Color Pixel Theory and Image Representation

Pre-work: Computer Vision

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Agenda

- Basics of Images
- Representation of Images
- PIL (Python Imaging Library)

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Basics of Images

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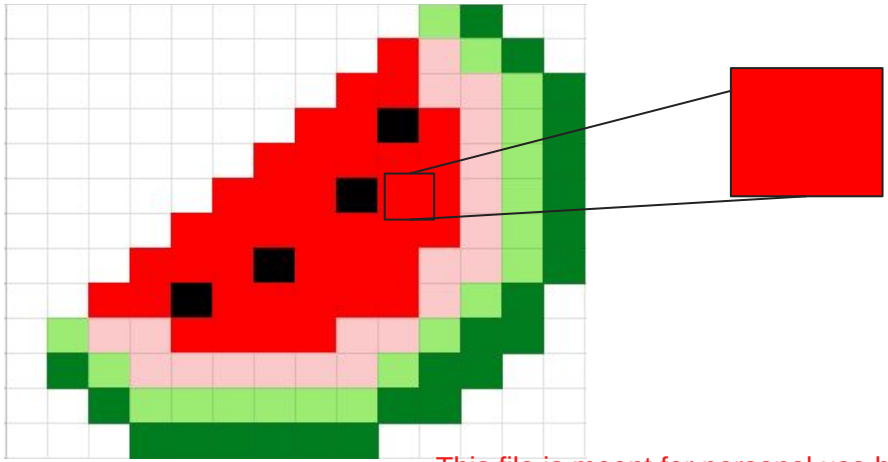
Basics of Images

- An image is made up of small square-like boxes or elements called **pixels**.
- Every image is simply a combination of multiple pixels, each of which has its own color.
- As seen below, an image is simply a combination of multiple pixels with individual colors.
- Every pixel in an image has an intensity value which ranges from 0 to 255.
  This is known as the **Pixel Intensity Value**.



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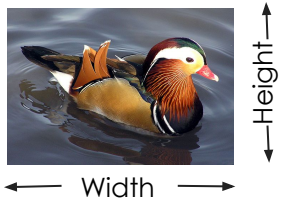
Basics of Images

- Images have three major components:

Size
This represents the height and width of an image. It is usually measured by number of pixels.

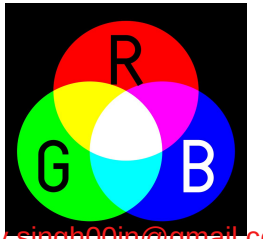
Color Space
This represents the different possible color spaces, like Grayscale, RGB, HSV. The image of the duck on the right is represented in RGB color space.

Channels
This explains the attributes of a color space - For example, RGB has three color channels: Red, Green and Blue.



