Homework 1 solution template
CMPSCI 370 Spring 2019, UMass Amherst
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Here is a template that your solutions should roughly follow. Include outputs as figures, and code should be included in the end.

1 Matrix manipulation

1. Create a $m \times n$ array of all zeros.

   ```
   import numpy as np
   array = np.zeros([m,n])
   ```

2. Create a random $m \times n$ array.

   ```
   array = np.random.uniform(0, 1, [m, n])
   ```

3. Code to compute its length (or norm).

   ```
   length = np.sqrt(np.sum(np.array(v)**2))
   ```

4. Given variables u and v representing arrays of size $n \times 1$, write down code to compute their

   (a) dot product

   ```
   dot = np.sum(np.multiply(u, v))
   ```

(b) angle

angle = np.degrees(np.arccos(np.dot(u, v) / (np.linalg.norm(u) * np.linalg.norm(v))))

(c) distance

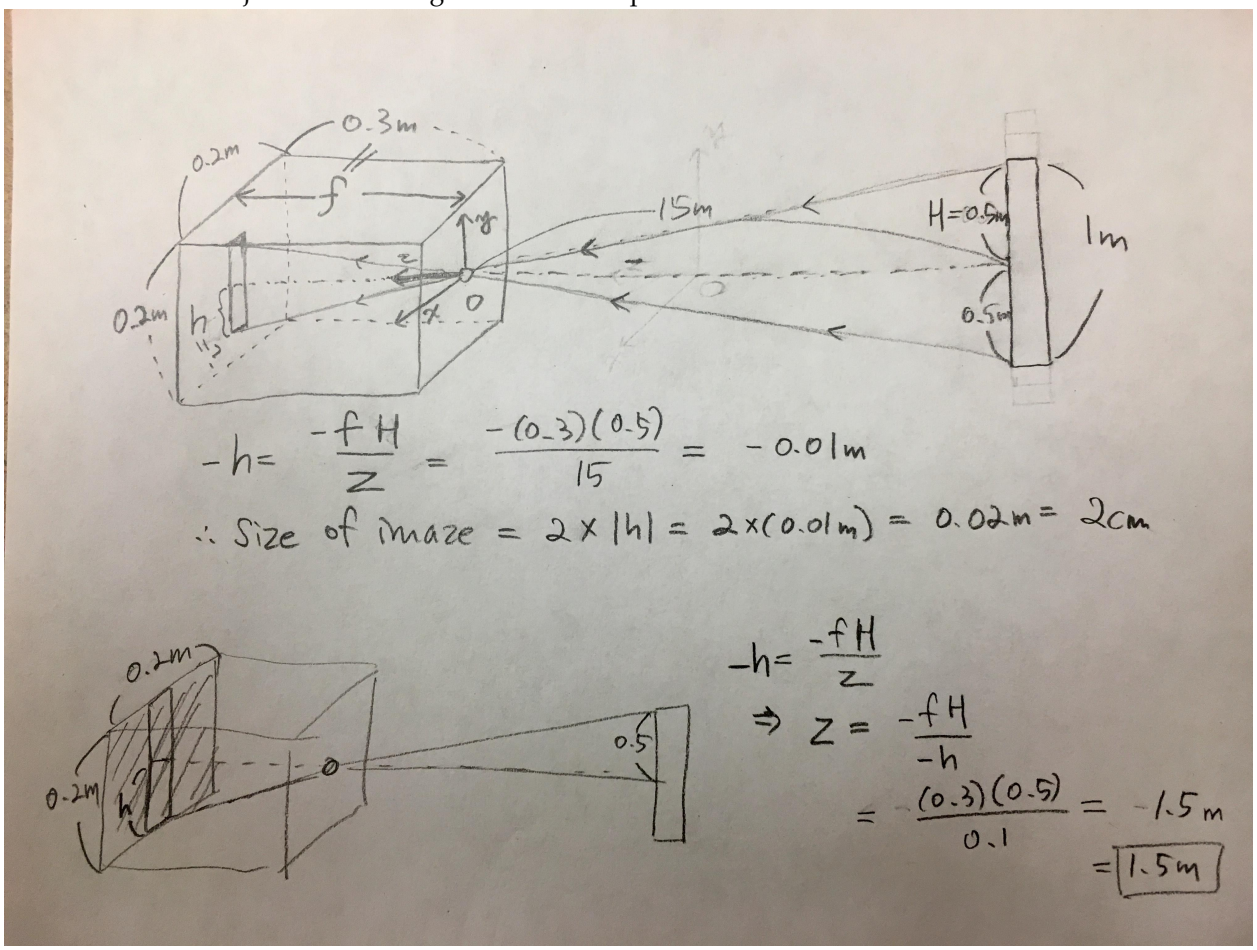
distance = np.sqrt(np.sum((np.array(u) - np.array(v))**2))

