Color management

Catania – 03/04/2008

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Advanced System Technology

Overview

- Digital Still Cameras have to acquire images with good visual quality colors

- Problems:
  - Color representation
  - Color rendition
  - Color Casting
  - Human Visual Color Perception

Colour representation

- Each pixel have to be represented in a colour space
- A **device dependent** colour space is a colour space where the colour rendition depends on:
  - The used parameters to represent it
  - The equipment used for display.

  Example: RGB, CMY, CMYK, HSB
- In a **device indipendent** colour space the pixel colour depends just on the used parameters to represent it

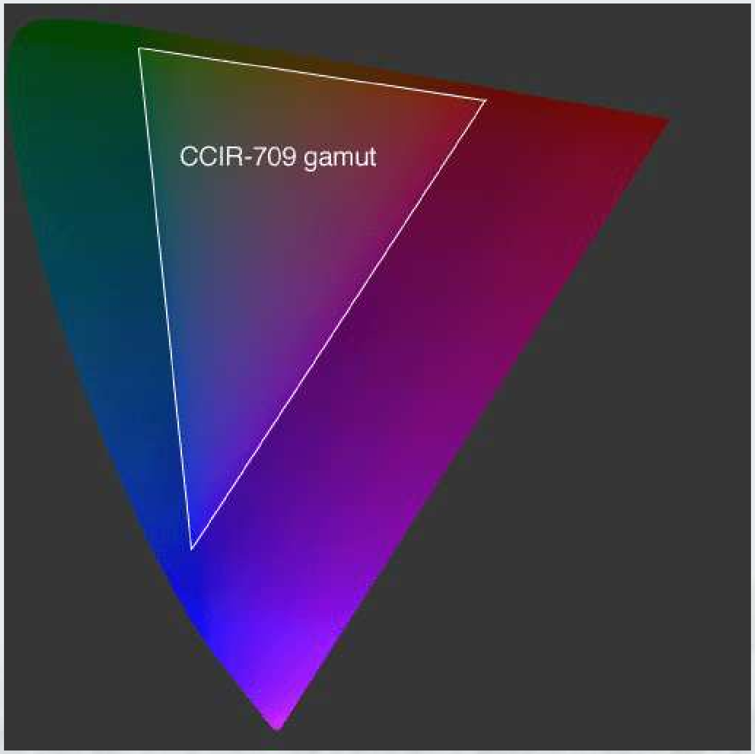
  Example: CIE XYZ, Lab

Color representation in DSC

- The generated image has to be represented in a device independent format
- It allows the image to be view in the same way by every device
- The s-RGB format is usually used

s-RGB representation

- Each pixel is described by a triplet (R,G,B)
- It was standardized
- Not all the colours can be represented in this representation
- In the figure is shown the s-RGB gamut (a colour gamut is the area enclosed by a colour space)



Human Visual Color Perception

- The image has to be seen as real as possible
- The RGB representation is easy to implement but non–linear with visual perception.
- Taking into account the HVS, a **Gamma** function is used at the end of the pipeline

DSC phases

- Three algorithms in the Digital Still Cameras (DSC) are related to this subject:
  - Matrixing
  - White Balance
  - Gamma correction

