Colour

[ignore the Matlab code, Python code is in practical]

Colour

Look at the meaning of colour – eyes response.

Colour in the computer.

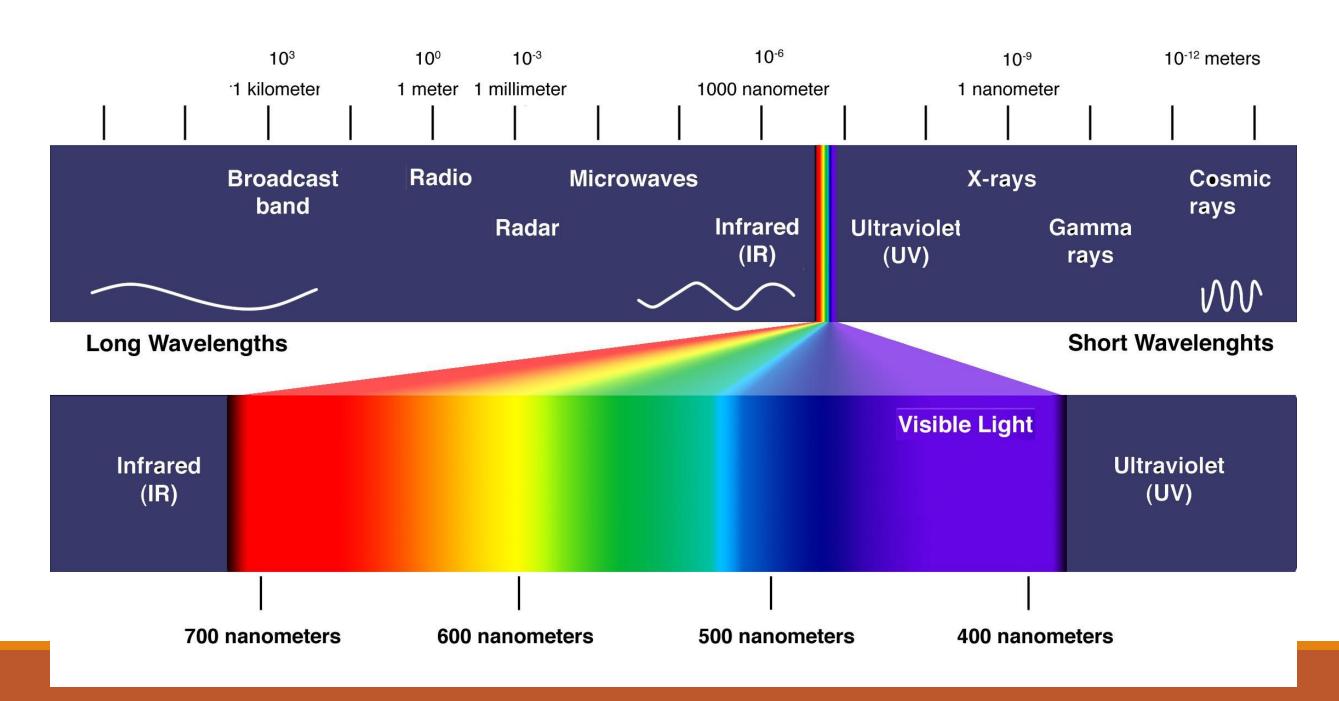
Properties of colour. Hue, Saturation and Luminance.

Limitations of luminance algorithms in computers.

Colour in Python

What is colour? Electromagnetic wave

Visible light is broken up into wavelengths ranging from Red to Violet. (rainbow). This is called the visible spectrum.



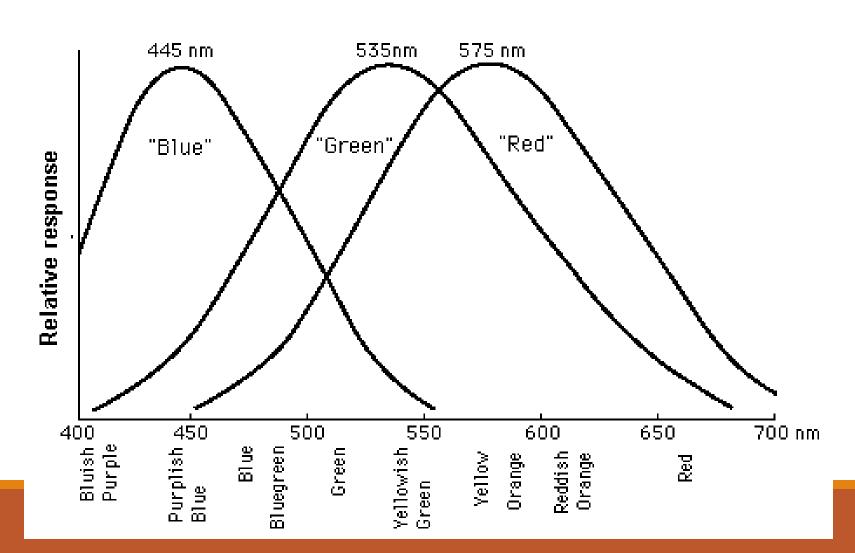
The eye's response to colour

We perceive colour through the stimulation of three types of receptors in our eye called cones.

One cone is more responsive to red, one to green and one to blue.

But there is overlap.

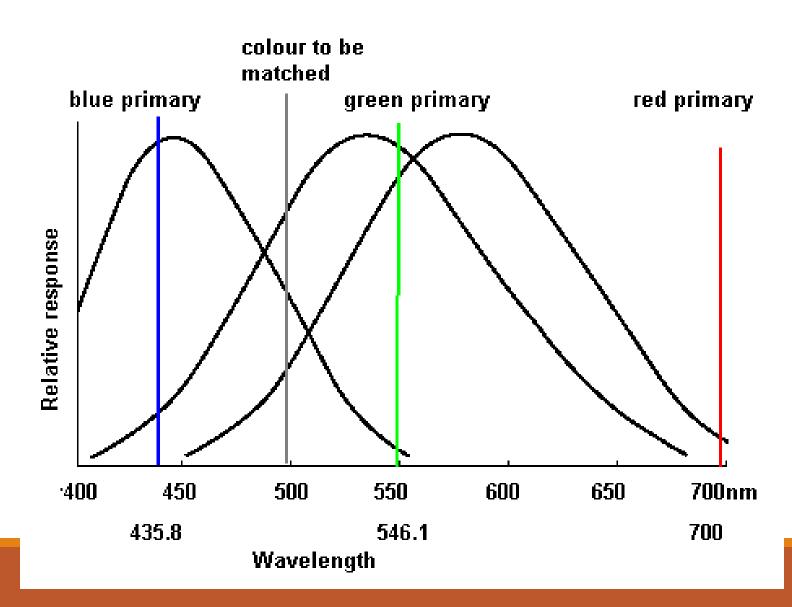
Any single wavelength may stimulate more than one type of receptor.



