

# OpenCV Computer Vision 1 Notes

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# Week 1: Getting Started with Images

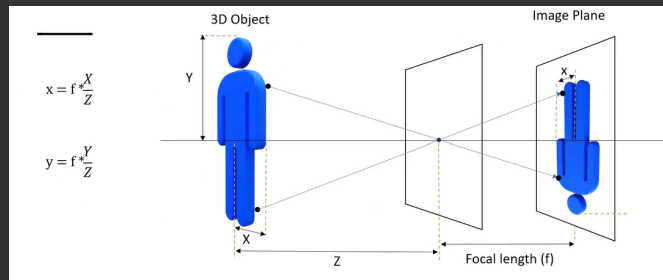
## Introduction

Some things we will learn

- What is color?
- How does a camera see an image?
- How to read/write images?
- How to manipulate pixels?
- Alot more!

## How is An Image Formed

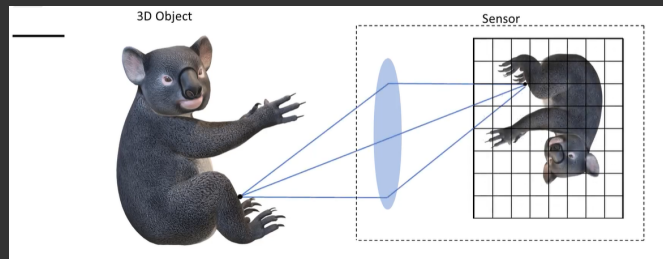
Throughout history the phenomena of imaging has been explored by many ancient civilizations. The most used primitive form of a camera that has been used was the pinhole camera. The pinhole camera works by taking the light waves that bounce off of an object and projecting them through a small hole.



*Fig. 1: PinHole Camera Example*

## Image Formation

Inside of a camera there is a sensor that is a large grid of nodes. These nodes are what eventually become “pixels”. Each node on the sensor gets a value between 0 and 255 which represents the digital grayscale image. The value for each node is determined by the strength of the light that hits it. The stronger the light the closer the value is to 255 as 255 is white and 0 is black. Each pixel is essentially an 8 bit representation of the intensity of the light at that position on the sensor.



*Fig. 2: Greyscale Digitalization*

## Bayer Pattern

Every pixel only records one color: red, green, or blue. The human eye is much more sensitive to green light than blue or red. The full RGB Image is then formed through a process called demosaicing where 2 missing values from each pixel are calculated from the neighbouring pixels

**For example:** If a pixel records the red value, based on the pixels around it the pixel will interpolate what the correct hue for the 2 missing colors.

