Color Pixel Theory and Image Representation

Pre-work: Computer Vision

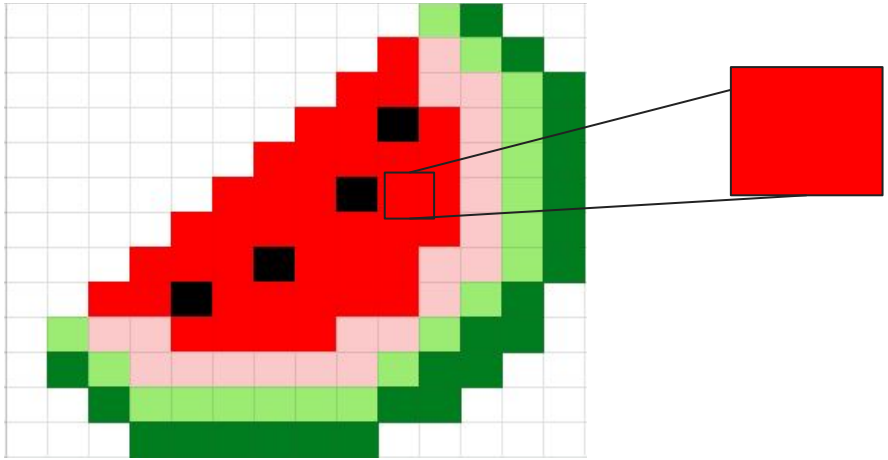
Agenda

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

Basics of Images

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**.



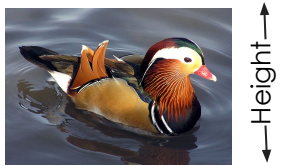
Basics of Images

- Images have three major components:

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

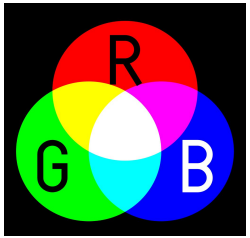
Color Space
This represents the different possible color spaces, like Grayscale, RGB, HSV. The image of the duck on the right is represented in RGB color space.

