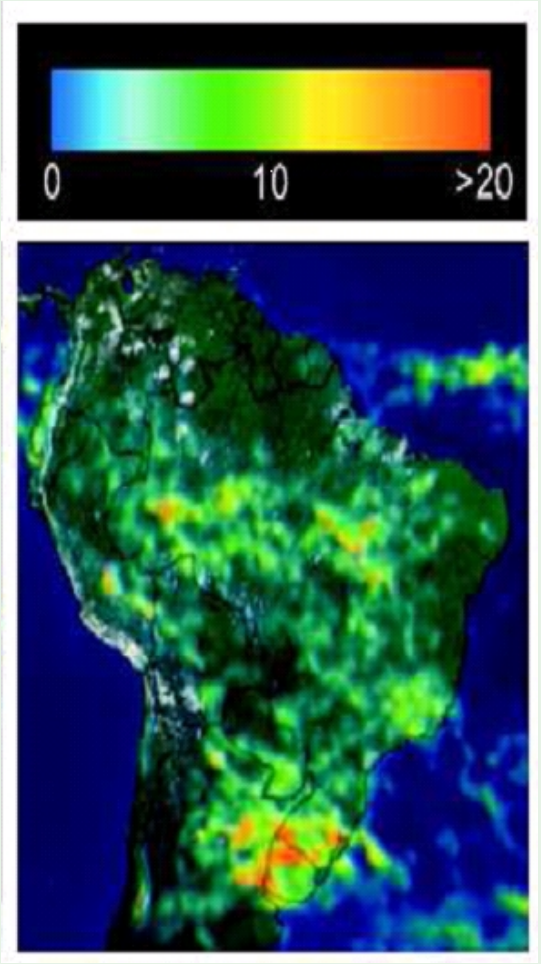




Full Color / Pseudo Color

Example





What to remember

- Achromatic vs. Chromatic
- How come that with RGB we can represent all (all?!?) colors?
- Subtractive Color vs. Additive Color
- Color Spaces
  - RGB: Used in cameras and the HVS
  - Normalized RGB: Decouples intensity and color: Used in Computer Vision
  - HSI: Decouples intensity, hue and saturity: Used in CG and Computer Vision
  - YUV: Used in commercial color TV
- Pseudo color: represent grayscales as colors

Exercises

- Questions about the lecture?
- What was good about the lecture and what oculd have been better?
- How many different 512×512 grayscale (8bit) images exist?
- How many different colors exist for 24bit pixel?
- How many different 512×512 color (24bit) images exist?

Questions

- Why can we use RGB to generate almost all pixel colors?
- What is the difference between Achromatic and Chromatic?
- What is the difference between Subtractive Color and Additive Color?
- Describe the four different color spaces (RGB, rg, HSI, YUV)
- What are their characteristics and where are they used?
- What is a pseudo color image?
-  How can a Pseudo color image be generated from a gray value image?