- Other enhancement algorithms can be applied in post-processing

Matrixing

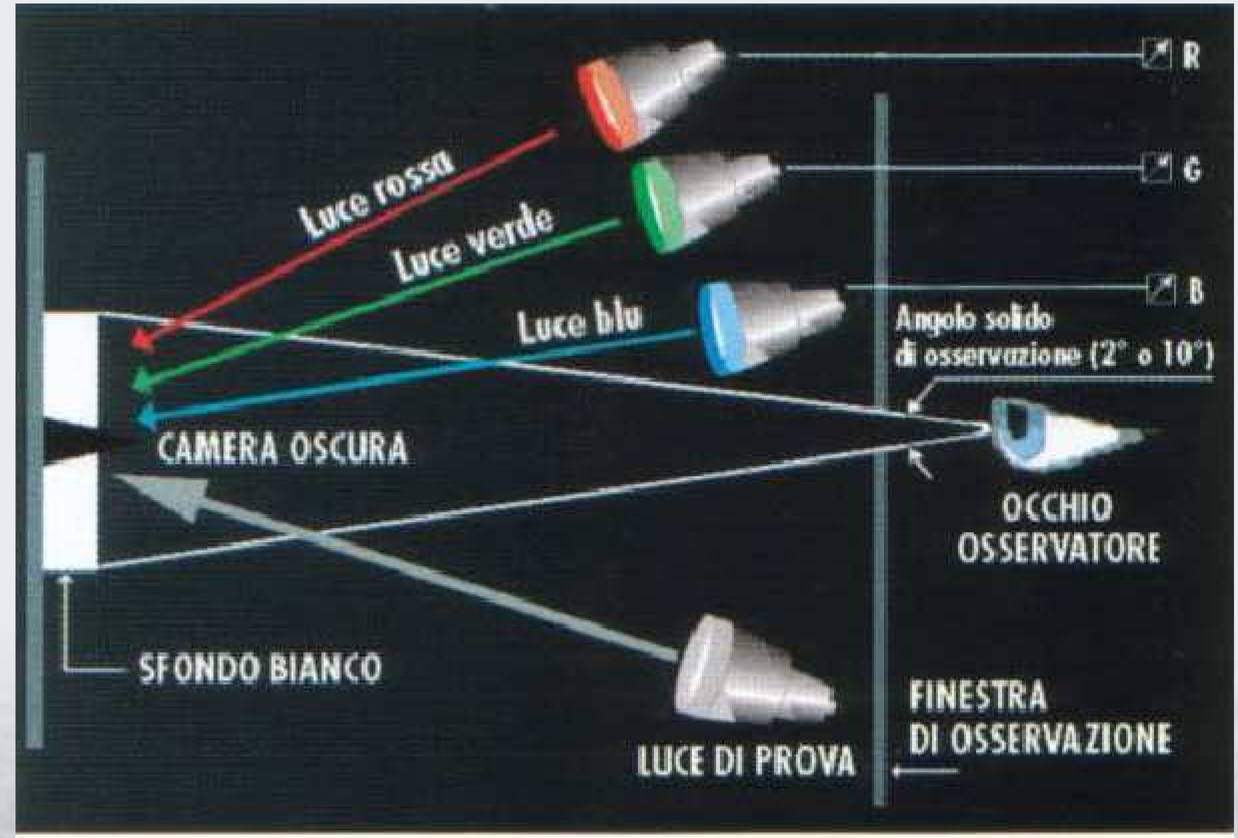
Matrixing

- It corrects the colour distortion due to the CFA

- The CFA has different filter frequency response than the HVS