5. Given an array $a \in \mathbb{R}^{m \times n}$ write code to reshape it to a vector of size $nm \times 1$.

reshaped = np.ndarray.flatten(a, 'C')

2 Image formation

1. Illustration of the object and the image formed in the pinhole camera.



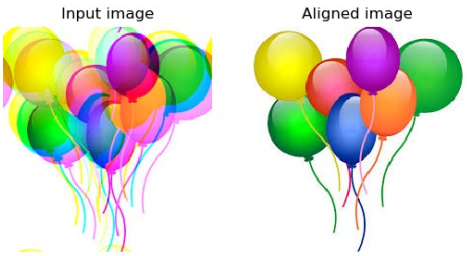
2. Calculations for the size of the object.
   2cm. (Explanation in the picture)

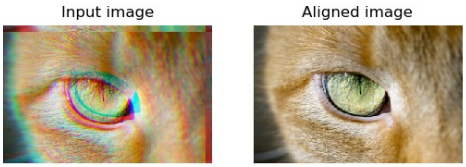
3. Calculations for the distance.
   1.5m (Explanation in the picture)

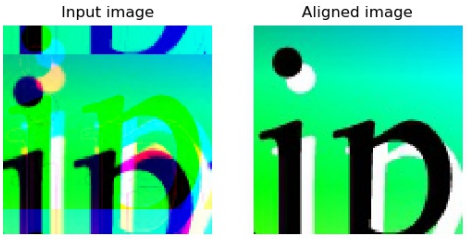
4. Time taken for the camera with a lens.
   0.1ms Because when the radius gets bigger by 10 times, because the whole are of the circle will be squared, which is 100 times, so it can absorb the same amount of light 100 times faster. So 10 ms become 0.1ms

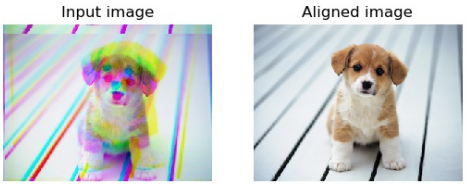
3 Aligning Prokudin-Gorskii images

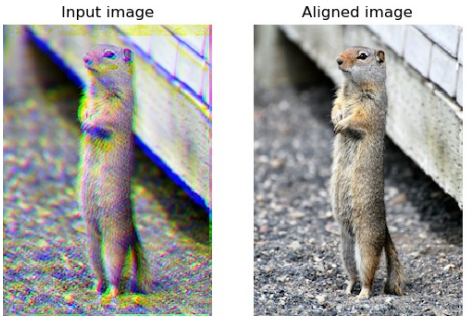
1. Outputs of `evalAlignment` on the toy images.