Grayscale

RGB



The RGB Color Space

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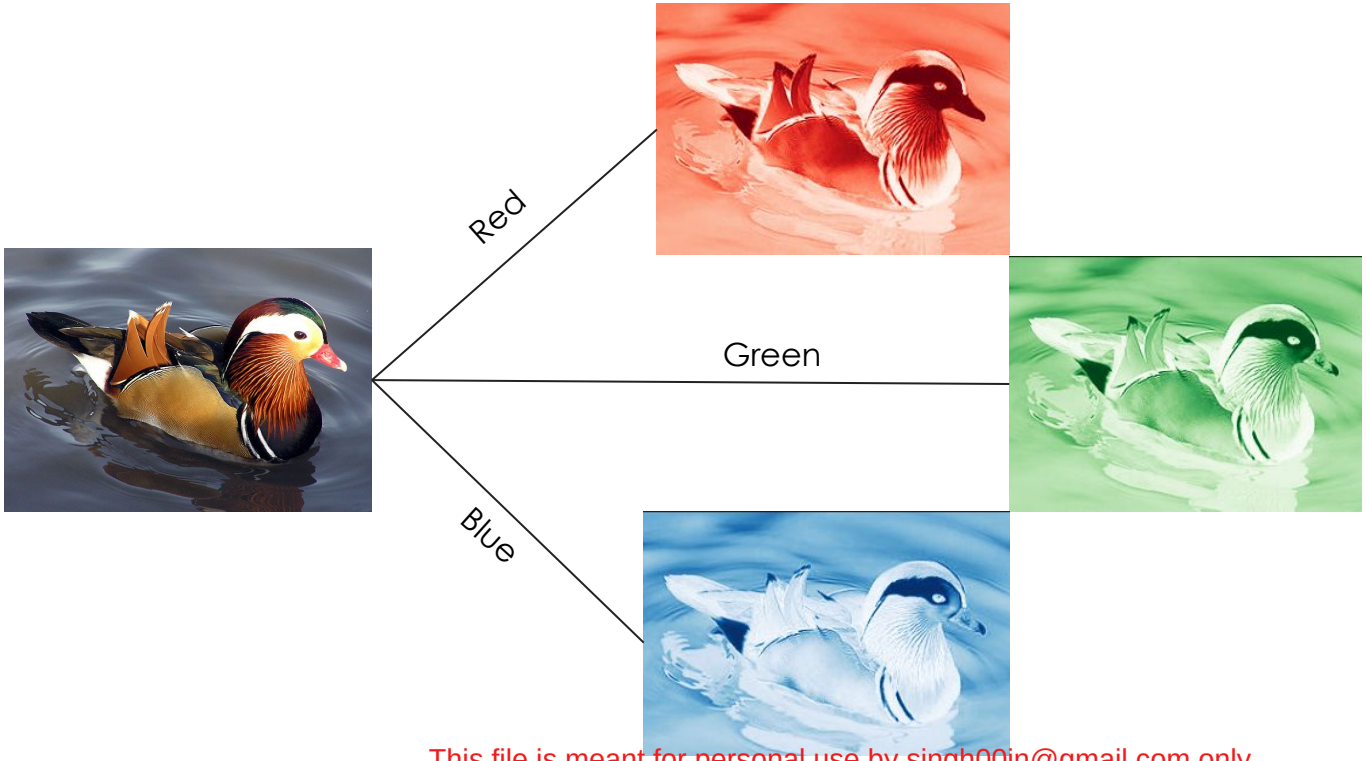
Basics of Images

- The RGB image can be broken down into three different channels as shown below:



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The RGB Color Scheme

- The colors of an image are determined by its pixel values. An RGB image has 3 color channels - Red, Green and Blue. Here each channel has a pixel value ranging from 0 to 255. For example, the number 0 in a channel means there is no color, and 255 means there is 100% color. If a pixel value is represented by [255,255,0], it means that we have 100% Red and Green colors, and there is no Blue color.

- **The higher the pixel intensity value, the more the brightness of the color.**

Color	Color Name	Pixel Intensity Values - RGB Color Space		
		R (Red)	**G** (Green)	**B** (Blue)
	Red	255	0	0
	Green	0	255	0
	Blue	0	0	255
	Yellow	255	255	0
	Cyan	0	255	255

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Grayscale Colors

- Grayscale colors are special in the RGB color scheme, because **every grayscale color** (from white to black to all shades of gray) **always has equal values for R, G and B.**

- Due to this, grayscale colors can be represented by a single number as opposed to the three numbers that three color channels require in RGB. **A grayscale image hence has only one channel,** where the pixel values range from 0 to 255. The pixel value 0 represents black and the value 255 represents white. The method of conversion of images from RGB, HSV, etc to a grey shaded image is called Grayscaling.

Color	Color Name	Pixel Intensity Values - RGB Color Space		
		R (Red)	**G** (Green)	**B** (Blue)
	Black	0	0	0
	White	255	255	255
	Dim Gray	100	100	100
	Very Light Gray	200	200	200