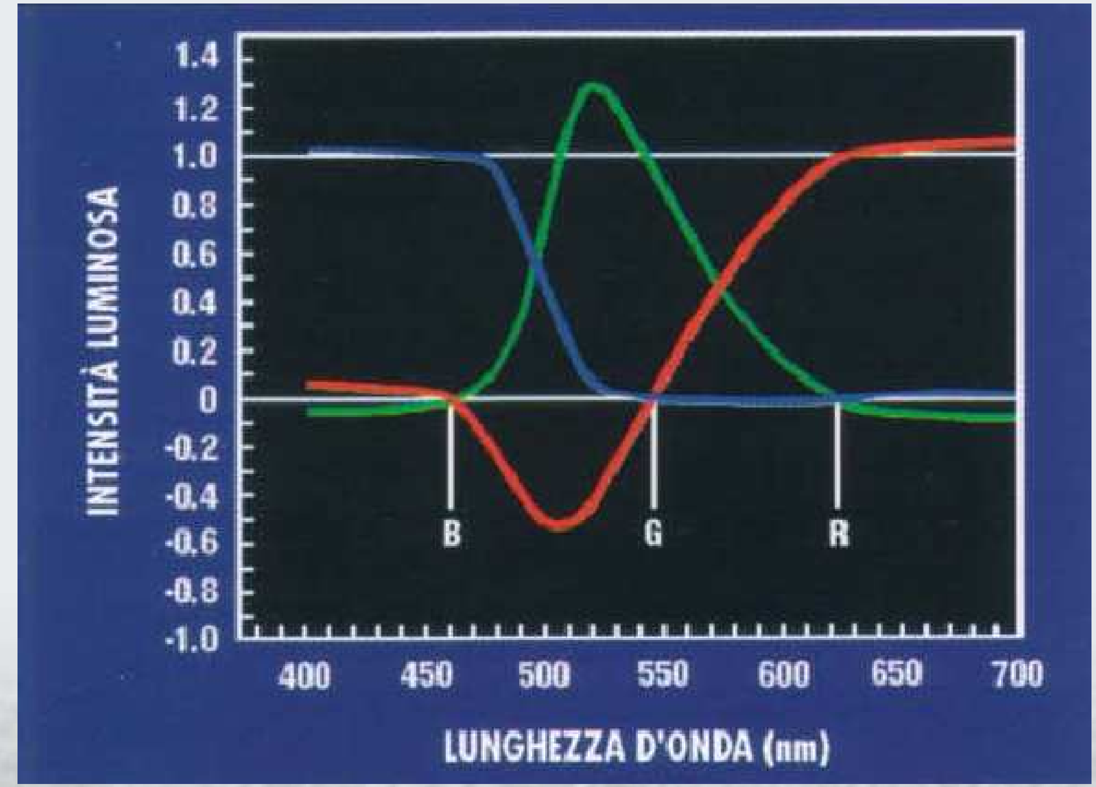
Human eye

- Human eye filter response retrieving phase



Human eye filter response

- The final results is the following



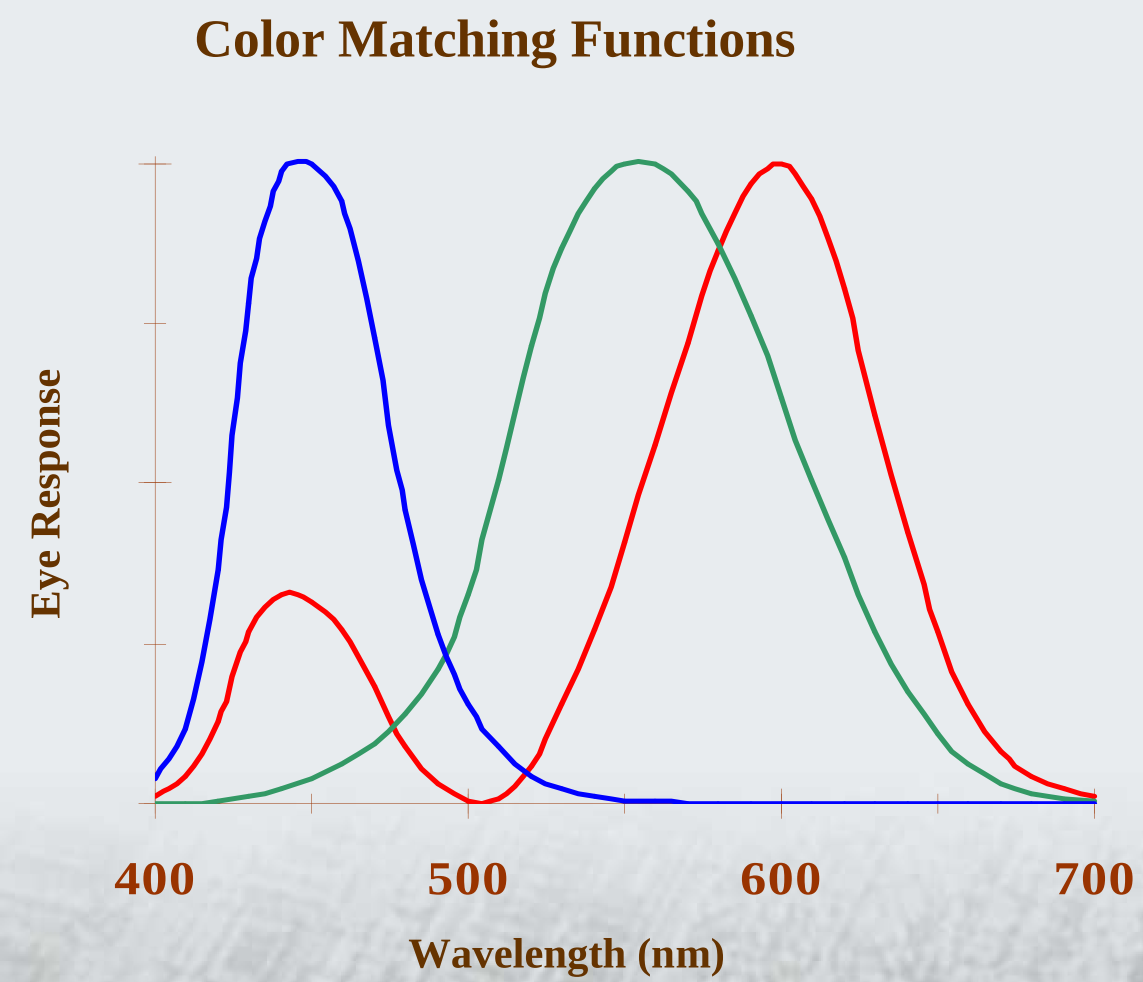