The eye's response to colour

If we can artificially stimulate the receptors to the same degree as a naturally occurring colour, then the eyes will perceive that colour.

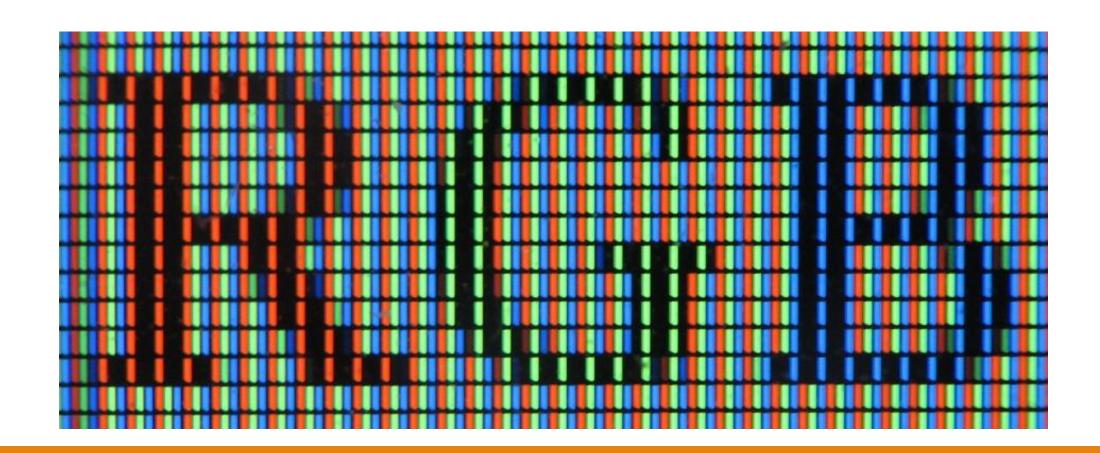
We therefore try three colours to stimulate the receptors.



Colour in the computer

The computer monitor only emits red, green and blue light.

It is the combination of these lights which give the perception of colour.

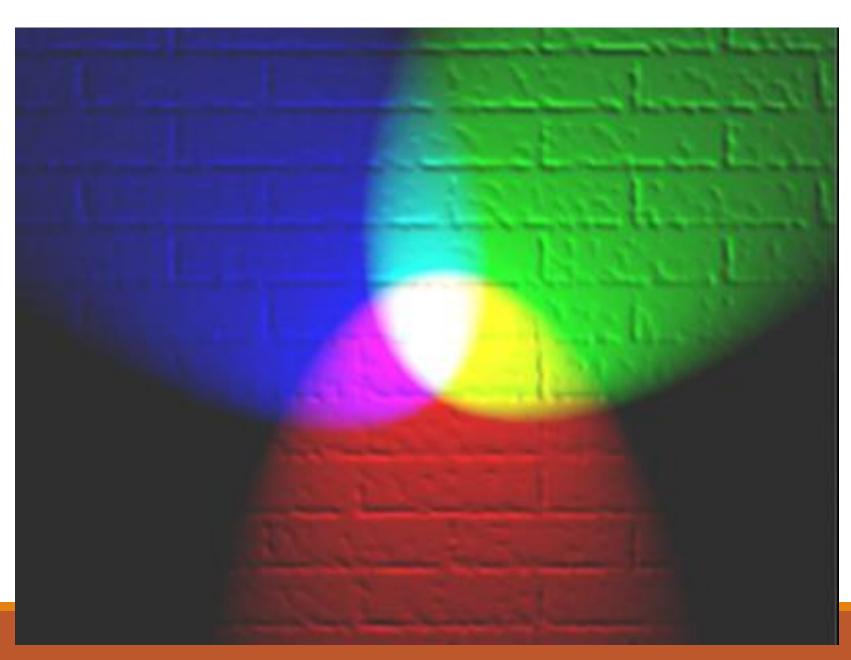


Mixing of colours

They are mixed together and the system is arranged so that mixing the maximum (and equal) values of red, green and blue produce a nominal

white colour.

This is called "additive mixing"



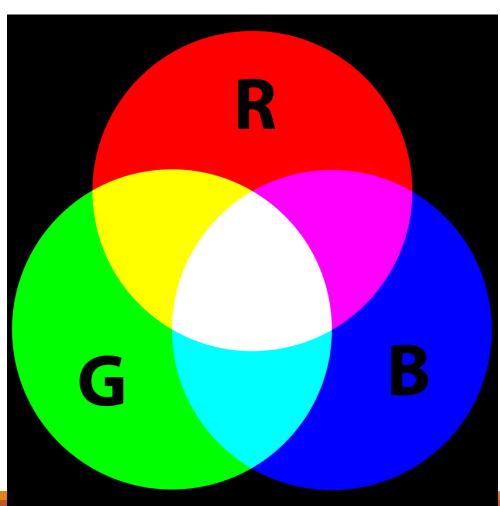
Primary & Secondary colours

Because Red, Green and Blue are used to produce all the other colours on the computer monitor, they are called primary colours.

If equal amounts of all primary colours give white, what do equal amounts of any two of them give?

- Red + Blue gives magenta
- Green + Blue gives cyan
- Red + Green gives yellow

These important results are called secondary colours and are easily generated.



24 bit colour

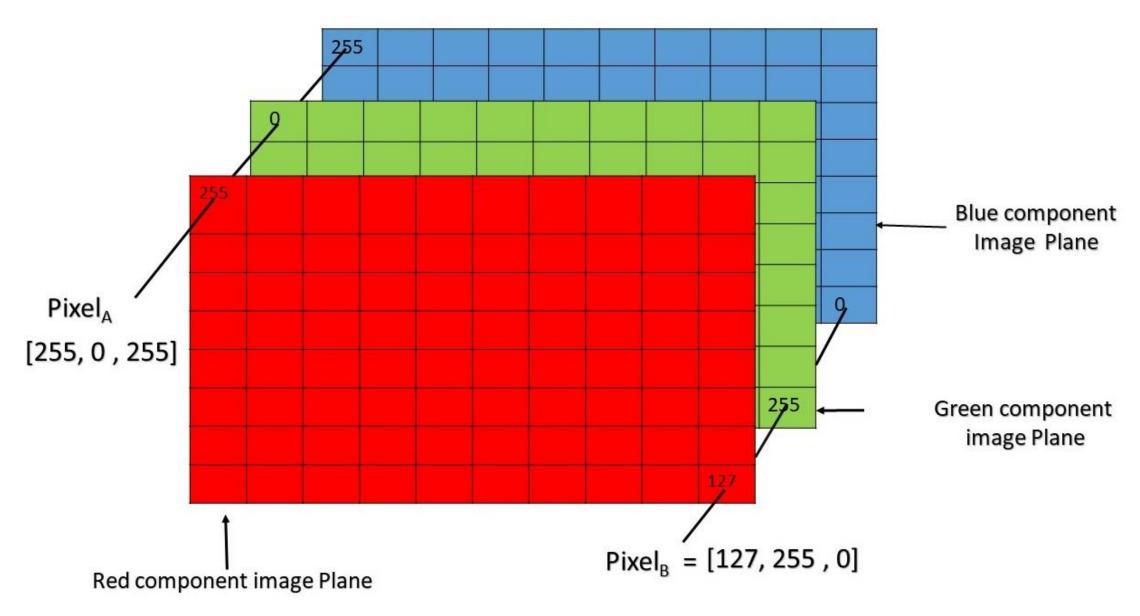
We will consider "true colour" or 24 bit colour in the computer.