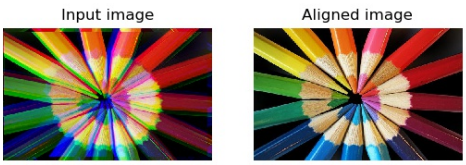


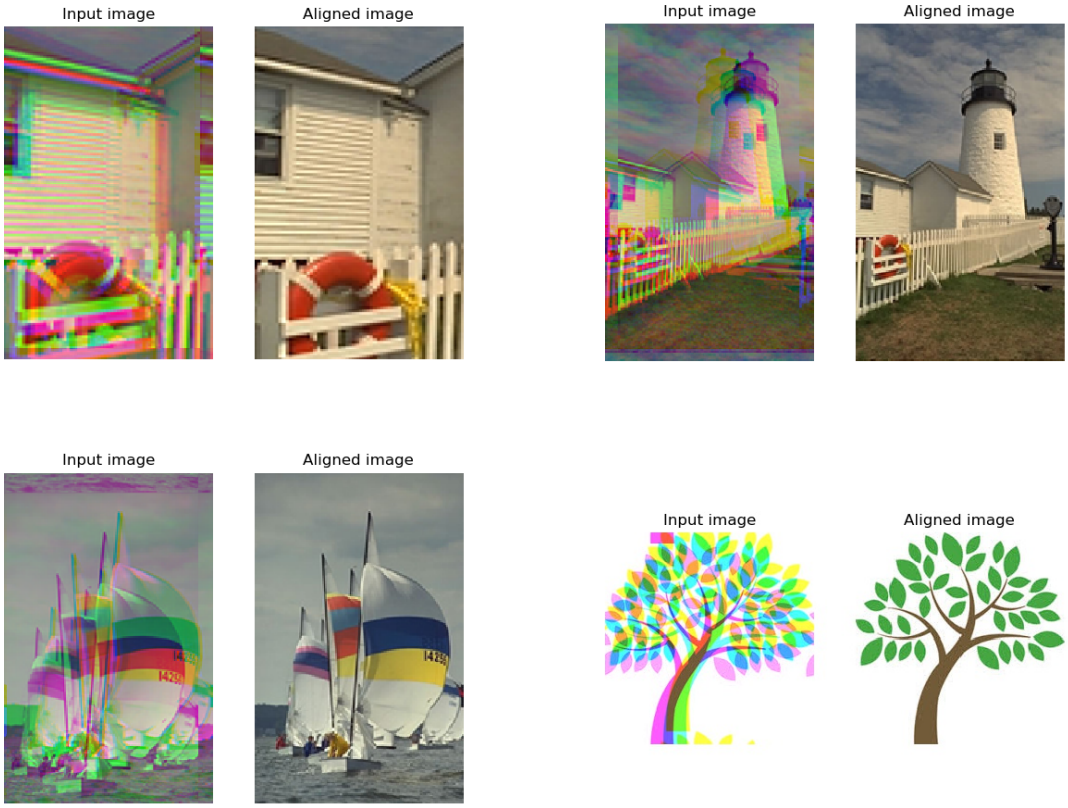








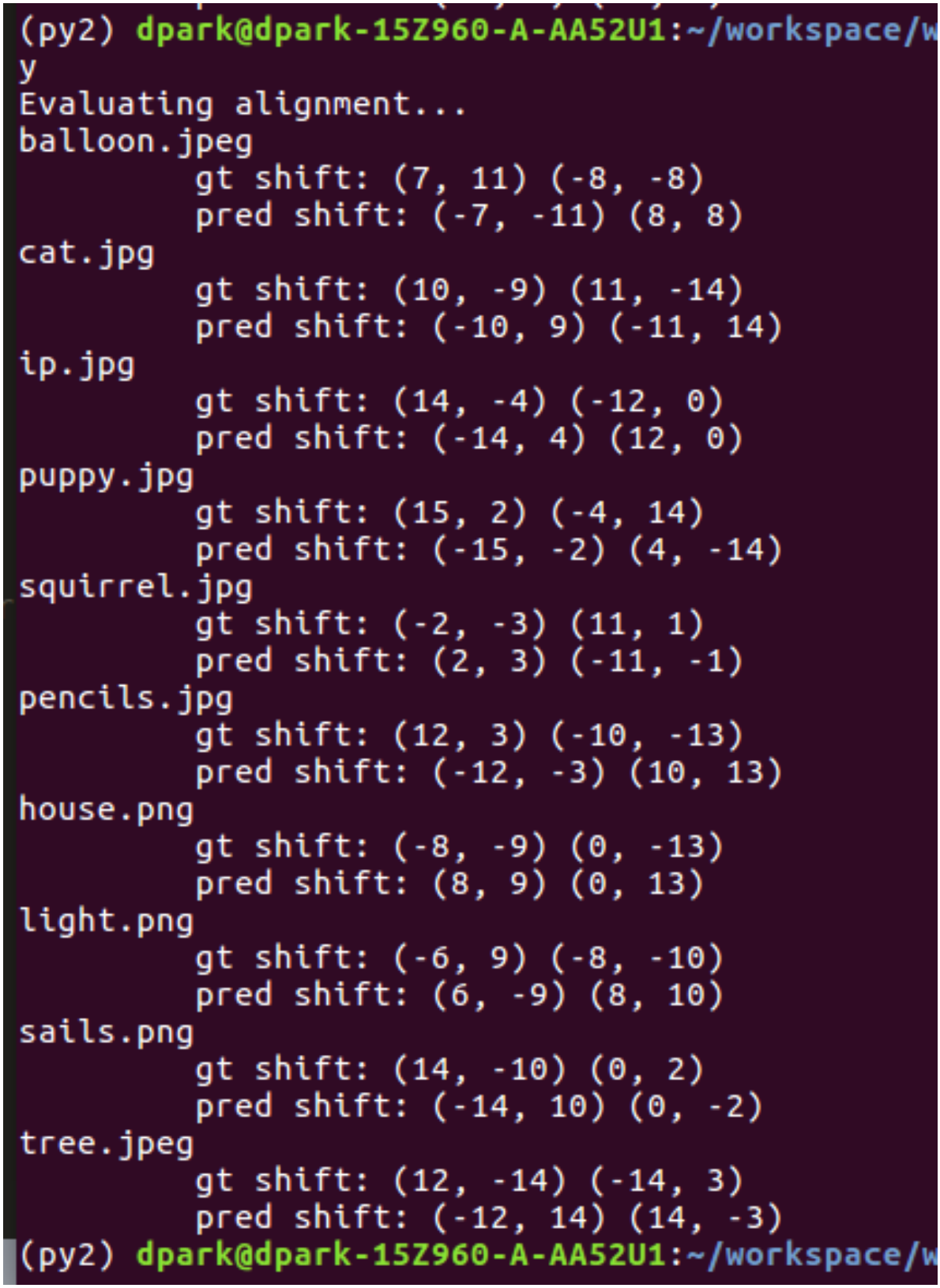




2. Output of `alignChannels.py` that shows the computed shifts as seen below.

```
(py2) dpark@dpark-15Z960-A-AA52U1:~/workspace/win10_workspace/CS370/Hw01/code$ python
Evaluating alignment...
balloon.jpeg
 gt shift: (7, 11) (-8, -8)
 pred shift: (-7, -11) (8, 8)
cat.jpg
 gt shift: (10, -9) (11, -14)
 pred shift: (-10, 9) (-11, 14)
ip.jpg
 gt shift: (14, -4) (-12, 0)
 pred shift: (-14, 4) (12, 0)
puppy.jpg
 gt shift: (15, 2) (-4, 14)
 pred shift: (-15, -2) (4, -14)
squirrel.jpg
 gt shift: (-2, -3) (11, 1)
 pred shift: (2, 3) (-11, -1)
pencils.jpg
 gt shift: (12, 3) (-10, -13)
 pred shift: (-12, -3) (10, 13)
house.png
 gt shift: (-8, -9) (0, -13)
 pred shift: (8, 9) (0, 13)
```

```
light.png
 gt shift: (-6, 9) (-8, -10)
 pred shift: (6, -9) (8, 10)
sails.png
 gt shift: (14, -10) (0, 2)
 pred shift: (-14, 10) (0, -2)
tree.jpeg
 gt shift: (12, -14) (-14, 3)
 pred shift: (-12, 14) (14, -3)
```



3. A figure that shows all the aligned color images. Only include the images from the Prokudin-Gorskii dataset in the original resolution. For example, do not take low-resolution screenshots of the outputs;

Instead save them using appropriate commands in Matlab and Python.

Figure 1: Aligned color images.