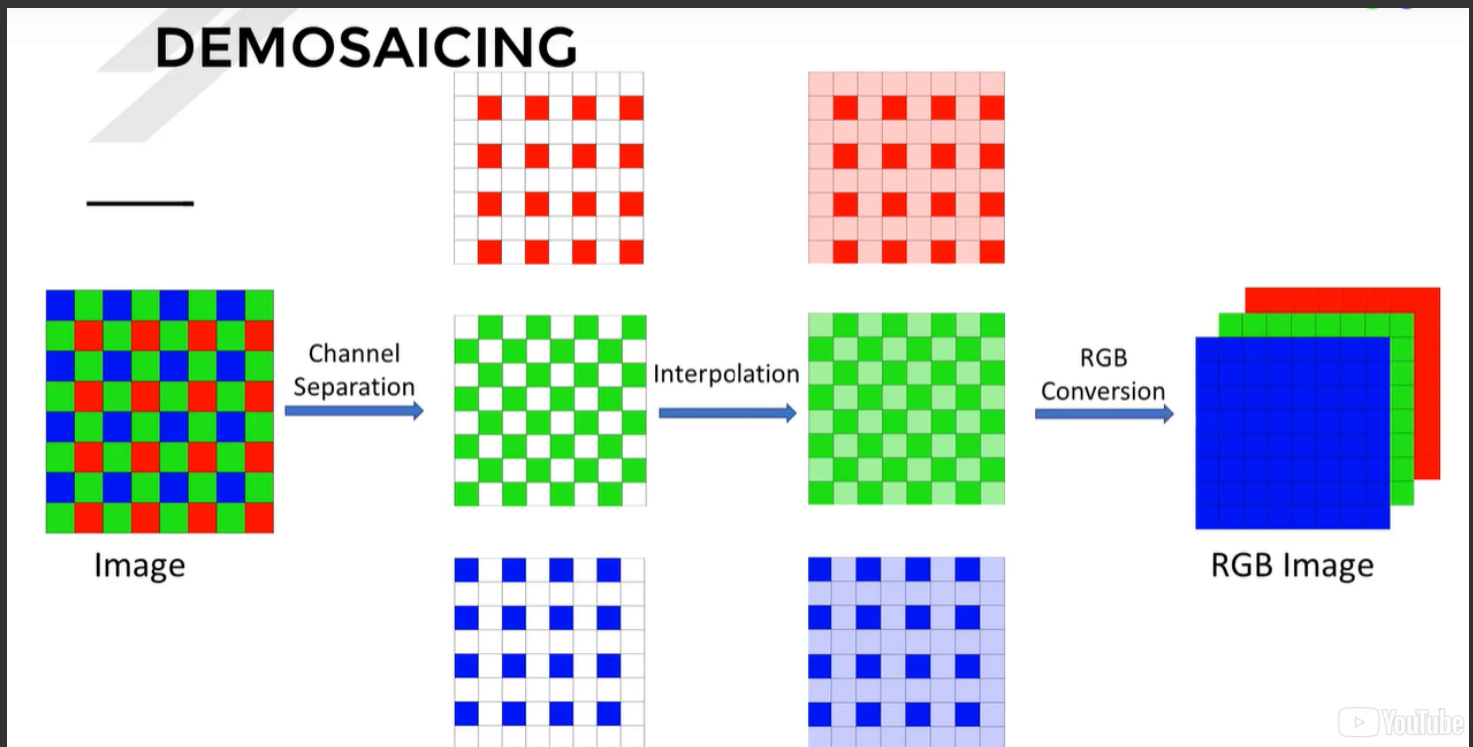


Fig. 3: Process of Demosaicing

## Image Format

Once a RGB image is created, they are typically stored and compressed as either Joint Photographic Expert Group (JEPGs) or Portable Network Graphics (PNGs).

### Image Storage

Within a JPEG file the image is broken up into two parts. There is the Image Header and the Data.

- Image Header
  - Width
  - Height
  - No. of channel
  - Color Profile
  - No. of bits per pixel

The second part is the data which actually contains the RGB values

## Image in OpenCV

When an image is first read in openCV the image is decompressed and stored in a standardized format. All images are stored into the **Mat Class** if the C++ version is being used, or a **Numpy array** if Python is being used.

### Mat Class

The Mat class is similar to a JPEG in structure but the difference is that instead of using RGB values it used BGR. It uses bgr because of historic reasons, aka that is how they initially did it and it makes no sense to back through and change all of the backend code now.

# Week 1: Reading/Writing/Modifying Images in OpenCV

## Image Formats

OpenCV can use two different formats, JPEG and PNG

### JPEG

- 1) Most Popular
- 2) Loss in image format
- 3) Small Filesize

### PNG

- 1) Very Popular
- 2) Lossless and lossy options
- 3) Supports transparency

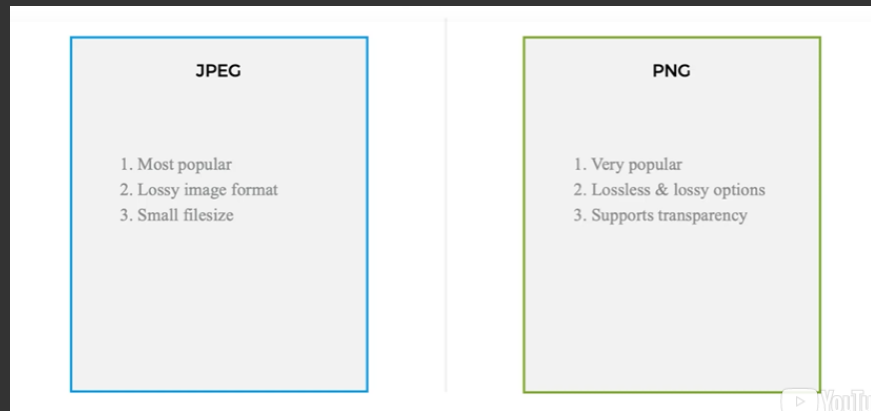


Fig. 4: JPEG vs PNG.