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



Grayscale

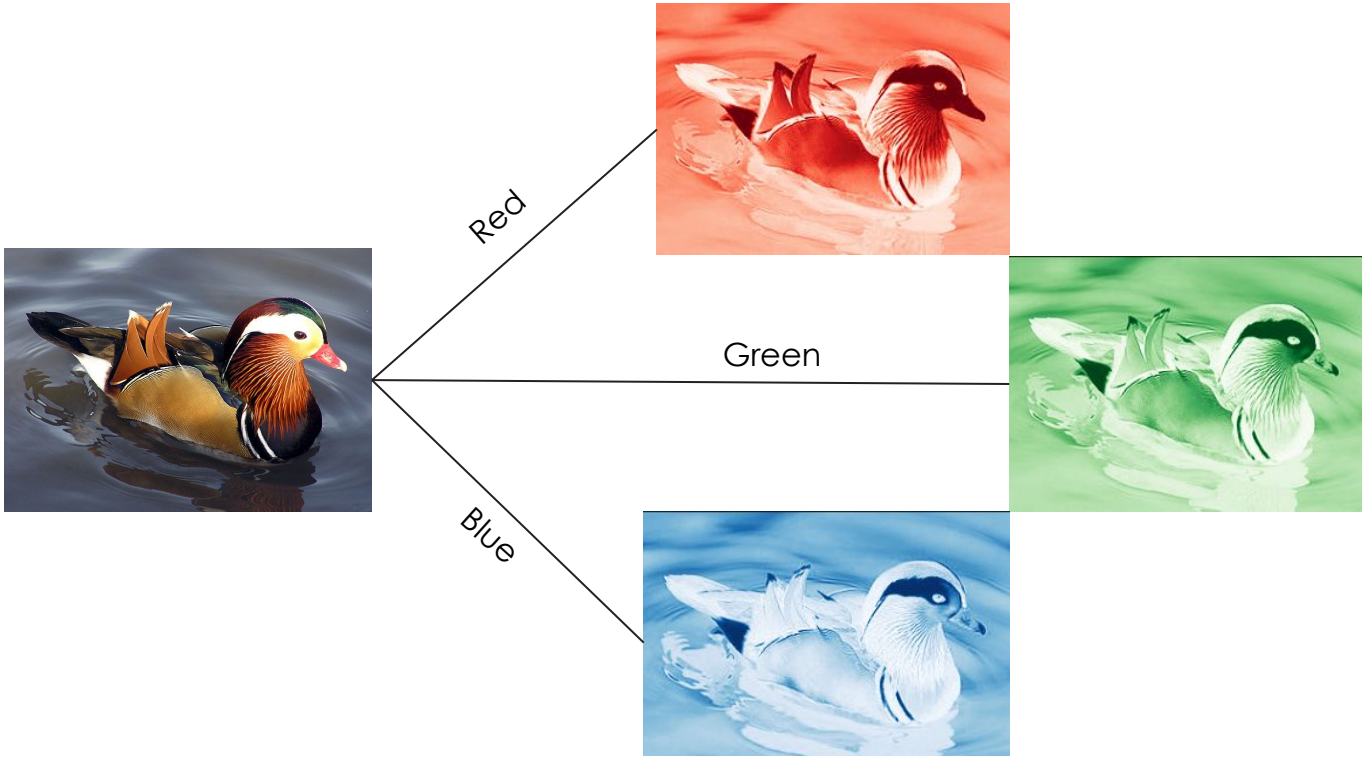
RGB



The RGB Color Space

Basics of Images

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



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

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.

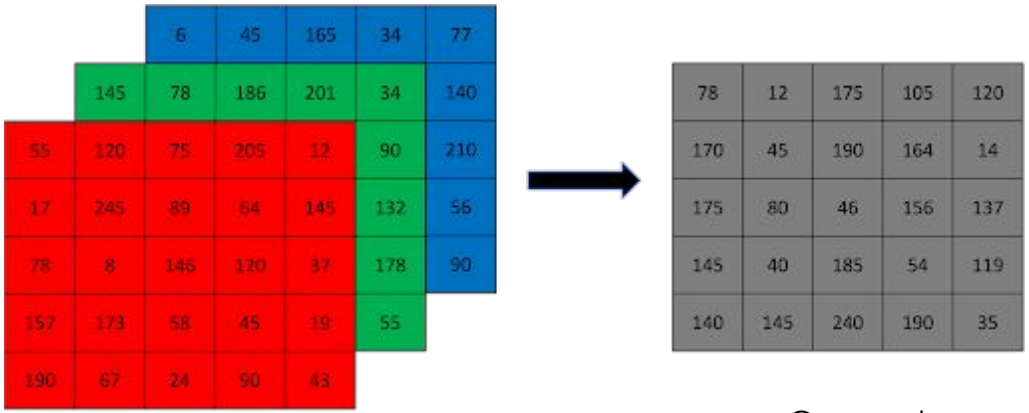
Color	Color Name	Pixel Intensity Values - RGB Color Space		
		R (Red)	**G** (Green)	**B** (Blue)
	Black	0	0	0
	White	255	255	255
	Dim Gray	100	100	100
	Very Light Gray	200	200	200

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.

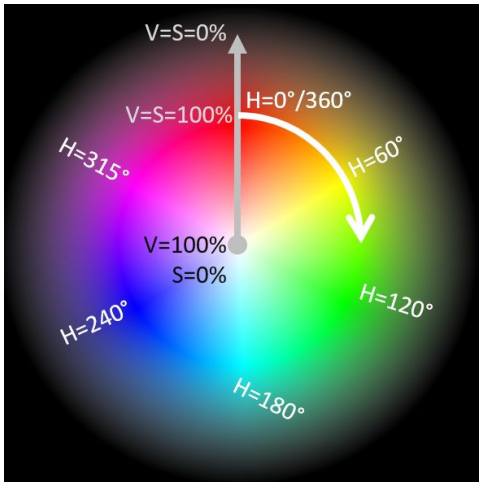


RGB

Grayscale

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.

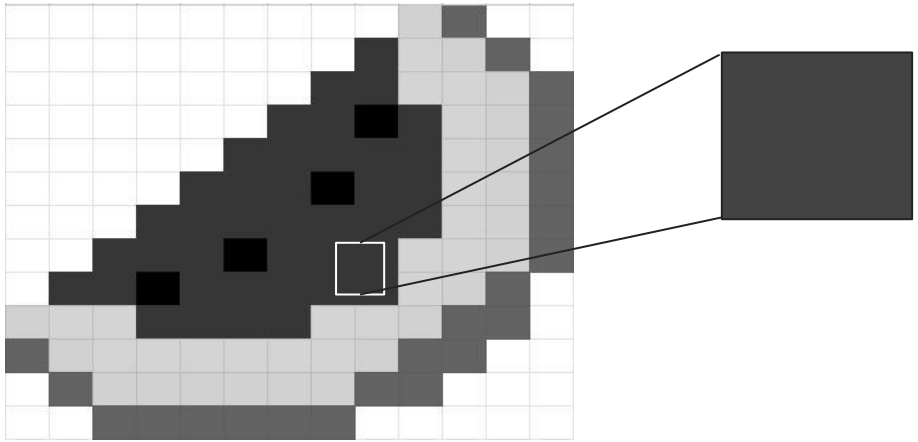


Representation of Images

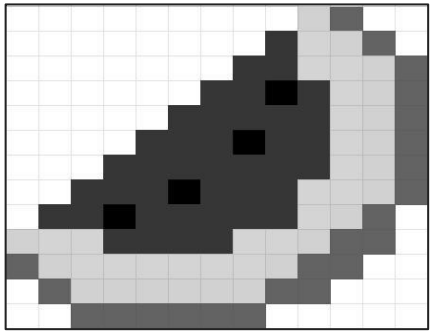
Representation of Images as Arrays

- **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.