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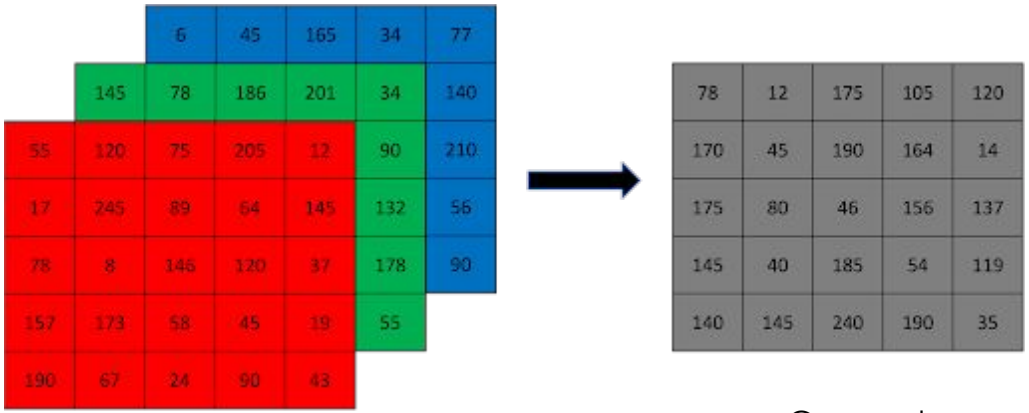
Grayscale Images

- Why is Grayscaling important in computer vision?

  Using a grayscale image over an RGB image helps in **dimensionality reduction** as an RGB image has 3 channels, whereas a grayscale image only has one. This helps with computational cost for the algorithm.

- In order to convert any color into its grayscale equivalent, one conversion formula often used is to simply add up the R, G and B values, and divide by 3 (the arithmetic average), as that would redistribute the total intensity of the three channels into each channel equally, hence creating a grayscale color.



RGB

Grayscale

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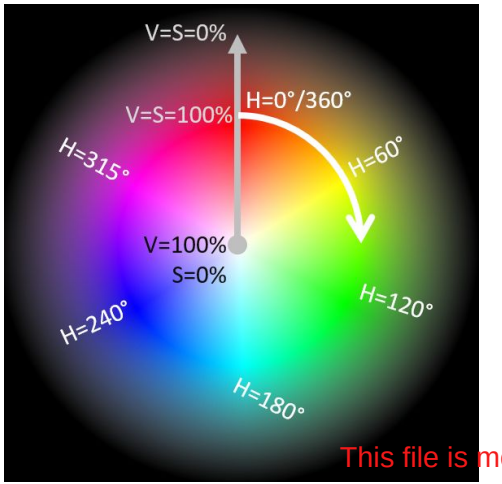
The HSV Color Scheme

- HSV stands for Hue Saturation Value. It has three main components which can be described as:
  - **Hue:** It is the color segment or color portion of the image. It is expressed in degrees so the values range from 0 to 360 degrees.
  - **Saturation:** It describes the amount of gray shade in a particular color. It is expressed in percentage so it ranges from 0 to 100 percent. 0 represents the highest gray shade, 100 appears as pure color.
  - **Value:** It represents the intensity or brightness of a color, it is also expressed in percentage so it ranges from 0 to 100 percent.



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Representation of Images

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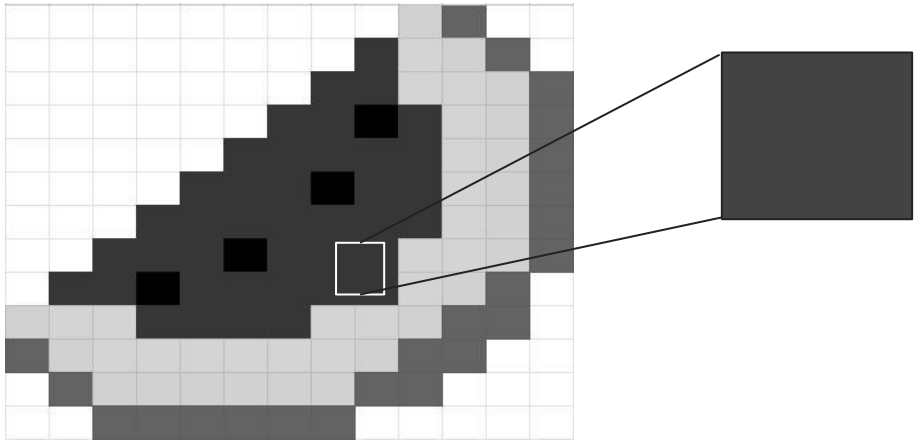
Representation of Images as Arrays

- **A grayscale image can be represented using a 2D array.** This is because each grayscale pixel would have just one channel and hence one number for its pixel intensity value, so an image, which is just a 2D array of pixels, would mathematically just be a 2D array of pixel intensity values.