### Transparent Images

Contains all three regular channels (Red, Green, Blue) and also contains an 'Alpha' channel that acts as a mask (255 or 0). The value that is put into the alpha channel is determined by the Opacity of the pixel. If the pixel is "Transparent", then there will be a 0 for that pixel in the Alpha channel. If the pixel is not "Transparent", then it will receive a value of 255.

\*\*\*Note: Alpha channels do not necessarily have to be binary. They can be tertiary or higher if for some reason that kind of masking is wanted/needed. Aka, there can be partial transparencies

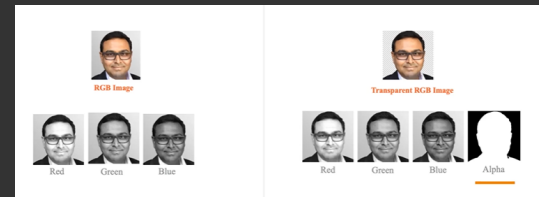


Fig. 5: RGB vs Transparent RGB.

## Reading The Image (Week One: Getting Started With Images)

To load an image through OpenCV use the **imread** function. This function is able to handle most, if not all of the image types that you may want to upload (these include JPEG, PNG, etc)

### Function Syntax: cv2.imread

`loadedimage = cv2.imread(filename, flags)`

this function (imread) will return the image as a matrix or None if something happened that it was not able to resolve.

This function has **two arguments**:

- 1) The **path** of the image file: this can be absolute or relative and is a mandatory argument
- 2) **Flags**: -1, 0, or 1. \*\*\*DEFAULT IS ONE\*\*\*

`cv2.IMREAD_UNCHANGED` or -1: Loads an image including the alpha channel (unchanged)

`cv2.IMREAD_GRAYSCALE` or 0: Loads the image in grayscale

`cv2.IMREAD_COLOR` or 1: Loads a color image and throws out transparency

## Manipulating Pixels (Week One: Getting Started With Images)

### Accessing Values

Since the openCV returns things as a matrix of values, you can just access them using the subscript notation of matrices. IMPORTANT: Numpy saves the matrix in row column format which is the opposite of x,y format. For example if you want to access the pixel to the right of the top left instead of (1,0), which is the cartesian representation of it, it would be [0,1]. This is an important distinction as it will allow you to actually access the correct variables.

```
print(testImage[0,0])
```

### Modifying Values

Just use a normal python = operation for this. You can either modify a single value or a whole region...that is next. There are a few reasons why people would want to change the values of the pixels. For one, if there is a known issue with the image or a known change that the user might want to change, they need to be able to access and modify the values. For example maybe the edges of the image are blurry so you just set them all to 0 so that there are no false positives.

```
testImage[0,0] = 200
print(testImage)
```

## Manipulating Groups of Pixels (Week One: Getting Started With Images)

### How To Access A Region

ROI - Region of Interest

```
test_roi = testImage[0 : 2, 0 : 4]
```

This code will return a resulting matrix that is 2 rows tall, and 4 columns long. This is a bit counterintuitive because if you count up from 0 (where subscript position starts), and go to the last number then both dimensions are missing 1 element. This is because python is inclusive of the lower bound but non inclusive of the upper bound. 0:2 tells python, hey! Look in this matrix and take out rows 0 and 1, stop before two, and also take columns 0, 1, 2, 3 and stop before four. Now stitch this all together into a matrix and return it! This way the programmer can select a specific part of the image that they are interested in using aka, Region of Interest. To set a region of interest to a specific value all you have to do is take the region, and use the equals operator.

```
testImage[0 : 2, 0 : 4] = 111
```

## Displaying An Image

Previously learned were the ways that you could display the matrices that made up a specific image and see the values that they contained. Also learned were the ways to modify a pixel or a ROI (Region of Interest). All of this however is pretty much useless as it isn't really possible to visualize a whole picture by just looking at the matrices. There is the need to actually display the image and when using python that is done with Matplotlib.

Matplotlib is a python library for data visualization and does a pretty good job as it. As the name implies, it is a library for plotting math related things. Matplotlib can be installed with a simple, **pip install matplotlib**. Make sure that you are on the virtualenv that you want to use it for (personally i just install everything system wide I know it is not the right way to do it but it is the way that I do it for ease of use).