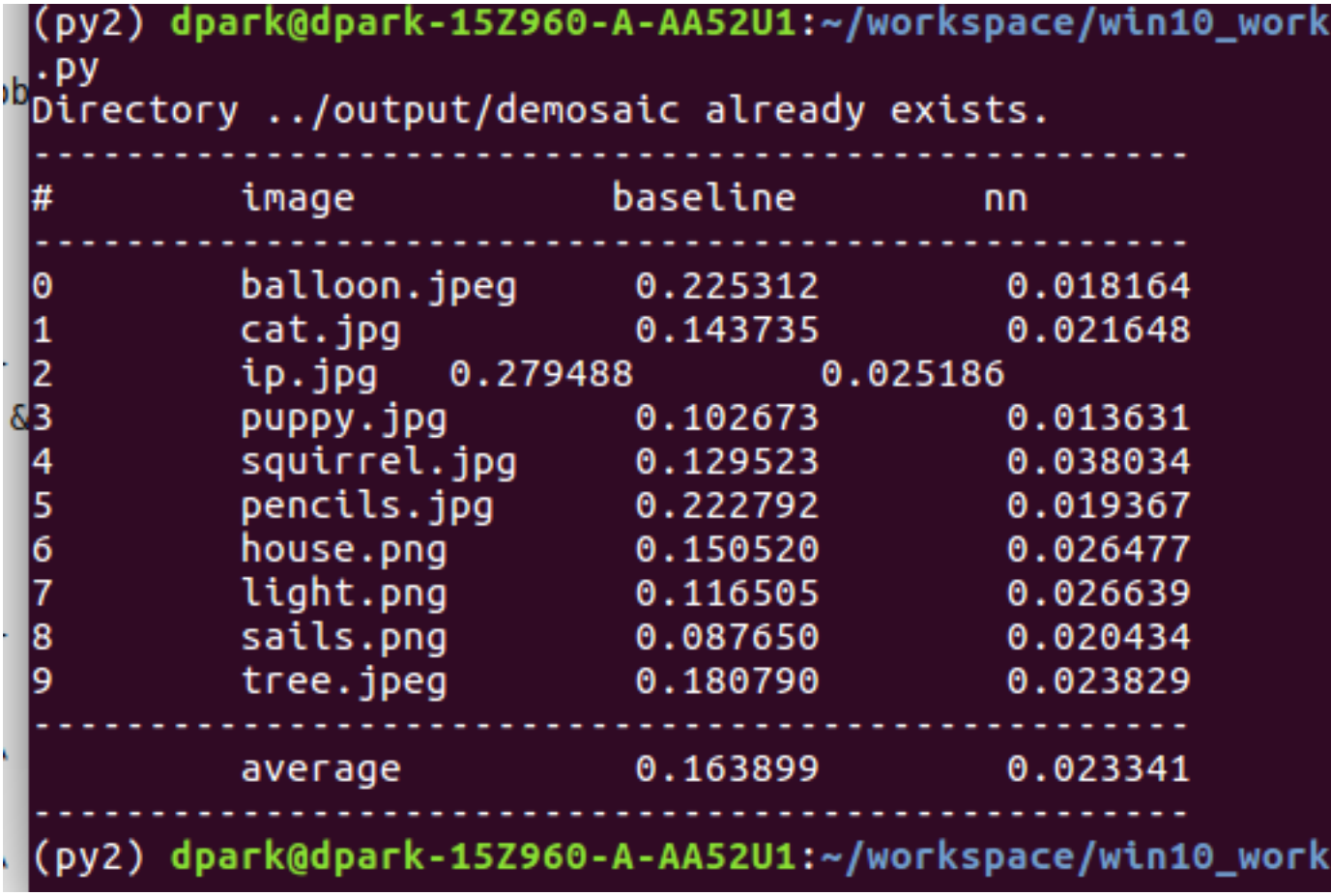
Output of alignProkudin.py

```
    (py2) dpark@dpark-15Z960-A-AA52U1:~/workspace/win10_workspace/CS370/Hw01/code$ python a
Directory ../output/prokudin-gorskii already exists.
00125v.jpg
 shift: G (-4, 1)  B (-9, -1)
00153v.jpg
 shift: G (-7, -2)  B (-14, 0)
00398v.jpg
 shift: G (-6, -1)  B (-11, -4)
00149v.jpg
 shift: G (-5, 0)  B (-9, -2)
00351v.jpg
 shift: G (-9, -1)  B (-13, -1)
01112v.jpg
 shift: G (-5, -1)  B (-5, -1)
```