These 24 bits are divided into three groups of 8 bits.

This gives a range of 0-255 for each colour.

Each group controls the intensity of the primary colours: red, green and blue.

Modifications to our bitmap structure for colour



Now we need three separate matrices, one for each colour. Each matrix holds values which represent the corresponding colour in the image

Colour in Python

Python stores (as does 24 bit .bmp) colour images in a three dimensional arrays.

You can think of the array as three colour (two dimensional) pictures/planes, each representing one of the colours red, green and blue, indexed as 0,1,2 respectively.

In Python syntax

P[row, column, colour plane] will select a single pixel

So P[40, 50, 1] will select the pixel on row 41, column 51 colour green(1)

Primary colours in Python



If we create an 3D array which is filled with zeros to experiment with colour. rgb = np.zeros((100,150,3));Cast it so as to use byte representation: rgb = np.zeros((100,150,3), dtype='uint8')Fill the red plane with 255: rgb[:,:,0] = 255 And view it import matplotlib.pyplot as plt

plt.imshow(rgb)

Primary colours in Python

Reset the red plane to zeros

$$rgb[:,:,0] = 0$$

and repeat for green

• and then blue (exercise).

Secondary colours in Python

You are now going to produce the secondary colours; yellow, cyan and magenta.

Fill your array with 255 on two of the planes only.

Fill blue and green you will get (cyan)

Fill red and green you will get (yellow)

Fill red and blue you will get (magenta)

White or neutral colours

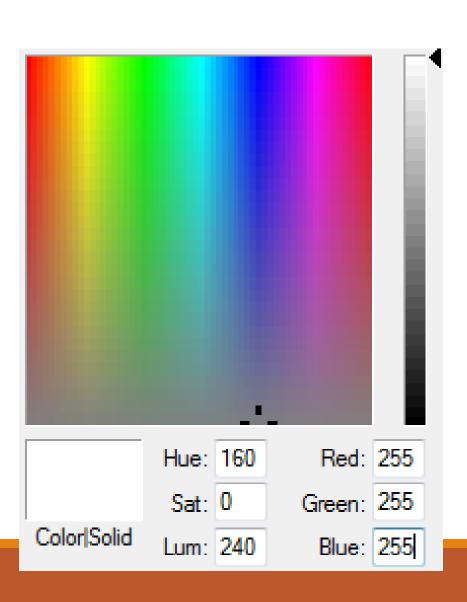
As mentioned above the maximum equal values of red, green and blue produce white light on the computer monitor.

That is when red=255, green= 255 and blue=255.

We can describe this 24 bit colour (in hex) as

FF FF FF.

3 byte representation



White or neutral colours

Lesser equal amounts of the three primary colours produce neutral colours (grey).

Put another way, these combinations have no colour cast.

Thus the colours:

- 000000 (0, 0, 0) (black),
- 404040 (64, 64, 64)
- and F0F0F0 (240, 240, 240) (nearly white)

are all examples of neutral colours.

They can be considered as proportions of white.