### Function Syntax: plt.imshow() vs cv2.imshow()

#### Matplotlib

- The matplotlib version of the function only has 1 mandatory argument, which is the image in the form of a matrix. A good practice is to also include the `colorbar()` function with it as well as it shows a gradient colorbar based on the values.

```
plt.imshow(matrix)
matrix - Image to be displayed
```

## OpenCV

- The OpenCV version of the function is similar to the Matplotlib version but where it differs is that it opens a separate window to view the image in. This version requires you to have OpenCV installed locally on your computer to run as it uses OpenCV packages.

```
cv2.imshow(window name, matrix)
Read the image: boy = cv2.imread(data_path + "/images/boy.jpg")
Display the image using imshow: cv2.imshow("Boy", boy)
Wait for user to press a key: cv2.waitKey(0)
Destroy the window: cv2.destroyAllWindows()
***These extra methods will be gone over in the next section***
```

## Addition Display Utility Functions (OpenCV)

### cv2.namedWindow

This function creates a display window with a specific name. The name provided is the first argument of the function. The second is a flag that determines whether or not the window can be resized.

The two flags are **cv2.WINDOW\_NORMAL**, which will all the window to be resized to fit the image that is sent to it, or **cv2.WINDOW\_AUTOSIZE** which is the default if nothing is sent.

### cv2.waitKey

This function can be used in image and video processing. The only argument that it takes is the milliseconds to wait for a key press. For example if you sent it 100 then it will wait for a key to be pressed for 100ms and proceed if the time has passed or the key has been pressed. If a 0 is passed in then it will wait indefinitely until a key is pressed

### cv2.destroyWindow

This function is pretty self explanatory. The only parameter that it takes is the window name. It will then destroy the window

### cv2.destroyAllWindows

Just like `destroywindow()` except it destroys all windows.

## Saving an Image

To save an image to the disk use a function called `imwrite` from the `cv2` library.

### Syntax

```
cv2.imwrite("test.jpg", testImage)
```

**Parameter 1:** is the filename to be saved as, if you would like to save it as a PNG then add a `.png` if you want it to be saved as a JPEG then save it as a `.jpg`

**Parameter 2:** is the matrix that you want to store to the new image file that is going to be created.

There are more params that can specify the compression quality and others but they don't really matter. If you want to find out more about it just look at the documentation online.

## Color Images

This will go over how to read a color image and it's properties.

To read a colored image you will still use the `cv2.imread()` function. The only difference between reading colored and non color images is that now if you check the "shape" of the matrix you will see that it has a 3rd dimension that is either 3 or 4. 3 for normal RGB (remember each channel is a color) or it will have 4, the 4th being the channel for transparency.

### Image Channels

If you read in a colored image using `cv2.imread()` and then print it using the `plt.imshow()` you will see that the image is inverted. This is because OpenCV as previously discussed handles RGB as BGR. If you use the **OpenCV** `imread` function then it knows in what order to interpret those channels. Unfortunately Matplotlib doesn't understand the order which is why I think that it just makes more sense to use the OpenCV show function. It allows more flexibility with the movable and possibly resizable window and also integrates seamlessly with OpenCV, as it should. You would think that they would all just standardize the data on one format but no, everyone wants to do it their own way and doesn't want to standardize...sigh. One day these companies will learn.

**Note:** If for some reason you still feel compelled to use the Matplotlib (if you are I truly don't understand why please shoot me a message on github), then you can simply reverse the order of the last dimension of the matrix. That will convert the RBG to BGR...just use OpenCV...there is no point to go through the hassle...please.

### Accessing Individual Channels

When wanting to pring the individual channels out and seeing what the image looks like just use the `imshow` method (please us `cv2`). The way to do this is remember that at the end of the day it is a python numpy array and that there are 3-4 channels on that last dimension of the array.

#### Code Examples of How to Show 3 channel subplots

```
plt.subplot(131);plt.imshow(img[:, :, 0]);plt.title("Blue Channel");
plt.subplot(132);plt.imshow(img[:, :, 1]);plt.title("Green Channel");
plt.subplot(133);plt.imshow(img[:, :, 2]);plt.title("Red Channel");
```

Keep in mind that this is not doing **anything fancy**... this is just basic accessing of arrays. Don't get too caught up with it. You are just selecting which part of the 3rd dimension to use (one is R, one is G, one is B). To really quickly explain the subplot function: 1 row, 3 columns, position (1) → 131