4 Color image demosaicing

1. Errors of the nearest neighbor interpolation algorithm.

```
(py2) dpark@dpark-15Z960-A-AA52U1:~/workspace/win10_workspace/CS370/Hw01/code$ python
Directory ../output/demosaic already exists.
-----------------------------------------------
#   image   baseline  nn
-----------------------------------------------
0   balloon.jpeg   0.225312   0.018164
1   cat.jpg   0.143735   0.021648
2   ip.jpg   0.279488   0.025186
3   puppy.jpg   0.102673   0.013631
4   squirrel.jpg   0.129523   0.038034
5   pencils.jpg   0.222792   0.019367
6   house.png   0.150520   0.026477
7   light.png   0.116505   0.026639
8   sails.png   0.087650   0.020434
9   tree.jpeg   0.180790   0.023829
-----------------------------------------------
   average    0.163899   0.023341
-----------------------------------------------
```



2. A figure (e.g., Figure 2) that shows the images obtained after interpolation.

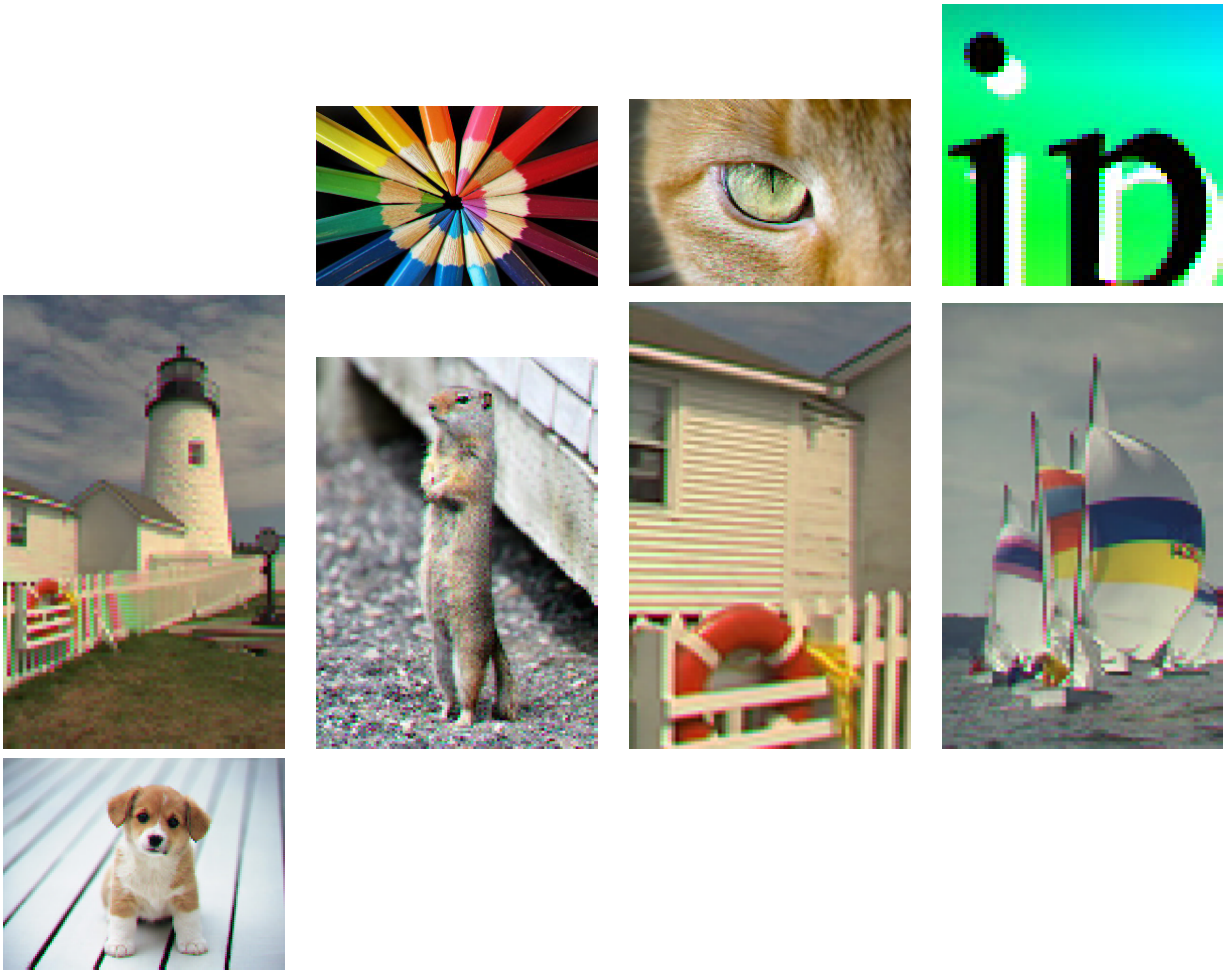
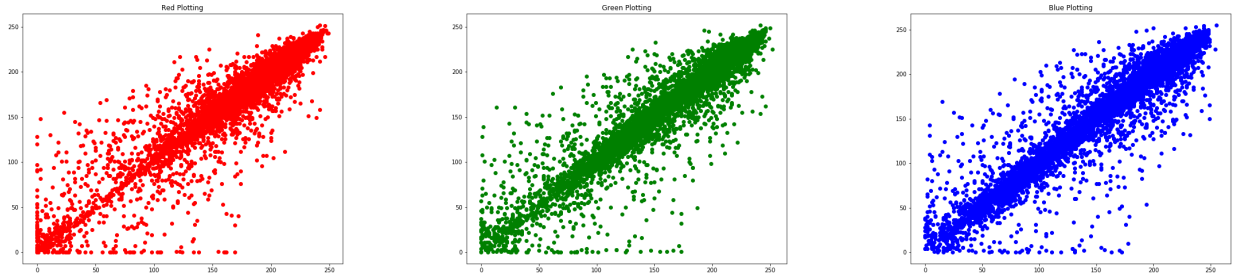