#000000	Gray Shades	HEX	RGB
#101010 rgb(16,16,16) #181818 rgb(24,24,24) #202020 rgb(32,32,32) #282828 rgb(40,40,40) #303030 rgb(48,48,48) #383838 rgb(56,56,56) #404040 rgb(64,64,64) #484848 rgb(72,72,72) #505050 rgb(80,80,80) #588588 rgb(88,88,88) #606060 rgb(96,96,96,96) #606068 rgb(96,96,96,96) #606068 rgb(104,104,104) #707070 rgb(112,112,112) #787878 rgb(120,120,120) #388888 rgb(136,136,136) #389898 rgb(152,152,152) #400000 rgb(160,160,160) #4000000 rgb(160,160,160) #5000000 rgb(28,218,192) #5000000 rgb(28,218,192) #5000000 rgb(218,218,128) #5000000 rgb(224,214,214) #5000000 rgb(224,224,224) #5000000 rgb(224,224,224) #5000000 rgb(240,240,240)		#000000	rgb(0,0,0)
#181818 rgb(24,24,24) #202020 rgb(32,32,32) #282828 rgb(40,40,40) #303030 rgb(48,48,48) #383838 rgb(56,56,56) #404040 rgb(64,64,64) #484848 rgb(72,72,72) #505050 rgb(80,80,80) #585858 rgb(88,88) #606060 rgb(96,96,96) #686868 rgb(104,104,104) #707070 rgb(112,112,112) #787878 rgb(120,120,120) #380880 rgb(128,128,128) #388888 rgb(136,136,136) #399990 rgb(144,144,144) #399898 rgb(152,152,152) #40A0A0 rgb(160,160,160) #4A8A8A rgb(186,168,168) #400000 rgb(192,192,192,192) #606060 rgb(200,200,200) #6000000 rgb(203,203,208) #608000 rgb(224,224,224) #688688 rgb(242,242,242) #686868 rgb(242,242,242)		#080808	rgb(8,8,8)
#202020		#101010	rgb(16,16,16)
#282828		#181818	rgb(24,24,24)
#303030		#202020	rgb(32,32,32)
#383838		#282828	rgb(40,40,40)
#404040 rgb(64,64,64) #484848 rgb(72,72,72) #505050 rgb(80,80,80) #585858 rgb(88,88,88) #606060 rgb(96,96,96) #666868 rgb(104,104,104) #707070 rgb(112,112,112) #787878 rgb(120,120,120) #808080 rgb(128,128,128) #888888 rgb(136,136,136,136) #909090 rgb(144,144,144) #989898 rgb(152,152,152) #A0A0A0 rgb(160,160,160) #A8A8AB rgb(168,168,168) #808080 rgb(176,176,176) #888888 rgb(184,184,184) #000000 rgb(192,192,192,192) #000000 rgb(208,208,208) #000000 rgb(216,216,216,16) #000000 rgb(224,224,224) #686868 rgb(240,240,240) #5878768 rgb(240,240,240) #5878768 rgb(248,248,248)		#303030	rgb(48,48,48)
#484848 rgb(72,72,72) #505050 rgb(80,80,80) #585858 rgb(88,88,88) #606060 rgb(96,96,96) #686868 rgb(104,104,104) #707070 rgb(112,112,112) #787878 rgb(120,120,120) #808080 rgb(128,128,128) #808080 rgb(128,128,128) #808080 rgb(128,128,128) #808080 rgb(152,152,152) #808080 rgb(160,160,160) #909090 rgb(144,144,144) #989898 rgb(152,152,152) #A0A0A0 rgb(60,160,160) #ABA8A8 rgb(168,168,168) #808080 rgb(176,176,176) #808080 rgb(176,176,176) #808080 rgb(128,128,128) #808080 rgb(169,160,160) #ABA8A8 rgb(168,168,168) #808080 rgb(176,176,176) #808080 rgb(176,176,176) #808080 rgb(162,192,192,192) #COCCOO rgb(192,192,192) #COCCOO rgb(192,192,192) #COCCOO rgb(203,208,208) #DOCOOO rgb(208,208,208) #BO8080 rgb(216,216,216) #EDECOO rgb(242,224,224) #EBEBEB rgb(232,232,232,232) #FOFOFO rgb(240,240,240) #FDFFOFO rgb(248,248,248)		#383838	rgb(56,56,56)
#505050 rgb(80,80,80) #585858 rgb(88,88,88) #606060 rgb(96,96,96) #686868 rgb(104,104,104) #707070 rgb(112,112,112) #787878 rgb(120,120,120) #808080 rgb(128,128,128) #888888 rgb(136,136,136) #909090 rgb(144,144,144) #989898 rgb(152,152,152) #A0A0A0 rgb(60,160,160) #A8A8A8 rgb(168,168,168) #808080 rgb(176,176,176) #888888 rgb(184,184,184) #COCOCO rgb(192,192,192) #COCCO rgb(202,202,200) #D000D0 rgb(208,208,208) #D080B0 rgb(162,162,166) #EDECE rgb(202,202,202,200) #D000D0 rgb(208,208,208) #D808D8 rgb(216,216,216) #EDECE0 rgb(232,232,232,332) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#404040	rgb(64,64,64)
#585858 rgb(88,88,88) #606060 rgb(96,96,96) #686668 rgb(104,104,104) #707070 rgb(112,112,112) #787878 rgb(120,120,120) #808080 rgb(128,128,128) #808080 rgb(138,136,136) #909090 rgb(144,144,144) #989898 rgb(152,152,152) #A0A0A0 rgb(160,160,160) #A8A8A8 rgb(168,168,168) #808080 rgb(176,176,176) #888888 rgb(164,184,184) #COCCCC rgb(192,192,192) #COCCCC rgb(192,192,192) #COCCCC rgb(202,200,200) #DOOOOO rgb(208,208,208) #DOOOOO rgb(208,208,208) #DOOOOO rgb(204,224,224,244) #EBEBEB rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8FBF8 rgb(248,248,248)		#484848	rgb(72,72,72)
#606060 rgb(96,96,96) #686868 rgb(104,104,104) #707070 rgb(112,112,112) #787878 rgb(120,120,120) #808080 rgb(128,128,128) #888888 rgb(136,136,136) #909090 rgb(144,144,144) #989898 rgb(152,152,152) #A0A0A0 rgb(160,160,160) #A8A8A8 rgb(168,168,168) #808080 rgb(176,176,176) #888888 rgb(184,184,184) #COCOCO rgb(192,192,192) #CBCBCB rgb(200,200,200) #D00000 rgb(208,208,208) #D80808 rgb(216,216,216) #E0E0E0 rgb(224,224,224) #EBEBEB rgb(232,232,232) #F0F0F0 rgb(240,240,240)		#505050	rgb(80,80,80)
#686868 rgb(104,104,104) #707070 rgb(112,112,112) #787878 rgb(120,120,120,120) #808080 rgb(128,128,128) #888888 rgb(136,136,136) #909090 rgb(144,144,144) #989898 rgb(152,152,152) #A0A0A0 rgb(160,160,160) #A8A8A8 rgb(168,168,168) #B0B0B0 rgb(176,176,176) #888888 rgb(184,184,184) #COCOCO rgb(192,192,192) #CBCBCB rgb(200,200,200) #000000 rgb(208,208,208) #D8D808 rgb(216,216,216) #E0E600 rgb(224,224,224) #E8E8E8 rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#585858	rgb(88,88,88)
#707070		#606060	rgb(96,96,96)
#787878		#686868	rgb(104,104,104)
#808080 rgb(128,128,128) #808080 rgb(128,128,128) #808088 rgb(136,136,136) #909090 rgb(144,144,144) #989898 rgb(152,152,152) #A0A0A0 rgb(160,160,160) #ABA8AB rgb(168,168,168) #808080 rgb(176,176,176) #888888 rgb(184,184,184) #COCOCO rgb(192,192,192) #CRCBCB rgb(200,200,200) #D00000 rgb(208,208,208) #D80808 rgb(216,216,216) #E0E0E0 rgb(224,224,224) #EBE8E8 rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		# 707070	rgb(112,112,112)
#888888 rgb(136,136,136) #909090 rgb(144,144,144) #989898 rgb(152,152,152) #AOAOAO rgb(160,160,160) #A8A8A8 rgb(168,168,168) #BOBOBO rgb(176,176,176) #B8B8B8 rgb(184,184,184) #COCOCO rgb(192,192,192) #C8CBCB rgb(200,200,200) #DODOOO rgb(208,208,208) #D8D8D8 rgb(216,216,216) #E0EOEO rgb(224,224,224) #E8E8E8 rgb(242,232,232,232) #F0F0FO rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#787878	rgb(120,120,120)
#909090 rgb(144,144,144) #989898 rgb(152,152,152) #A0A0A0 rgb(160,160,160) #A8A8A8 rgb(168,168,168) #808080 rgb(176,176,176) #888888 rgb(184,184,184) #C0C0C0 rgb(192,192,192) #C8C8C8 rgb(200,200,200) #D0D000 rgb(208,208,208) #D8D8D8 rgb(216,216,216) #E8E8E8 rgb(232,232,232) #F8F8F8 rgb(248,248,248)		#808080	rgb(128,128,128)
#989898 rgb(152,152,152) #A0A0A0 rgb(160,160,160) #A8A8A8 rgb(168,168,168) #B0B0B0 rgb(176,176,176) #B8B8BB rgb(184,184,184) #COCCCO rgb(192,192,192) #CSCBCB rgb(200,200,200) #D0D0D0 rgb(208,208,208) #D8D8D8 rgb(216,216,216) #E0E0E0 rgb(224,224,224) #EBEBBB rgb(232,232,232) #F0F0F0 rgb(248,248,248)		#888888	rgb(136,136,136)
#AOAOAO rgb(160,160,160) #ASASAS rgb(168,168,168) #BOBOBO rgb(176,176,176) #BSBSBS rgb(184,184,184) #COCCCO rgb(192,192,192) #CSCSCS rgb(200,200,200) #DODOCO rgb(208,208,208) #DSDSDS rgb(216,216,216) #EOEOEO rgb(224,224,224) #EBESES rgb(232,232,232) #FOFOFO rgb(240,240,240) #FSFSFS rgb(248,248,248)		#909090	rgb(144,144,144)
#ASASAS rgb(168,168,168) #B0B0B0 rgb(176,176,176) #B8B8B8 rgb(184,184,184) #C0C0C0 rgb(192,192,192) #C8C8CB rgb(200,200,200) #D0D0D0 rgb(208,208,208) #D8D8D8 rgb(216,216,216) #E0E0E0 rgb(232,232,232) #F0F0F0 rgb(248,248,248)		#989898	rgb(152,152,152)
#808080 rgb(176,176,176) #888888 rgb(184,184,184) #C0C0C0 rgb(192,192,192) #C8C8C8 rgb(200,200,200) #D0D0D0 rgb(208,208,208) #D8D8D8 rgb(216,216,216) #E0E0E0 rgb(224,224,224) #E8E8E8 rgb(232,232,232) #F0FDF0 rgb(240,240,240) #F8FBF8 rgb(248,248,248)		#A0A0A0	rgb(160,160,160)
#88888 rgb(184,184,184) #COCOCO rgb(192,192,192) #C8C8C8 rgb(200,200,200) #D00000 rgb(208,208,208) #D8D8D8 rgb(216,216,216) #E0E0E0 rgb(224,224,224) #E8E8E8 rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#ABABAB	rgb(168,168,168)
#C0C0C0 rgb(192,192,192) #C8C8C8 rgb(200,200,200) #D0D0D0 rgb(208,208,208) #D8D8D8 rgb(216,216,216) #EDE0E0 rgb(224,224,224) #EBE8E8 rgb(232,232,232) #F0F0F0 rgb(248,248,248)		#B0B0B0	rgb(176,176,176)
#C8C8C8 rgb(200,200,200) #D0D0D0 rgb(208,208,208) #D8D8D8 rgb(216,216,216) #E0E0E0 rgb(224,224,224) #E8E8E8 rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#B8B8B8	rgb(184,184,184)
#D0D0D0 rgb(208,208,208) #D8D8D8 rgb(216,216,216) #E0E0E0 rgb(224,224,224) #E8E8E8 rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#C0C0C0	rgb(192,192,192)
#D8D8D8 rgb(216,216,216) #E0E0E0 rgb(224,224,224) #E8E8E8 rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#C8C8C8	rgb(200,200,200)
#E0E0E0 rgb(224,224,224) #E8E8E8 rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#D0D0D0	rgb(208,208,208)
#E8E8E8 rgb(232,232,232) #F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#D8D8D8	rgb(216,216,216)
#F0F0F0 rgb(240,240,240) #F8F8F8 rgb(248,248,248)		#E0E0E0	rgb(224,224,224)
#F8F8F8 rgb(248,248,248)		#EBEBEB	rgb(232,232,232)
		#F0F0F0	rgb(240,240,240)
#FFFFFF rgb(255,255,255)		#F8F8F8	rgb(248,248,248)
		#FFFFFF	rgb(255,255,255)