Another way to split the image up into the separate components would be to use the `cv2.split` function.

```
# Split the image into the B,G,R components
b,g,r = cv2.split(img)

# Show the channels
plt.figure(figsize=[20,5])
plt.subplot(141);plt.imshow(b);plt.title("Blue Channel");
plt.subplot(142);plt.imshow(g);plt.title("Green Channel");
plt.subplot(143);plt.imshow(r);plt.title("Red Channel");

# Merge the individual channels into a BGR image
imgMerged = cv2.merge((b,g,r))
# Show the merged output
cv2.imshow("Merged Output", imgMerged[:, :, :])
```

**Note:** I did make a change to the lesson code here. The lesson code uses the `plt.imshow` method which takes RGB, not the BGR values that have been merged. Instead of wasting time and in the future making a mistake by not flipping the channels, I changed it to the `cv2 imshow` which you should use as it integrates better.



## Images the Alpha (fourth) Channel

The best way that I can relate the alpha channel metaphorically would be like a 6th sense. The three other channels are like the 5 senses of color and the Alpha Channel is the Fourth Channel (see the comparison to the sixth sense here). This is an original metaphor that I came up with so I am pretty stoked about it. Here is the code to use the alpha channel through OpenCV.

**Example:**

```
# Path of the image to be read
image_path = data_path + "images/panther.png"

# read the iamge
# the example passes a flag of -1 so that the image is read as is but to code correctly we should use the created flag for
# readability.
img_png = cv2.imread(image_path, cv2.IMREADUNCHANGED)

# First 3 channels will be combined to form BGR image # Mask is the alpha channel of the original image imgBGR =
imgPNG[:, :, 0:3] imgMask = imgPNG[:, :, 3] plt.figure(figsize=[15,15])
plt.subplot(121);plt.imshow(imgBGR[:, :, :-1]);plt.title('Color channels');
plt.subplot(122);plt.imshow(imgMask, cmap='gray');plt.title('Alpha channel');
```

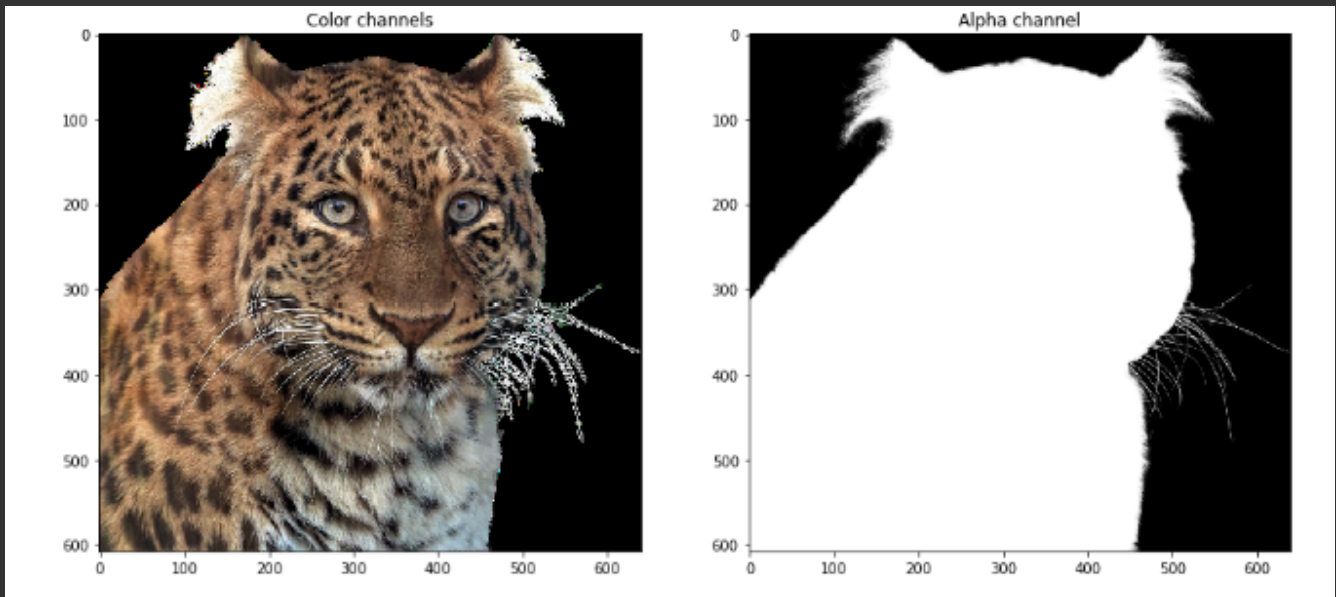


Fig. 6: Example of a binary alpha mask.