A Grayscale image only consists of a 2D array of grayscale pixels, such as the pixel highlighted below



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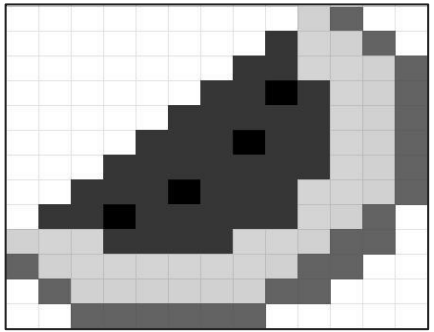
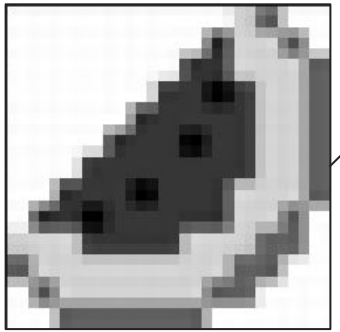
Representation of Images as Arrays



440 x 340



30 x 30

The 2D Array Representation of the Image

249	250	248	250	248	250	249	249	250	248	250	248	250	248	249	249	249	250	248	250	237	210	203	123	108	196	250	248	250	249
254	255	253	255	253	255	254	254	255	253	255	253	255	253	254	254	254	255	255	255	247	209	200	104	85	195	255	255	255	254
251	253	251	253	251	253	251	252	253	251	253	251	253	251	252	252	251	253	182	123	152	211	206	168	164	156	153	187	253	252
254	255	253	255	253	255	254	254	255	253	255	253	255	253	254	254	255	255	138	32	92	215	212	212	217	130	79	142	255	255
251	253	251	253	251	253	252	252	253	251	253	251	253	251	252	250	198	188	111	44	97	214	210	207	210	158	128	152	202	203
254	255	253	255	253	255	254	254	255	253	255	253	255	253	255	252	80	44	52	50	99	217	214	211	212	211	217	168	90	94
252	254	252	254	252	254	253	253	254	252	254	252	254	248	235	231	82	51	51	45	90	199	197	209	211	208	212	167	95	99
253	254	252	254	252	254	253	253	254	252	254	252	254	215	67	66	56	56	25	3	22	64	73	196	213	208	212	167	95	99
254	255	253	255	253	255	254	254	255	253	255	255	255	216	52	51	54	56	22	0	14	52	62	196	214	209	213	168	95	99
251	253	251	253	251	253	252	252	253	251	253	182	103	97	54	54	54	55	46	39	44	53	64	195	212	207	211	167	95	99
254	255	253	255	253	255	254	254	255	255	255	158	39	49	54	54	56	56	56	56	55	52	64	196	214	209	213	168	95	99
251	253	251	253	251	253	252	252	253	185	164	112	50	54	54	54	35	31	44	55	54	52	64	194	212	207	211	167	95	99
254	255	253	255	253	255	255	255	255	95	39	50	54	54	54	53	6	0	30	56	54	52	64	196	214	209	213	168	95	99
252	253	251	253	251	253	247	221	219	92	49	54	54	54	54	53	17	10	35	56	54	52	64	195	213	208	212	167	95	99
253	254	252	254	252	255	227	63	55	55	54	54	54	54	54	54	53	53	54	54	54	51	63	195	213	208	212	167	95	99
253	254	252	254	252	253	225	60	51	54	54	54	53	54	54	54	54	54	54	54	54	54	65	196	214	208	213	168	95	99
252	253	251	253	188	83	85	55	54	54	56	33	10	19	54	54	54	54	54	50	90	185	184	207	211	207	211	167	95	99
254	255	255	255	178	41	50	56	56	54	56	26	0	8	54	54	54	54	54	49	99	219	216	212	212	212	218	169	88	93
251	253	176	139	107	51	50	26	25	47	56	43	30	35	54	54	54	54	54	49	98	213	210	208	210	167	145	152	170	171
255	255	108	33	44	50	42	0	0	41	55	55	56	56	54	54	50	49	49	44	95	215	211	211	216	133	85	146	255	255
240	241	140	91	95	97	85	18	15	45	55	54	54	54	54	55	89	97	95	92	127	212	207	180	180	125	91	146	253	252
208	209	212	215	214	218	192	59	52	53	52	52	52	52	51	55	188	218	214	215	212	211	203	107	95	97	93	146	255	253
201	201	207	212	210	214	191	68	62	63	63	63	63	63	62	66	187	214	210	212	208	203	195	108	97	101	98	149	254	253
109	107	177	212	208	211	208	195	195	194	195	194	195	194	195	196	207	211	208	212	179	107	109	100	93	178	230	236	253	252
91	88	174	217	211	212	211	213	214	213	214	213	214	213	214	214	211	212	211	217	179	94	97	94	86	192	255	255	255	254
190	189	151	130	162	211	207	207	208	207	208	207	208	207	208	208	207	211	165	133	124	97	102	177	188	227	253	251	253	252
255	255	143	79	137	218	212	212	213	212	213	212	213	212	213	213	212	218	142	85	91	93	99	238	255	255	255	253	255	254
251	253	178	139	153	167	166	166	167	166	167	166	167	166	166	166	167	151	143	145	145	149	237	253	251	253	251	253	252	
254	255	255	255	194	89	95	95	95	95	95	95	95	95	95	95	89	179	255	255	255	255	254	255	253	255	253	255	254	
252	253	252	254	192	93	99	99	99	99	99	99	99	99	99	99	92	177	254	252	253	252	252	253	251	253	251	253	252	