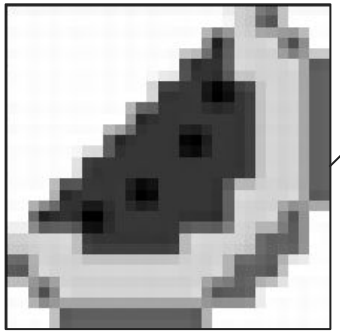
A Grayscale image only consists of a 2D array of grayscale pixels, such as the pixel highlighted below



Representation of Images as Arrays



440 x 340



30 x 30

The 2D Array Representation of the Image

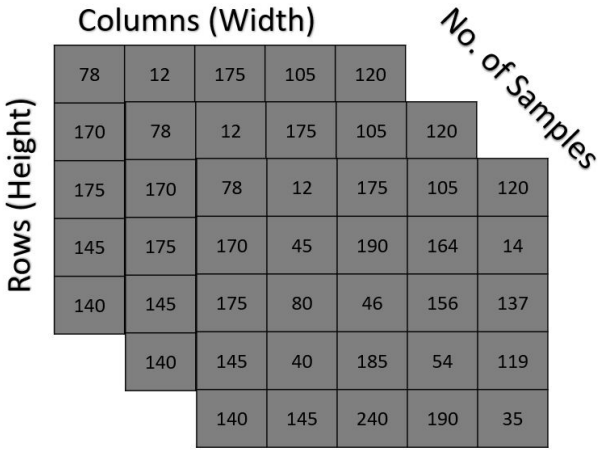
```
249 250 248 250 248 250 249 249 250 248 250 248 250 248 249 249 249 250 248 250 237 210 203 123 108 196 250 248 250 249
254 255 253 255 253 255 254 254 255 253 255 253 255 253 254 254 254 255 255 255 247 209 200 104  85 195 255 255 255 254
251 253 251 253 251 253 251 252 253 251 253 251 253 251 252 252 251 253 182 123 152 211 206 168 164 156 153 187 253 252
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  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  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  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
251 253 178 139 153 167 166 166 167 166 167 166 167 166 167 166 166 167 151 143 145 145 149 237 253 251 253 251 253 252
254 255 255 255 194  89  95  95  95  95  95  95  95  95  95  95  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  99  92 177 254 252 253 252 252 253 251 253 251 253 252
```

Matrix of size 30 x 30

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)

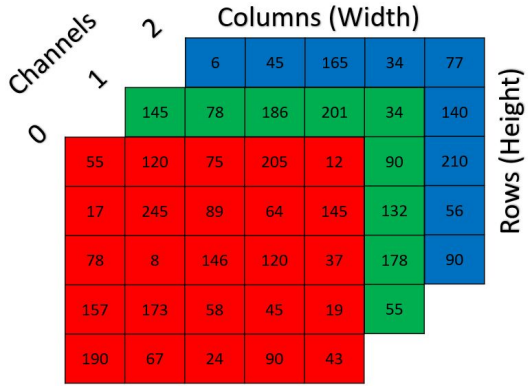


Representation of Images as Arrays

- **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)

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).

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.

PIL (Python Imaging Library)

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.

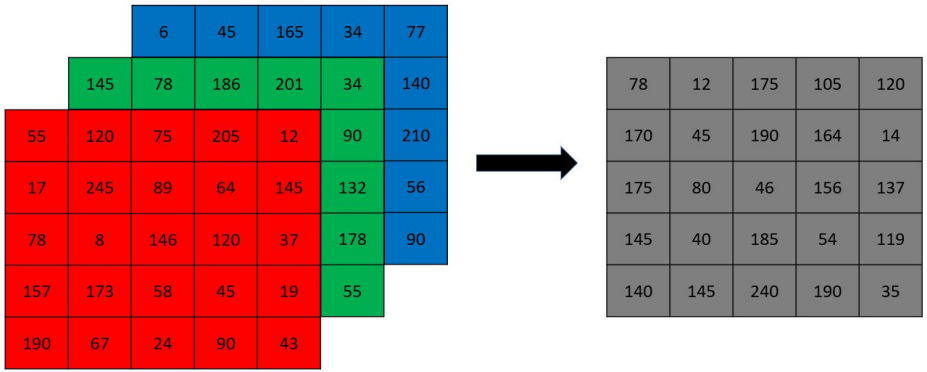
Python Imaging Library

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



Thank You