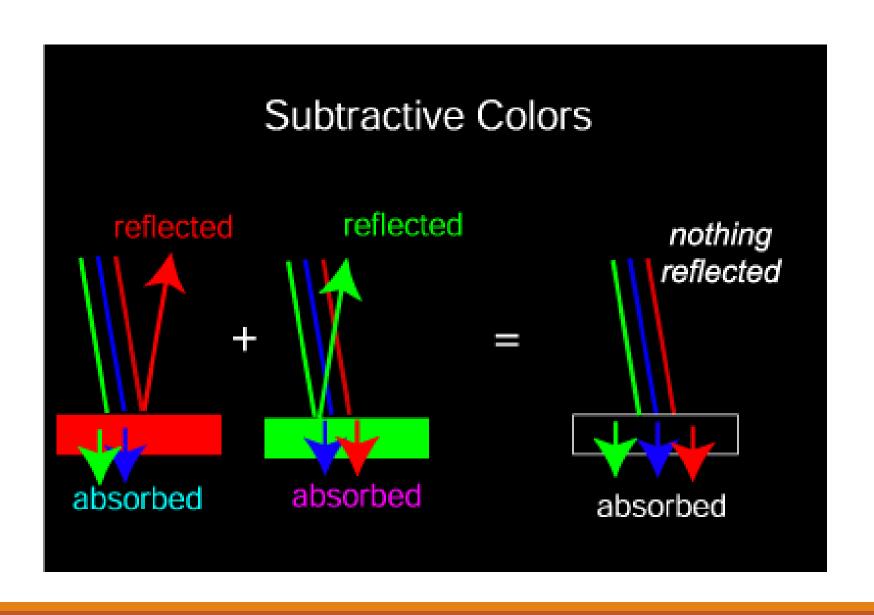
White or neutral colours in Python

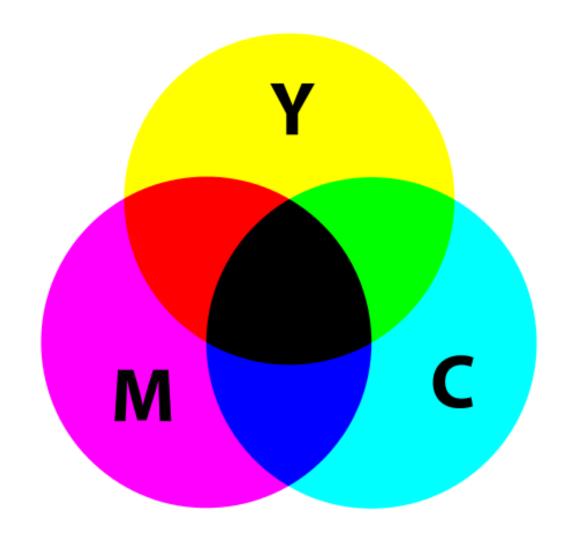
Exercises

- •If you fill all the planes with 255 you will get a white image.
- Do this plane by plane as before. (it is possible to do it in one go).
- Change the values in all arrays between 0 and 255.
- The colours should be neutral.
- Save the imageplt.imsave("imageName.jpg",np_imgArray)

Mixing of colours

Do not confuse with "subtractive mixing" (dyes) which subtract to give black, this mainly used with printers.



