



# Color Pixel Theory and Image Representation

## Pre-work: Computer Vision

This file is meant for personal use by [tinlong@iscopedesign.com](mailto:tinlong@iscopedesign.com) only.  
Sharing or publishing the contents in part or full is liable for legal action.



# Agenda

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

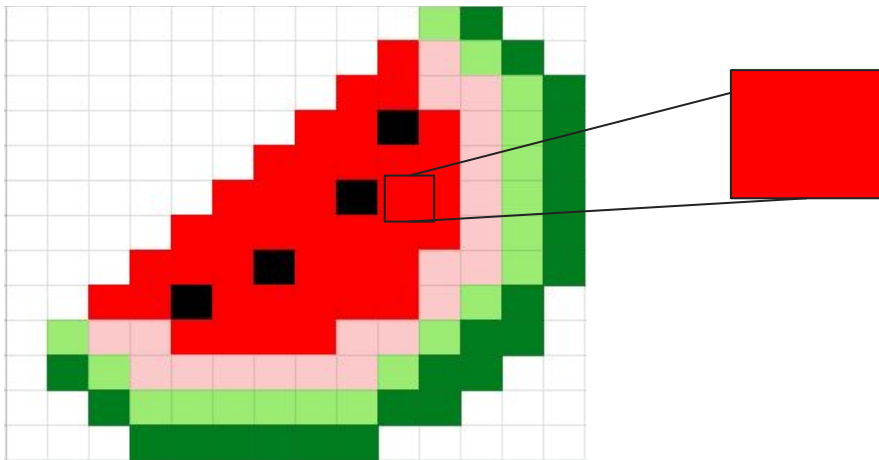


# Basics of Images

This file is meant for personal use by [tinlong@iscopedesign.com](mailto:tinlong@iscopedesign.com) only.  
Sharing or publishing the contents in part or full is liable for legal action.

# 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**.



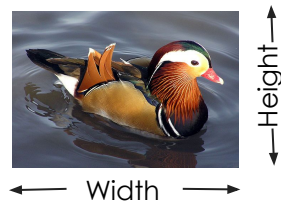
This file is meant for personal use by tinlong@iscopedesign.com only.  
Sharing or publishing the contents in part or full is liable for legal action.

# 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.



Grayscale



RGB

## Channels

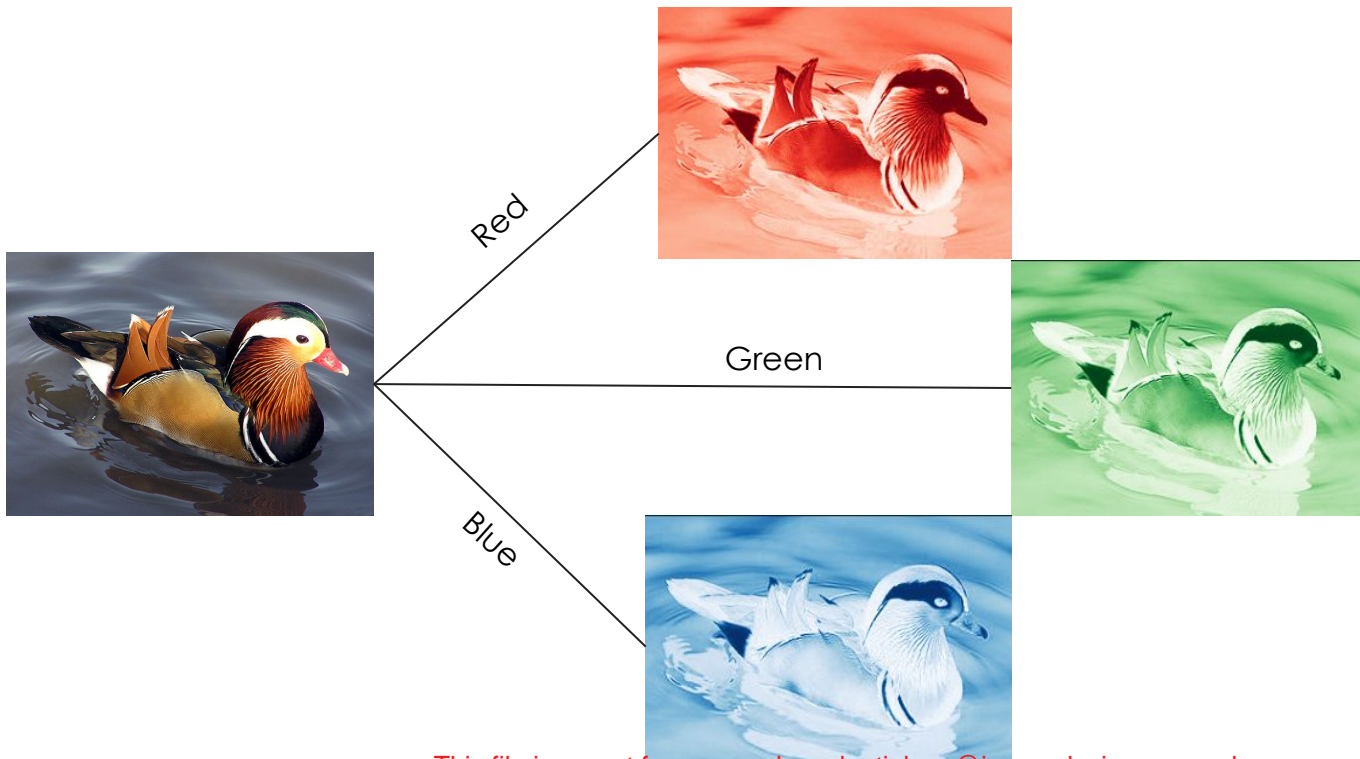
This explains the attributes of a color space - For example, RGB has three color channels: Red, Green and Blue.