CFA frequency responce

- The CFA has, for each pixel, a colour filter (Bayer format)

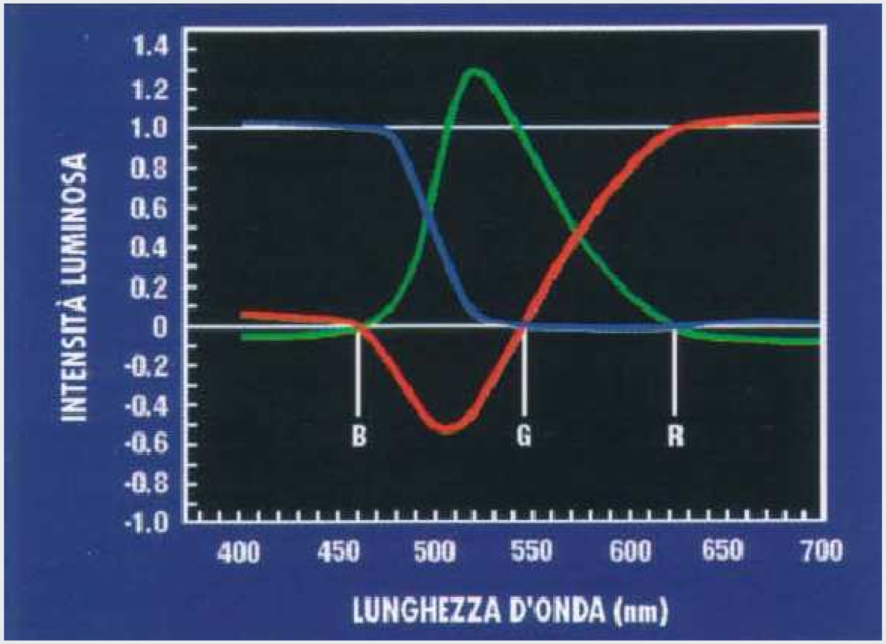
- Using a statistical retrieving phase, the frequency response is retrieved for each colour