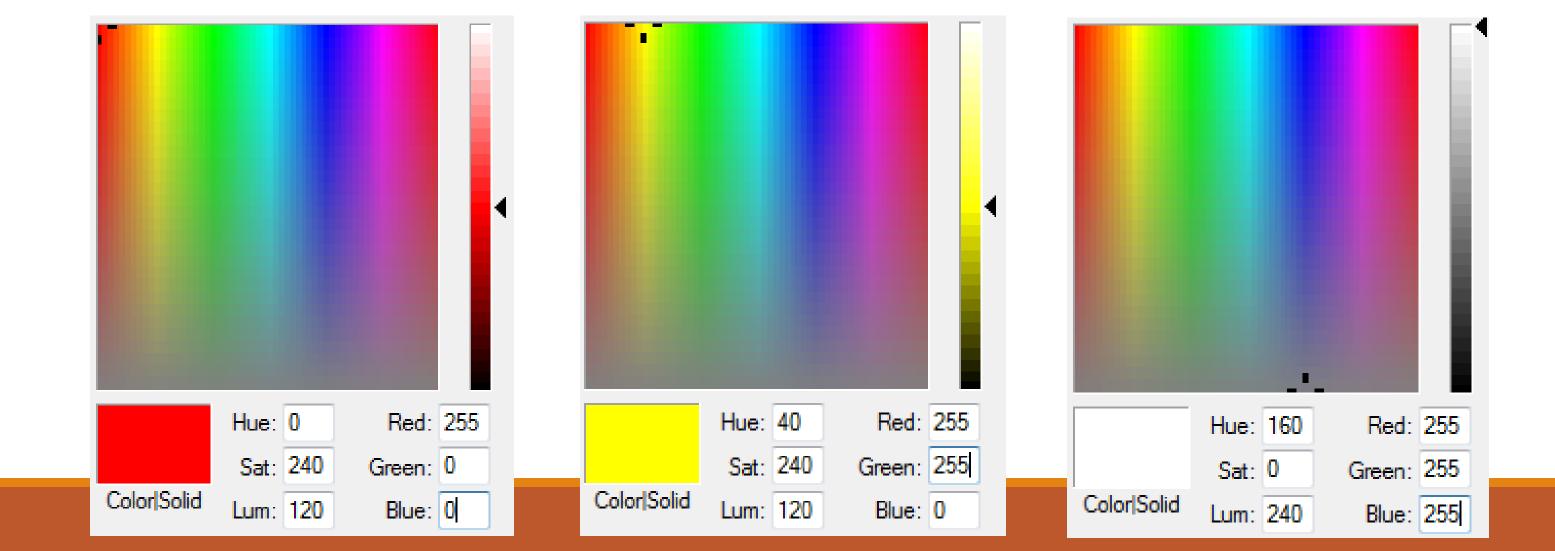


Mixing of colours



If a colour contains only one or two primary colours, it is said to be fully (100%) saturated.

In other words the colour is as "strong" (saturated) as it can be.



If we add the missing primary colour(s) we desaturate the colour.

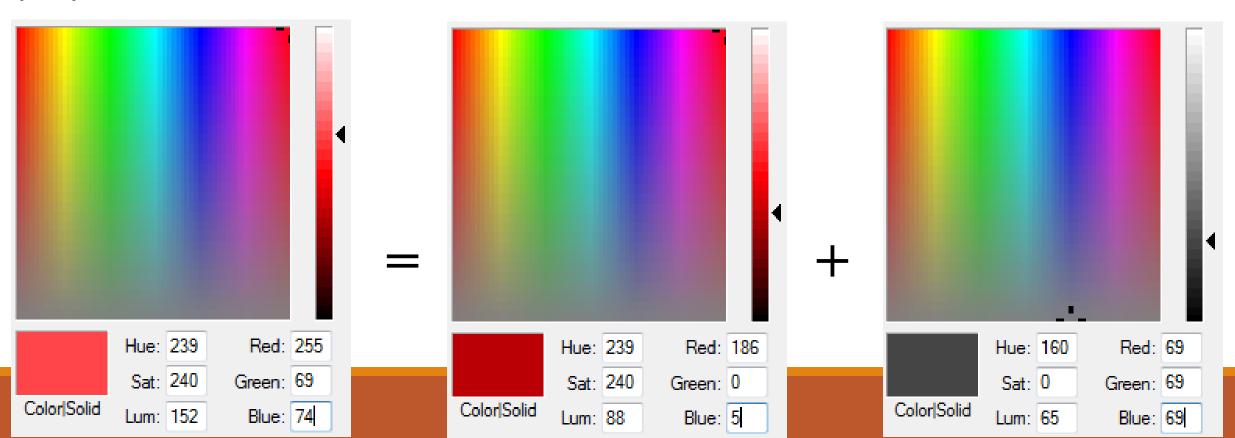
We are effectively adding some white.

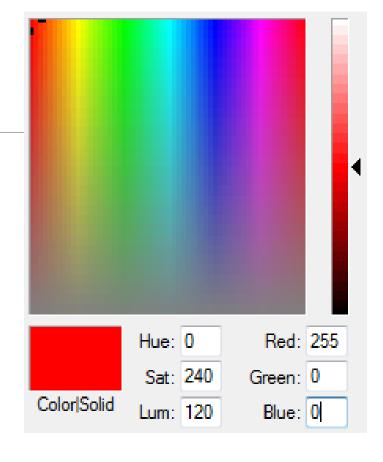
Take a red colour FF0000 (255,0,0)

blue and green are missing; so add some.

$$FF454A = BA0005 + 454545 \mid (255, 69, 74) = (186,0,5) + (69, 69, 69)$$

454545 is the proportion of white we have added.





Adding more white/grey (equal amounts of red, green and blue) desaturates the colour.

"Pastel" colours are desaturated colours.

White (and greys) are totally desaturated. (0% saturation)

For example pink is desaturated red.

From the above description the equation for saturation is intuitive:

$$Saturation = \frac{\max(red, green, blue) - \min(red, green, blue)}{\max(red, green, blue)} \times 100\%$$

So if any primary colour is missing then min=0 and saturation=100%

If all primary colours are present in equal amounts, then max=min and saturation =0%.