The RGB  
Color  
Space

# Basics of Images






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



This file is meant for personal use by tinlong@iscopedesign.com only.  
Sharing or publishing the contents in part or full is liable for legal action.

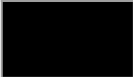


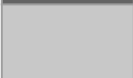
# The RGB Color Scheme

- 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 Grayscale.

| 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      |

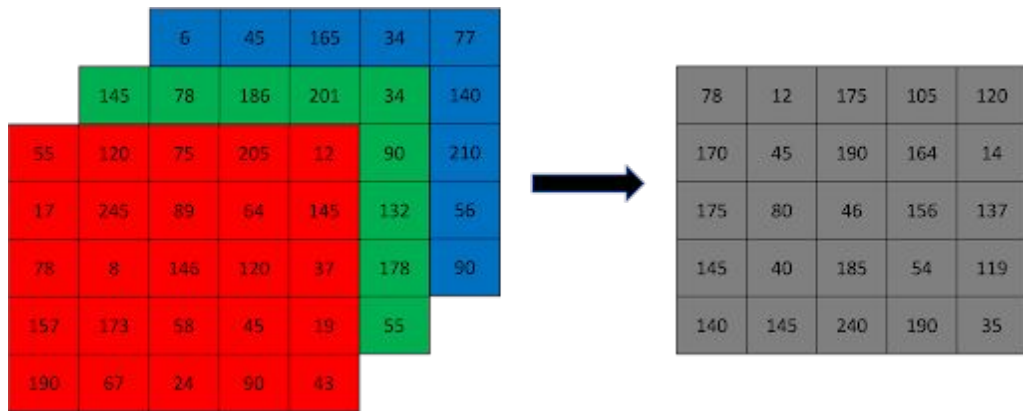


# Grayscale Images

- Why is Grayscale 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.



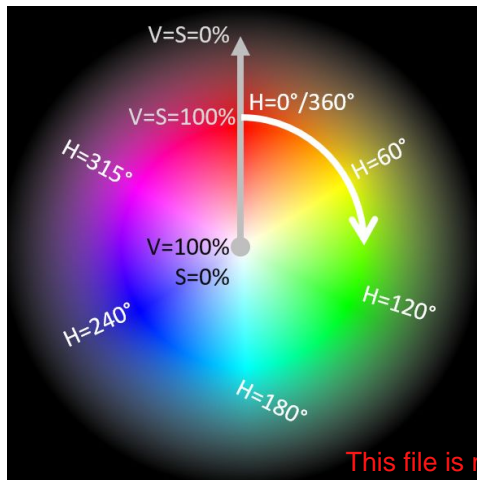
RGB

Grayscale

This file is meant for personal use by tinlong@iscopedesign.com only.  
Sharing or publishing the contents in part or full is liable for legal action.

# 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.



This file is meant for personal use by tinlong@iscopedesign.com only.  
Sharing or publishing the contents in part or full is liable for legal action.



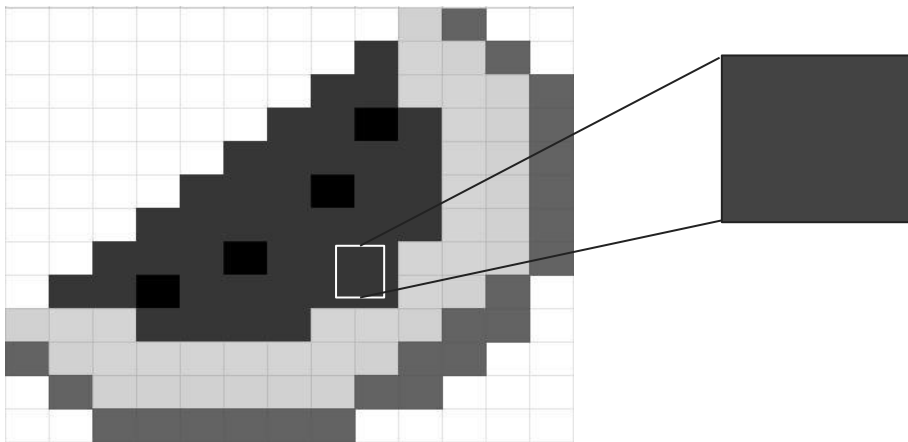
# Representation of Images

This file is meant for personal use by [tinlong@iscopedesign.com](mailto:tinlong@iscopedesign.com) only.  
Sharing or publishing the contents in part or full is liable for legal action.