Matrix of size 30 x 30

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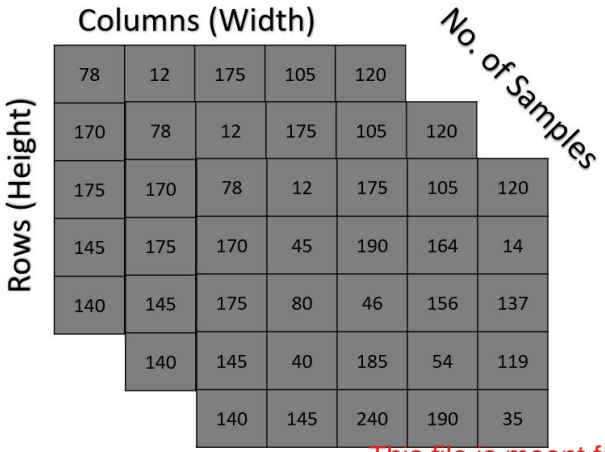
Representation of Images as Arrays

- Representing **multiple grayscale images** on the other hand, would require using multiple 2D arrays, or in other words, **a 3D array.** The extra dimension present (generally at the beginning) would show the number of sample images, while the other two dimensions would be the height and width of each image. This can be represented as:

  Shape: (no. of samples, height, width)
  Ex: (3,16,16)



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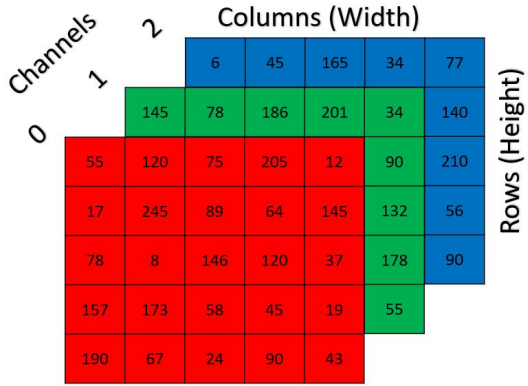
Representation of Images as Arrays

- **A single RGB image is also a 3D array with the depth dimension always having a value of 3,** since each pixel of the 2D image has three channels (R, G and B).