I have learned one possible advantage to using Matplotlib which is why I kept this example as is, is the fact that there is an easy way to have subplots all display next to each other where if you were doing this with OpenCV they would all be separate windows...Still not sure what is better...will keep writing about it. If only they just standardized :(

# Basic Image Operations

## Creating New Images

### Create a copy of an image

Copying an image is a fairly easy task. The numpy data type has a built in `copy()` function that can be accessed through the dot operator. Once you had read an image using the `imread()` function you can just simply take that numpy matrix and use the `.copy()` function to copy it over.

```
image = cv2.imread(datapath)
image_copy = image.copy()
```

### Creating an Empty Image

To create an empty image just create a numpy array full of 0's using the `np.zeros` function.

```
emptyMatrix = np.zeros((100,200,3), dtype='uint8')
```

This will make a black image that is the size that has been specified. the second parameter is the data type that you want the 0's to be. If you want to make it a white picture then you would change it to `np.ones` and then multiply the entire matrix by 255.

### Creating an empty matrix that is the same size as the original

To do this use the numpy function called `ones_like()` and pass in the image that you want a blank copy of to be made. This will return a new array that is full of ones and is the same size as the image passed in.

### Cropping an Image

Cropping is just extracting a rectangular region from the image. To do this just remember that the image really is a python numpy array. Just pull out the part that you want by slicing the values that you want out of it.

```
# Crop out a rectangle
# x coordinates = 170 to 320
# y coordinates = 40 to 200
crop = image[40 : 200, 170 : 320]
```

### Copying/Pasting a part of an image

To copy a region of interest the only thing you have to make sure is that the size of the region that you have copied is the same as the region that you are going to paste it into.

1) Copy the part of the original image by slicing the numpy array. 2) Go to wherever you want to paste the image and set those values in the array to the array that represents the crop.

3) Something that can help is the `shape` variable that numpy arrays have. For example you can do **image\_x, image\_y** `image.shape[:number of dimensions]`, where number of dimensions is how many dimensions you are going to split it out into.

### Resizing an Image

To resize an image use the `cv2.resize` function.

**Syntax:** `dst = cv2.resize( src, dsize[, dst[, fx[, fy[, interpolation]]]] )` where:

**src:** input image

**dst:** output resized image

**dsize:** output image size

**fx:** the scale factor along the x axis **fy:** the scale factor along the y axis **interpolation:** interpolation method (Bilinear/Bicubic, etc), interpolation flags can be found here

## Resizing an Image Continued

There are two main ways of using the resize method to effectively resize an image.

### 1) Specify the new width and height:

The biggest downside of this is that you, the programmer, will have to keep track of the aspect ratio as the method will not preserve it. Here is an example