# Representation of Images as Arrays

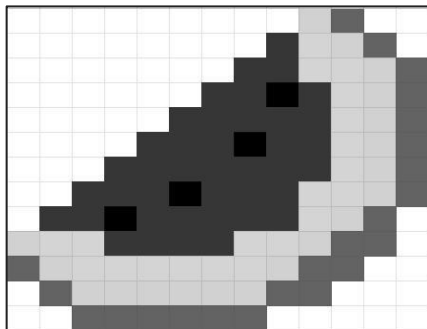
- **A grayscale image can be represented using a 2D array.** This is because each grayscale pixel would have just one channel and hence one number for its pixel intensity value, so an image, which is just a 2D array of pixels, would mathematically just be a 2D array of pixel intensity values.

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

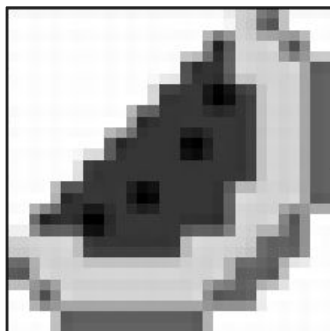


This file is meant for personal use by tinlong@iscopedesign.com only.  
Sharing or publishing the contents in part or full is liable for legal action.

# 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 | 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 | 255 | 255 | 247 | 209 | 200 | 104 | 85  | 195 | 255 | 255 | 254 | 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 | 150 | 128 | 152 | 202 | 203 |
| 254 | 255 | 253 | 255 | 253 | 255 | 254 | 254 | 255 | 253 | 255 | 253 | 255 | 253 | 255 | 252 | 88  | 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  | 98  | 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  | 55  | 52  | 64  | 196 | 214 | 209 | 213 | 168 | 95  | 99  | 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  | 53  | 17  | 10  | 35  | 56  | 54  | 52  | 64  | 195 | 213 | 208 | 212 | 167 | 95  | 99  | 99  |
| 253 | 254 | 252 | 254 | 252 | 255 | 227 | 63  | 55  | 55  | 54  | 54  | 54  | 54  | 54  | 53  | 53  | 54  | 54  | 54  | 51  | 63  | 195 | 213 | 208 | 212 | 167 | 95  | 99  | 99  |
| 253 | 254 | 252 | 254 | 252 | 253 | 225 | 60  | 51  | 54  | 54  | 54  | 53  | 54  | 54  | 54  | 54  | 54  | 54  | 54  | 54  | 65  | 196 | 214 | 208 | 213 | 168 | 95  | 99  | 99  |
| 252 | 253 | 251 | 253 | 188 | 83  | 85  | 55  | 54  | 56  | 33  | 10  | 19  | 54  | 54  | 54  | 54  | 54  | 50  | 90  | 185 | 184 | 207 | 211 | 207 | 211 | 167 | 95  | 99  | 99  |
| 254 | 255 | 255 | 255 | 178 | 41  | 50  | 56  | 56  | 54  | 56  | 26  | 0   | 8   | 54  | 54  | 54  | 54  | 49  | 99  | 219 | 216 | 212 | 212 | 212 | 218 | 169 | 88  | 93  | 99  |
| 251 | 253 | 176 | 139 | 107 | 51  | 50  | 26  | 25  | 47  | 56  | 43  | 30  | 35  | 54  | 54  | 54  | 54  | 49  | 98  | 213 | 210 | 208 | 210 | 167 | 145 | 152 | 170 | 171 | 99  |
| 255 | 255 | 108 | 33  | 44  | 50  | 42  | 0   | 0   | 41  | 55  | 55  | 56  | 56  | 54  | 54  | 50  | 49  | 44  | 95  | 215 | 211 | 211 | 216 | 133 | 85  | 146 | 255 | 255 | 99  |
| 248 | 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 | 210 | 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 | 100 | 100 | 93  | 178 | 230 | 236 | 253 | 252 |
| 91  | 88  | 174 | 217 | 211 | 212 | 211 | 213 | 214 | 213 | 214 | 213 | 214 | 214 | 214 | 211 | 212 | 211 | 217 | 179 | 94  | 97  | 94  | 86  | 192 | 255 | 255 | 255 | 254 | 254 |
| 190 | 189 | 151 | 130 | 162 | 211 | 207 | 207 | 208 | 207 | 208 | 207 | 208 | 207 | 208 | 207 | 211 | 165 | 133 | 124 | 97  | 102 | 177 | 188 | 227 | 253 | 251 | 253 | 251 | 252 |
| 255 | 255 | 143 | 79  | 137 | 218 | 212 | 212 | 213 | 212 | 213 | 212 | 213 | 212 | 213 | 212 | 218 | 142 | 85  | 91  | 93  | 99  | 238 | 255 | 255 | 255 | 253 | 255 | 254 | 254 |
| 251 | 253 | 178 | 139 | 153 | 167 | 166 | 166 | 167 | 166 | 167 | 166 | 167 | 166 | 166 | 167 | 151 | 143 | 145 | 145 | 149 | 237 | 253 | 251 | 253 | 251 | 253 | 251 | 252 | 252 |
| 254 | 255 | 255 | 255 | 194 | 89  | 95  | 95  | 95  | 95  | 95  | 95  | 95  | 95  | 95  | 95  | 89  | 179 | 255 | 255 | 255 | 255 | 255 | 254 | 255 | 253 | 255 | 253 | 254 | 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 | 251 | 252 |