Figure 2: Demosaiced images using nearest neighbor interpolation.

I don't know why but nn-dmsc images for Balloon and Tree are not shoing on Latex. So I included screenshot of them here.

3. The three plots for the `puppy.jpg` image.



(a) red (b) green (c) blue

Figure 3: The value of pixels against the values of their neighbor.

What I observe: If the plotted graph showed very high correlation then our demosaic algorithm will work perfectly but there are some outliers on each channel so that we can not avoid losing some information by that errors.

5 Solution code

Include the source code for your solutions as seen below (only the files you implemented are necessary). In latex the command `verbatiminput{alignChannels.m}` allows you to include the code verbatim as seen below. Regardless of how you do this the main requirement is that the included code is readable (use proper formatting, variable names, etc.) A screenshot of your code works too provided you include a link to source files.

5..1 alignChannels.py

```
    # This code is part of:
#
#   CMPSCI 370: Computer Vision, Spring 2018
#   University of Massachusetts, Amherst
#   Instructor: Subhransu Maji
#
#   Homework 1

import numpy as np

def alignChannels(img, max_shift):

    # Check if image is big enough to do cropping for the better alignment
    if img.shape[0] > (max_shift[0]*20) and img.shape[1] > (max_shift[1]*20):
        # print("Image is big enough to do Cropping!!! for better alignments")
        img_aligned = img[max_shift[0]*2:-max_shift[0]*2, max_shift[1]*2:-max_shift[1]*2]
    else:
        # image is small, so no cropping.
        img_aligned = img[:,:,:]

    # Get a reference channel to compare when align
    red = img_aligned[:,:,0]
    # convert it to a 1D vector
    r_flat = red.flatten()

    # storage to record shifting numbers
    pred_shift = np.array([[0, 0], [0, 0]])

    # Compare: RED -> BLUE
    # search for all possible combination of shifts for one color channel
    max_dot_b = 0
    for i in range(-max_shift[0], max_shift[0]+1):
     for j in range(-max_shift[1], max_shift[1]+1):
            # get separate 2D matrix for a color
            blue = np.roll(img_aligned[:,:,1], [i, j], axis=[0,1])

            # convert the obtained 2D matrix into a flatten matrix so it becomes a 1D vecto
            b_flat = blue.flatten()

            # get a dot product(inner product) between two color channel vectors to check s
            new_dot = np.dot(r_flat, b_flat)

            # if found a better shift(smaller scalar value from dot product)
            if new_dot > max_dot_b:
             max_dot_b = new_dot
             pred_shift[0] = np.array([i, j])

    # Compare: RED -> GREEN
    # search for all possible combination of shifts for one color channel
    max_dot_g = 0
    for i in range(-max_shift[0], max_shift[0]+1):
     for j in range(-max_shift[1], max_shift[1]+1):
```

```
 # get separate 2D matrix for a color
 green = np.roll(img_aligned[:,:,2], [i, j], axis=[0,1])

 # convert the obtained 2D matrix into a flatten matrix so it becomes a 1D vector
 g_flat = green.flatten()

 # get a dot product(inner product) between two color channel vectors to check similari
 new_dot = np.dot(r_flat, g_flat)

 # if found a better shift(smaller scalar value from dot product)
 if new_dot > max_dot_g:
 max_dot_g = new_dot
 pred_shift[1] = np.array([i, j])

# align the image with predicted shifting numbers
img_aligned[:,:,1] = np.roll(img_aligned[:,:,1], [pred_shift[0][0], pred_shift[0][1]],
img_aligned[:,:,2] = np.roll(img_aligned[:,:,2], [pred_shift[1][0], pred_shift[1][1]],

return (img_aligned, pred_shift)
```