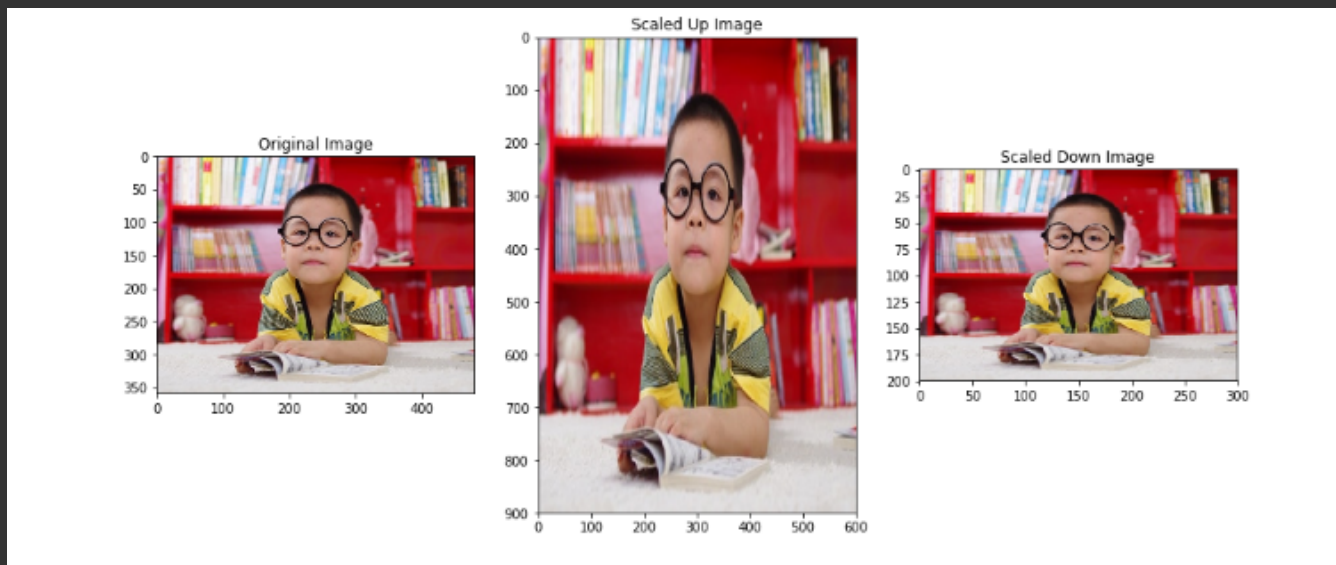
```
# Set rows and columns
resizeDownWidth = 300
resizeDownHeight = 200

resizedDown = cv2.resize(image, (resizeDownWidth, resizeDownHeight), interpolation = cv2.INTER_LINEAR)

# Mess up with the aspect ratio
resizeUpWidth = 600
resizeUpHeight = 900

resizedUp = cv2.resize(image, (resizeUpWidth, resizeUpHeight), interpolation = cv2.INTER_LINEAR)

plt.figure(figsize=[15,15])
plt.subplot(131);
plt.imshow(image[:,:,:-1]);plt.title("Original Image")
plt.subplot(132);
plt.imshow(resizedUp[:,:,:-1]);plt.title("Scaled Up Image")
plt.subplot(133);
plt.imshow(resizedDown[:,:,:-1]);plt.title("Scaled Down Image")
```



*Fig. 7:* Resizing an image using the first Method

## 2) Specify a Scaling Factor:

This method is more useful when you want to resize the image but preserve the original aspect ratio of the image. Here is the example code.

```
# Scaling Down the image 1.5 times by specifying both scaling factors
scaleUpX = 1.5
scaleUpY = 1.5

# Scaling Down the image 0.6 times specifying a single scale factor.
scaleDown = 0.6

scaledDown = cv2.resize(image, None, fx= scaleDown, fy= scaleDown, interpolation= cv2.INTER_LINEAR)
scaledUp = cv2.resize(image, None, fx= scaleUpX, fy= scaleUpY, interpolation= cv2.INTER_LINEAR)
```



Fig. 8: Resizing an image using the second Method

As you can see the aspect ratio has not been disturbed as well as it is a lot easier to just do it this way. The only difference with doing it this way is that you have to do some quick math on what the change in aspect ratio should be.

## Creating an Image Mask

Masking is a very important part of computer vision as it allows the program to ignore or highlight specific parts of the program based on certain conditions.

I will now show how to create a mask based on pixel intensity or color.

Lets say that we want to focus on creating a mask for the color red. Thinking about this logic is pretty simple and it just is that the red channel should have fairly high values (150+), and the other two channels should have low values (less than 100).

The easiest way to do this is by using the OpenCV method called **inRange**. This function takes an image and returns a binary image (black or white) based on the parameters that are passed into it.

**Here is the syntax:**

```
dst = cv2.inRange(src, lowerb, upperb[, dst])
```

**src:** the input array

**lowerb:** inclusive lower boundary array or a scalar

**upperb:** inclusive upper boundary array or a scalar

**dst:** output array of the same size as **src** and CV\_8U data type.

```
mask2 = cv2.inRange(image, (0,0,150), (100,100,255))
plt.figure(figsize=[15,15])
plt.subplot(121);plt.imshow(image[...,:-1]);
plt.title("Original Image")
plt.subplot(122);plt.imshow(mask2);
plt.title("Masked Image")
```

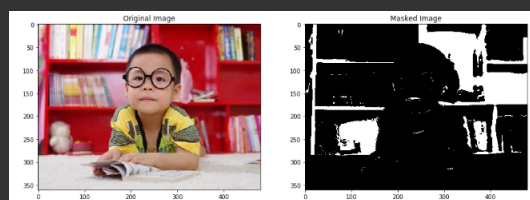


Fig. 9: Masking the image based on red

# Mathematical Operations On Images

## DataType Conversion

Understanding the datatypes of the variables that are representing images is extremely important to making sure that the desired results are being achieved. The data type can drastically change the outcome of the project as it can hinder the amount of data being stored to each variable as well as causing errors in the processing of said data (overflow errors, etc). Knowing the datatypes that are being used and knowing what they need to be is part of the foundation to correctly process images.