- The frequency response is different from the HVS

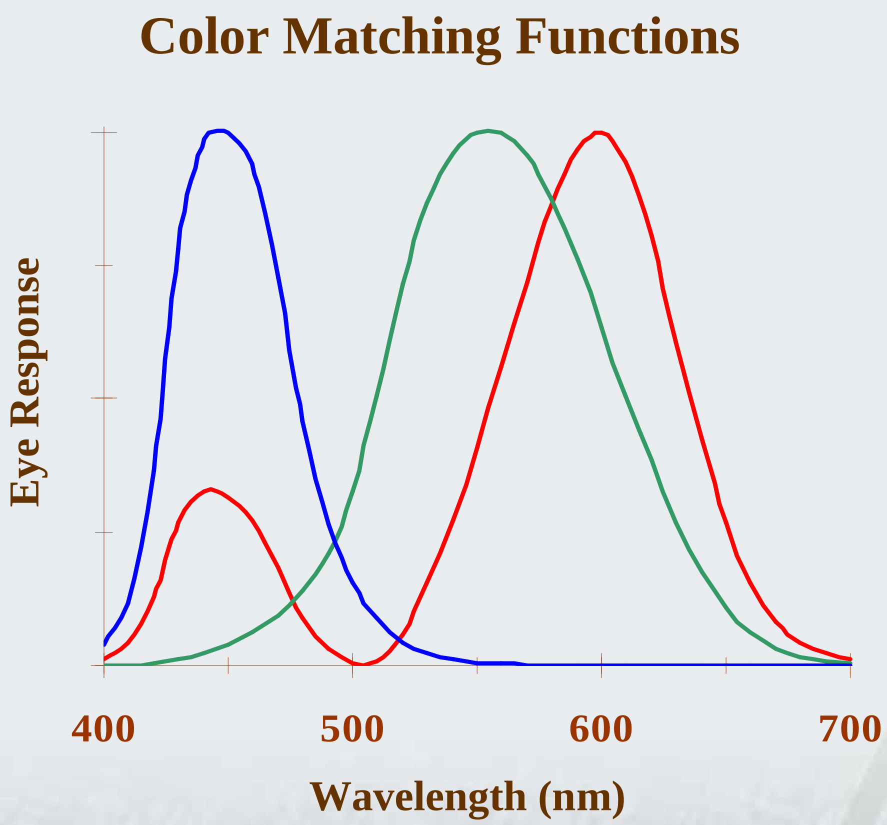
CFA frequency response curves



HVS vs CFA



1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
INTENSITÀ LUMINOSA
B
G
R
400
450
500
550
600
650
700
LUNGHEZZA D'ONDA (nm)



Color Matching Functions
Eye Response
400
500
600
700
Wavelength (nm)

The algorithm

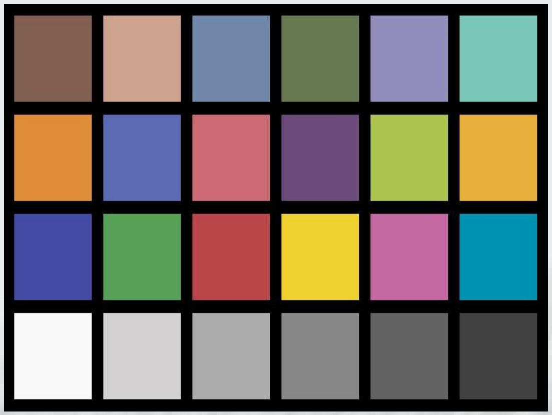
- The matrixing problem is solved through a linear transform of the RGB input colour.

- The extra-diagonal coefficients allow to delete the chromatic interferences

$$\begin{bmatrix} R_b \\ G_b \\ B_b \end{bmatrix} = \begin{bmatrix} 1 & k_{rg} & k_{rb} \\ k_{gr} & 1 & k_{gb} \\ k_{br} & k_{bg} & 1 \end{bmatrix} \begin{bmatrix} R_i \\ G_i \\ B_i \end{bmatrix}$$

Tuning phase

- The coefficients are to be retrieved for each device
- Usually a statistical retrieving phase is used with the Macbeth chart
  - Several image acquisitions of the chart (without dominant colours)
  - Mean (to reduce the noise effects)
  - Linear regression obtaining the k_{ij} values



White Balance

Auto White Balance

- It take into account the illuminant chromatic distortion
- The HVS is able to see real white objects
- The CFA is not able to do so!