- However, **representing multiple RGB images would require a 4D array**, because an extra dimension is required to show the number of sample images. For example:

  Shape: (samples, height, width, color channels) e.g. (5,16,16,3)



A single RGB Image can also be represented as a 3D array with a depth of 3, on account of having 3 channels (R, G and B)

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Pixel Normalization

- So to recap, in **Grayscale Images**, **each pixel can be represented by a single number.** However in **RGB colored images**, **each pixel has to be represented by a vector of three numbers,** for the three primary color channels: red, green, and blue.

- As we also saw earlier, the pixel intensity values of the RGB digital color space **vary from 0 to 255**.

- These pixel intensity values representing the image, can also be **normalized / rescaled** into a range from **[0,1]**, as this helps reduce the storage used for each image's pixel values.

- This kind of normalization / scaling is preferred for neural networks in computer vision, since computational cost is always an important consideration in Deep Learning.
  It is implemented using a **rescaling ratio** by which each pixel can be multiplied in order to achieve the desired range. An example of such a ratio is **1/255** (about 0.0039).

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Common Image Characteristics

- There are certain standard image resolution and aspect ratios that are often used with images in real-world applications.

- **The Aspect Ratio** of an image is a term used to describe the ratio of the width of an image to its height. It is usually denoted with two numbers separated by a colon.

  A few common image aspect ratios are 1:1, 3:2, 5:4 and 16:9.

- **The Resolution** of an image, on the other hand, is a term that describes how many pixels the image consists of.

  For example: An image with a width of 640 pixels and a height of 480 pixels is said to have a resolution of 640x480, which is over 0.3 MP (Megapixels).

  The higher the number of pixels in an image, the higher its resolution.

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PIL (Python Imaging Library)

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PIL (Python Imaging Library)

- Manipulating the pixel intensity values of an image (also called **Filtering**), is an important part of the image pre-processing stage of Computer Vision.
- Performing image manipulation tasks manually through code can be a tedious task, so libraries such as **PIL** (Python Imaging Library) and **OpenCV**, which have in-built pixel alteration functions, are often used to achieve such tasks.
- The PIL library consists of methods that can extract the pixelmap from an image and change pixel intensities by iterating over each pixel value.

Python Imaging Library

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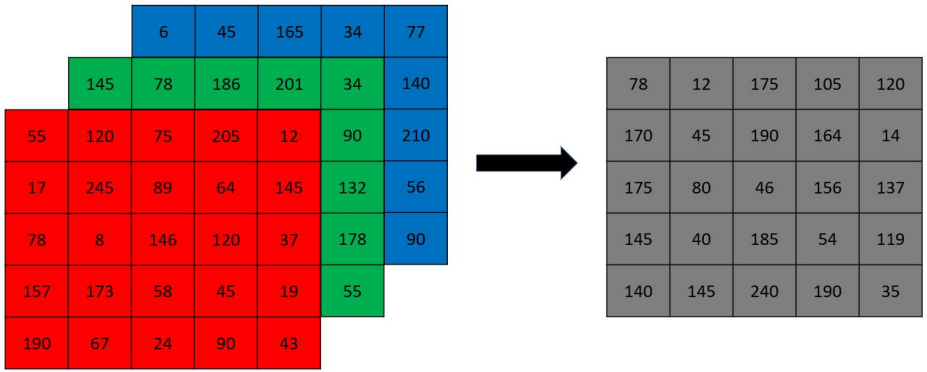
RGB to Grayscale Conversion

- Simple averaging formula to convert an RGB image into a Grayscale image:
  Grayscale= **(R+G+B)/3**

- While the above method achieves equal intensity redistribution, a more research-oriented formula, taking into account the increased sensitivity of the human eye to green over the other colors, has been developed that uses a weighted average of the pixel intensity values instead:
  Grayscale = (0.299*R + 0.587*G + 0.114*B)

Simple averaging formula: RGB to Grayscale Conversion



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