Microsoft Saturation

Microsoft have a different idea about saturation. It is a variation of equation.

$$Saturation = \frac{\max(red, green, blue) - \min(red, green, blue)}{\max(red, green, blue) + \min(red, green, blue)} \times 240$$

But it is modified according to the brightness values.

Microsoft set the maximum saturation as 240, that is why we multiply by 240.

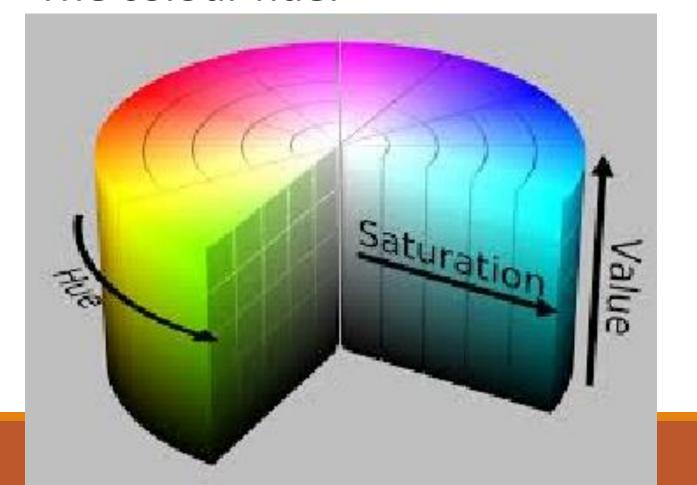
Saturation & Hue

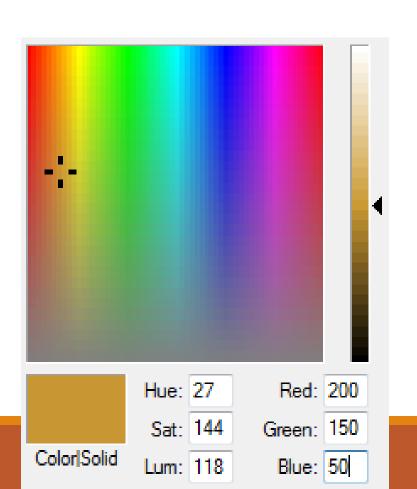
We can make a desaturated colour saturated by removing the min(r,g,b) from all colours.

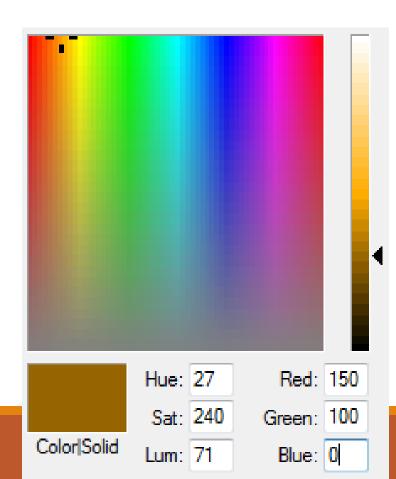
Then the smallest colour primary will be missing.

But one property of colour remains the same.

The colour hue.





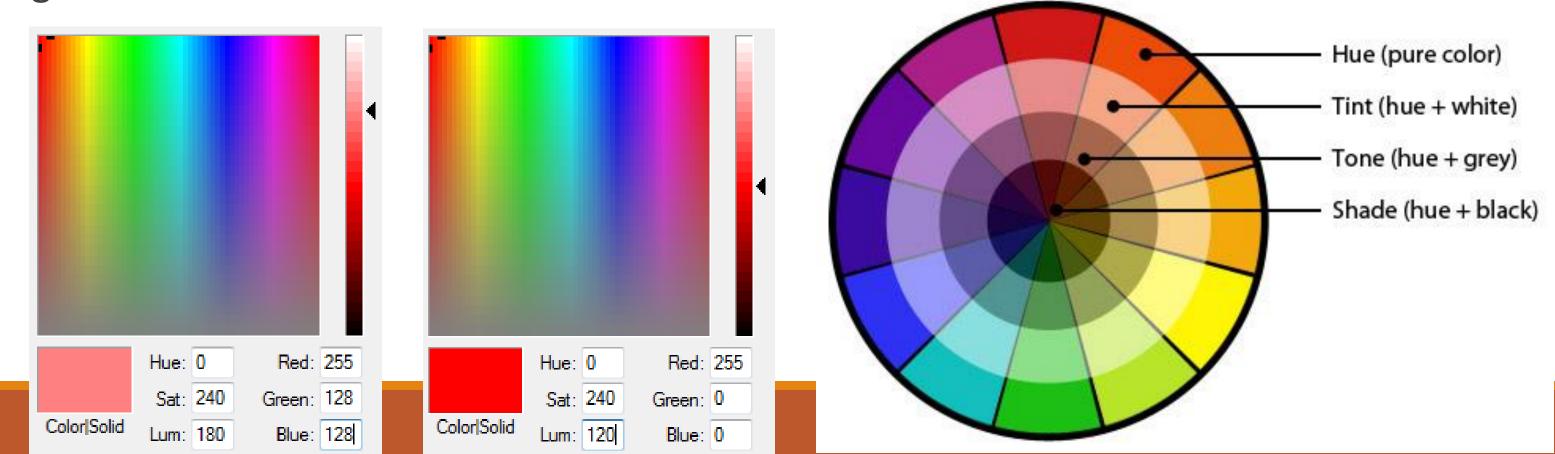


Hue is the attribute of a visual sensation according to which an area appears to be similar to one of the perceived colours (e.g., red, green, blue, etc.)