Color correction

- Color correction is based on the (Von Kries) diagonal hypothesis
- It states that a color balancing can be obtained by a different gain application on each color channel.
- On a RGB image representation a diagonal transform is performed as follows:

$$\begin{bmatrix} R_b \\ G_b \\ B_b \end{bmatrix} = \begin{bmatrix} k_r & 0 & 0 \\ 0 & k_g & 0 \\ 0 & 0 & k_b \end{bmatrix} \begin{bmatrix} R_i \\ G_i \\ B_i \end{bmatrix}$$

Typical approaches

- They are based on strong assumption in the scene content
- Two classical methods are used:
  - Gray world approach (GW)
  - White patch approach (WP)

Gray World approach

- It assumes that the average of all surface reflactance in a scene is gray. Each deviation is due to the illuminant.
- The algorithm works as follow:
  - Retrieve the mean value for each color channel
  - Retrieve the k_i coefficients in order to set these value in the mid point

White Patch approach

- It assumes that a white object is always in the scene (i.e. the maximum values for each channel is to be the maximum allowed).

- The algorithm works as follow:
  - Retrieve the max value for each channel (Rmax, Gmax, Bmax)
  - Retrieve the k_i coefficients in order to set these value in the maximum allowed by the representation

Gw and WP limits

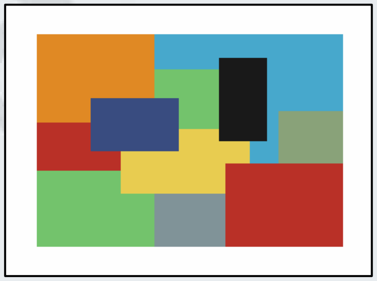
gray-world hypothesis problem scenary:

- ✓ very simple scenes with few colors.
- ✓ images with a limited range of dominant hues, i.e. underwater images,
- ✓ synthetic graphic…

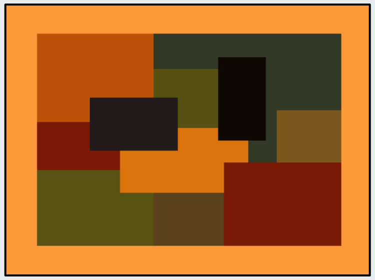
White-patch hypothesis problem scenary:

- ✓ High contrast scenes: white pixels could be saturated or clipped.
- ✓ Noise sensitivity
- ✓ metallic and specular surfaces
- ✓ a real white object could be present on the scene

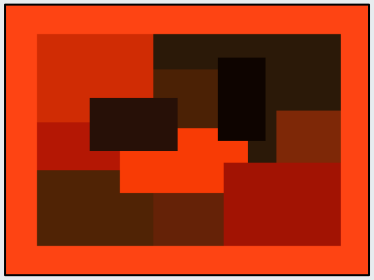
GW and WP critical examples



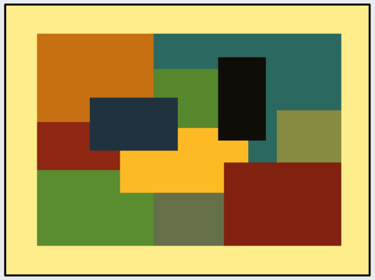
Original image



Neon illuminant

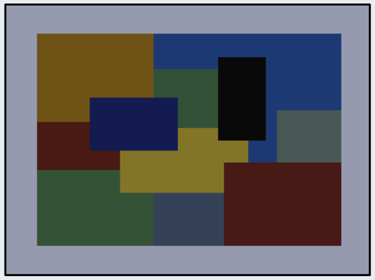


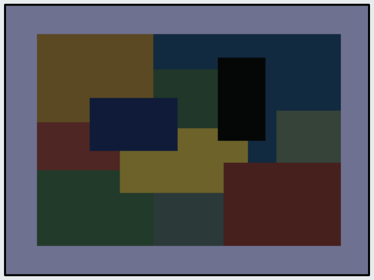
Red

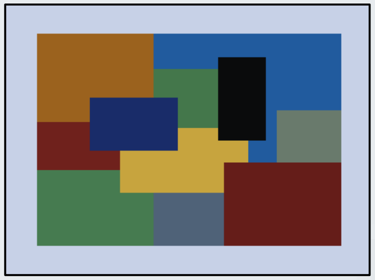


Nitraphot

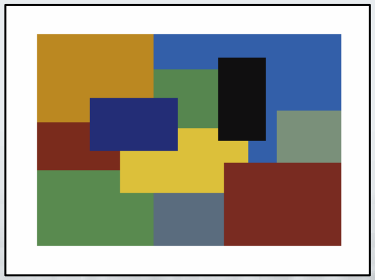
Recovered images under gray world assumption