Matrix of size 30 x 30

This file is meant for personal use by tinlong@iscopedesign.com only.  
Sharing or publishing the contents in part or full is liable for legal action.

# 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)**

| Columns (Width) |     |     |     |     | No. of Samples |     |
|-----------------|-----|-----|-----|-----|----------------|-----|
|                 |     |     |     |     |                |     |
| Rows (Height)   | 78  | 12  | 175 | 105 | 120            |     |
|                 | 170 | 78  | 12  | 175 | 105            | 120 |
|                 | 175 | 170 | 78  | 12  | 175            | 105 |
|                 | 145 | 175 | 170 | 45  | 190            | 164 |
|                 | 140 | 145 | 175 | 80  | 46             | 156 |
|                 |     | 140 | 145 | 40  | 185            | 54  |
|                 |     | 140 | 145 | 240 | 190            | 35  |

This file is meant for personal use by tinlong@iscopedesign.com only.  
Sharing or publishing the contents in part or full is liable for legal action.

# 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)**

|          |   | Columns (Width) |     |     |     |     | Rows (Height) |
|----------|---|-----------------|-----|-----|-----|-----|---------------|
|          |   | 0               | 1   | 2   |     |     |               |
| Channels | 2 |                 |     |     |     |     |               |
|          | 1 |                 |     |     |     |     |               |
|          | 0 |                 |     |     |     |     |               |
|          |   | 55              | 120 | 75  | 205 | 12  | 90            |
|          |   | 17              | 245 | 89  | 64  | 145 | 132           |
|          |   | 78              | 8   | 146 | 120 | 37  | 178           |
|          |   | 157             | 173 | 58  | 45  | 19  | 55            |
|          |   | 190             | 67  | 24  | 90  | 43  |               |

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)

This file is meant for personal use by [tinlong@iscopedesign.com](mailto:tinlong@iscopedesign.com) only.  
Sharing or publishing the contents in part or full is liable for legal action.

# 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 pixmap from an image and change pixel intensities by iterating over each pixel value.



# RGB to Grayscale Conversion

- Simple averaging formula to convert an RGB image into a Grayscale image:

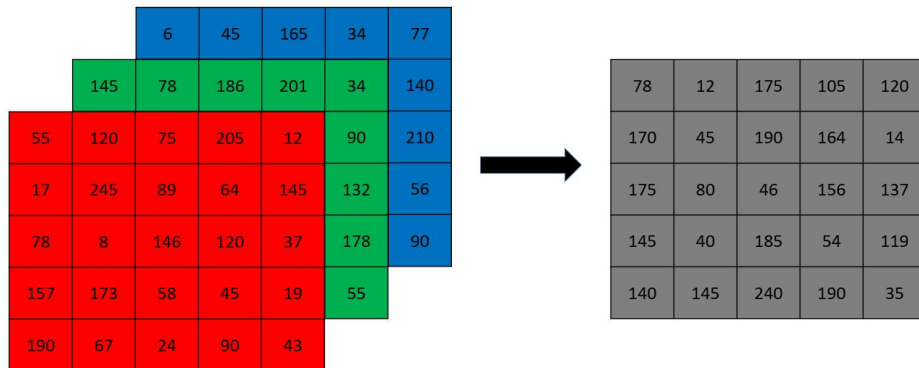
**Grayscale=**

$$(R+G+B)/3$$

- 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

This file is meant for personal use by [tinlong@iscopedesign.com](mailto:tinlong@iscopedesign.com) only.  
Sharing or publishing the contents in part or full is liable for legal action.