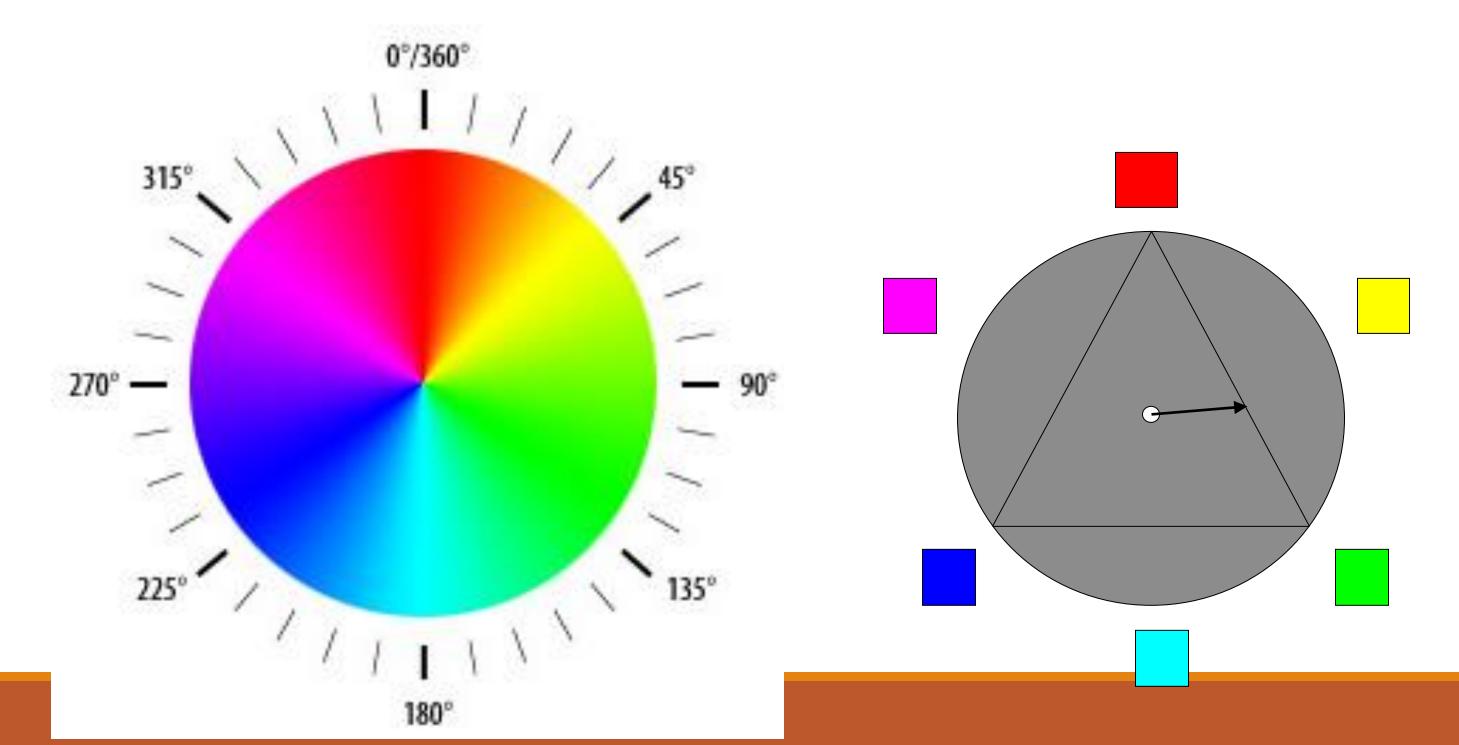
So pink FF8080 (255,128,128) has the same hue as red.

It is expressed in degrees around a colour circle.

Colours from red to blue are arranged around the circle and the colour is specified in degrees.



Angular position of arrow determines the colour (hue).



And if we do this while considering all primary colours at maximum, we get a set of equations. One for each case.

When red is dominant

$$Hue = 60 \times (\frac{green \ value - blue \ value}{\max(r, g, b) - \min(r, g, b)})$$

When green is dominant

$$Hue = 60 \times (2 + \frac{blue \ value - red \ value}{\max(r, g, b) - \min(r, g, b)})$$

When blue is dominant

$$Hue = 60 \times (4 + \frac{red\ value - green\ value}{\max(r, g, b) - \min(r, g, b)})$$

Hue anomalies

The first equation can give negative values (when red green is minimum. However since the answer is in degrees of a circle we can add 360 degrees and get a positive (valid) answer)



Lets get the hang of this with some exercises.

Calculate the colour hue if (in decimal) green=255, blue = 45 and red = 50

Max(50,255,45)=255 so green is dominant we use

$$Hue = 60 \times (2 + \frac{blue \ value - red \ value}{\max(r, g, b) - \min(r, g, b)})$$

- Min(50,255,45)=45

• So in the equation
$$Hue = 60 \times (2 + \frac{blue \ value - red \ value}{\max(r,g,b) - \min(r,g,b)})$$
$$= 60 \times (2 + \frac{45 - 50}{255 - 45})$$
$$= 119^{\circ} \text{ (rounded)}$$



= 79 Microsoft units. Check it!

Brightness

Brightness is a perception of the light emitted (or reflected) from an object.

But our eyes are more sensitive to green light than it is for red and blue light.

For the red, green and blue lights emitted by a computer monitor our eyes sensitivities are 30%, 59% and 11% respectively.

Brightness/Value/Intensity/Luma

Brightness, value, lightness, Intensity are terms used to loosely associate brightness with a colour.

HSV stands for hue, saturation, and value. An alternative is HSB (B for brightness)

In computer systems no weight is given to the different colours.

"Value" is generally taken to be max(rgb)

Brightness, lightness, "luma" as (max(r,g,b)-min(r,g,b))/2

Intensity as (r + g + b) / 3

Colour spaces

RGB and HSB are called colour spaces

This means that a colour can be described by suitable selection of the variables in the colour space.

Other colour spaces exist

- YUV (one luma (Y') and two chrominance (UV) components)
- Lab (L for lightness and a and b for the color-opponent dimensions)

Production of a greyscale image

Although a greyscale image can be produced from a colour image, by reducing the saturation in HSL colourspace.

But better results would be obtained by taking the changes in sensitivity of the eye into account.

So use from the YUV system Y=0.3R+0.59G+0.11B

Exercises



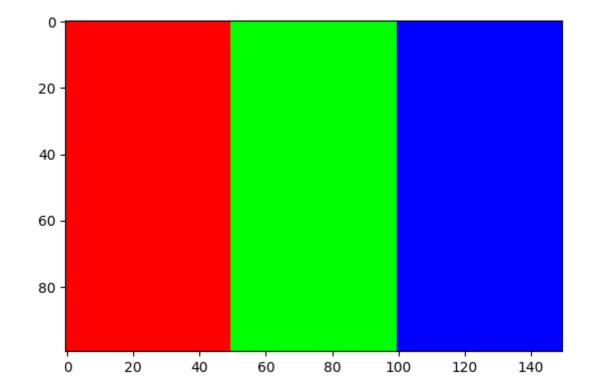
The eyes differing sensitivity to colour



Make up an array with the first 50 columns red, the next 50 green and the last 0 blue.

Use 255 for all values.

```
rgb = np.zeros((100,150,3), dtype='uint8')
rgb[:,0:50,0] = 255 # red
rgb[:,50:100,1] = 255 #green
rgb[:,100:150,2] = 255 #blue
plt.imshow(rgb)
```



What is the brightest colour?

What is the darkest colour?

Sketch how you think it would look in monochrome.

True luma demo code



Code 1

rgb2hsv=cv2.cvtColor(rgb,cv2.COLOR_RGB2HSV)
plt.imshow(rgb2hsv[:,:,2],cmap='gray')

Code 2

rgb2gray=cv2.cvtColor(rgb,cv2.COLOR_RGB2GRAY)
plt.imshow(rgb2gray,cmap='gray')