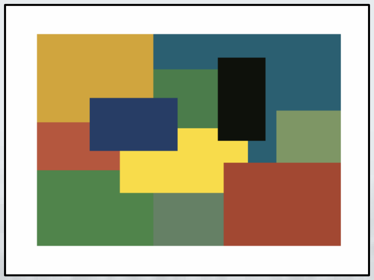


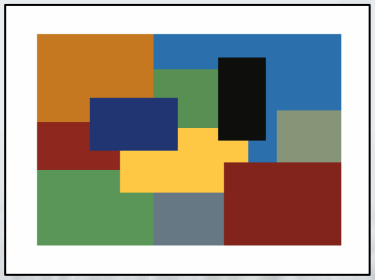




Recovered images under white patch assumption







critical examples

Critical example with constrained approach

Underwater image

AWB Processed image

with constrained approaches, chromatic distortion is introduced when a real dominant hue is present.

Gamma

Gamma correction

- HVS has a non-linear response to colour intensity
- A Gamma correction is to be applied in order to enhance the image quality
- The Gamma controls the overall brightness of an image

How to

- The Gamma is usually an exponential value

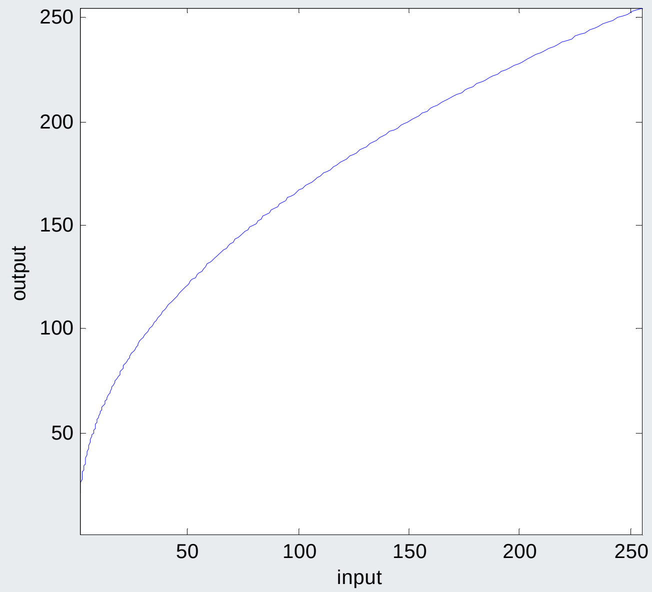
- All the colour channel is powered with the Gamma value:

$$new\_val = \left(\frac{old\_val}{\max\_val} \right)^{\gamma} \cdot \max\_val$$

- Where *max_val* is the maximum allowed value (e.g. 255 for 8 bit-depth representation)

Implementation

- For Gamma=2.2 the transform is:



- The implementation is usually performed with a Look Up Table (LUT); the output is retrieved with the code:

output=LUT[input]

Example

Original

Gamma=2.2

Advanced techniques

Post processing techniques

- Other techniques can better enhance the colour rendition
- Usually they are a post-processing algorithms
- Different approaches exists in literature

An example

- The technique individuates the scene components and adapts the colour taking into account such regions
- The algorithm works as follows:
  - Image segmentation
  - Object classification (e.g. sky, vegetation, skin)
  - Object colour enhancement
  - Image Merging
- The technique provides better visual quality results, but has a high computational cost.

Color Enhancement

A Post-Processing Solution based on expected colors

Image Segmentation → **Image Classification** → **Expected Color Enhancement**

An example of automatic scene classification

■ Sky ■ Vegetation