The cv2.imread function for python uses the numpy array which has a default datatype of **unsigned integers (8 bits)**. This is important as to do most of the operations that we will want to do we should convert the array to something that allows each pixel to have 16, 32, or 64 bits of data.

To convert an array just use the numpy functions to convert the array.

```
import numpy as np
image = cv2.imread(Data_Path)
image = np.float32(image)
```

This takes the array that was just read in and converts the data type of it to 32 bit floats. This gives much more capability to processing this data.

## Contrast Enhancement

Contrast is essentially the difference between the darkest pixels and the brightest pixels in the image. The maximum contrast of an image is also known as the **Dynamic Range**.

The easiest way of improving contrast is by using Intensity Scaling. This essentially just takes a scale factor and multiplies all of the pixel's intensity values by it.

$$\text{Enhanced Intensity (Contrast)} = \text{IntensityFactor} \times \text{Intensity}$$

Here is a code example of enhancing the contrast:

```
# Clip the values to [0,255] and change it back to uint8 for display
contrastImage = image * (1+contrastPercentage/100)
clippedContrastImage = np.clip(contrastImage, 0, 255)
contrastHighClippedUint8 = np.uint8(clippedContrastImage)
# Convert the range to [0,1] and keep it in float format
contrastHighNormalized = (image * (1+contrastPercentage/100))/255
contrastHighNormalized01Clipped = np.clip(contrastHighNormalized,0,1)
plt.figure(figsize=[20,20])
plt.subplot(131);
plt.imshow(image[...,:-1]);
plt.title("original Image");
plt.subplot(132);
plt.imshow(contrastHighClippedUint8[...,:-1]);
plt.title("converted back to uint8");
plt.subplot(133);
plt.imshow(contrastHighNormalized01Clipped[...,:-1]);
plt.title("Normalized float to [0, 1]");
```



Fig. 10: Contrast Enhancement

Don't forget to normalize the values back down to what they should be!!!. You cannot just multiply them all and display them because the libraries that display the image still require standardized data to correctly display them.

## Brightness Enhancement

Brightness is the measure of light falling on the scene and can in terms of RGB can be thought of as the mean of the three values. To make images brighter you should be adding an arbitrary value to the intensity of the image.

$$\text{Output Image} = \text{Intensity} + \text{Offset}$$

For an image there are 255 intensity values (0 to 255). Here is some code that would increase the brightness by 50 levels. Keep in mind that you cannot simply add 50 to numpy values as they will over flow (what I mean by that is that if you had a numpy array of unsigned 8 bit integers and added 50 to 210, the result wouldn't be 260 or cap itself at 255, it would be 4. Overflow sucks and that is why you really should work with floats as they make arithmetical operations much easier). To get around this issue you can either use floats or you can use the open cv addition function.

```
cv2.add(image matrix, amount to add)
```

OR

Convert to either a normalized 32/64 bit float

OR

Convert to a 32/64 bit integer

Keep in mind that the last two options are just using the numpy methods to quickly convert the data types.

## APPLICATION: Sunglasses Filter

In this really quick fun program we will be taking an image of Elon Musk and giving him some cool shades because even though the world is dying to the corona virus, he needs it because his future is still too bright. We will also give him a mask because he is a germaphobe and doesn't want to get sicko mode. The program will be located in the programs folder for this weeka and will probably be called something along the lines of sunglasses filter. This part of the notebook is mainly to just document the takeaways that I got from this quick project.

The idea of using a mask is quite simple but also quite effective. Using the alpha mask allows to actually merge images well on top of each other and makes it so that you don't have to do in and do stuff in photoshop to get it to work. The idea that you normalize values between 0 and 1 helps a lot when working with the numbers as then a lot of errors are clear up. To give the project my own touch I gave Elon a mask to stay safe during this Corona Virus thing. He's pretty safe now, no germs are gunna get to him!



*Fig. 11: Filter Project*