5..2 mosaicImage.py

```
    # This code is part of:
#
#   CMPSCI 370: Computer Vision, Spring 2018
#   University of Massachusetts, Amherst
#   Instructor: Subhransu Maji
#
#   Homework 1

import numpy as np

def mosaicImage(img):
    ''' Computes the mosaic of an image.

    mosaicImage computes the response of the image under a Bayer filter.

    Args:
        img: NxMx3 numpy array (image).

    Returns:
        NxM image where R, G, B channels are sampled according to RGRG in the
        top left.
    '''

    image_height, image_width, num_channels = img.shape
    assert(num_channels == 3) #Checks if it is a color image

    # make an empty matrix
    result = np.empty((image_height, image_width))

    # take red channel
    result[::2, ::2] = img[::2, ::2, 0]

    # take blue channel
    result[1::2, 1::2] = img[1::2, 1::2, 1]

    # take green channel
    result[1::2, 0::2] = img[1::2, 0::2, 2]
    result[0::2, 1::2] = img[0::2, 1::2, 2]

    return result
```

5..3 demosaicImage.py

```
    # This code is part of:
#
#   CMPSCI 370: Computer Vision, Spring 2018
#   University of Massachusetts, Amherst
#   Instructor: Subhransu Maji
#
#   Homework 1

import numpy as np

def demosaicImage(image, method):
    ''' Demosaics image.

    Args:
        img: np.array of size NxM.
        method: demosaicing method (baseline or nn).

    Returns:
        Color image of size NxMx3 computed using method.
    '''

    if method.lower() == "baseline":
        return demosaicBaseline(image.copy())
    elif method.lower() == 'nn':
        return demosaicNN(image.copy()) # Implement this
    else:
        raise ValueError("method {} unkown.".format(method))


def demosaicBaseline(img):
    '''Baseline demosaicing.

    Replaces missing values with the mean of each color channel.

    Args:
        img: np.array of size NxM.

    Returns:
        Color image of sieze NxMx3 demosaiced using the baseline
        algorithm.
    '''
    mos_img = np.tile(img[:, :, np.newaxis], [1, 1, 3])
    image_height, image_width = img.shape

    red_values = img[0:image_height:2, 0:image_width:2]
    mean_value = red_values.mean()
    mos_img[:, :, 0] = mean_value
    mos_img[0:image_height:2, 0:image_width:2, 0] = img[0:image_height:2, 0:image_width:2]

    blue_values = img[1:image_height:2, 1:image_width:2]
    mean_value = blue_values.mean()
    mos_img[:, :, 2] = mean_value
```

```
    mos_img[1:image_height:2, 1:image_width:2, 2] = img[1:image_height:2, 1:image_width:2]

    mask = np.ones((image_height, image_width))
    mask[0:image_height:2, 0:image_width:2] = -1
    mask[1:image_height:2, 1:image_width:2] = -1
    green_values = mos_img[mask > 0]
    mean_value = green_values.mean()

    green_channel = img
    green_channel[mask < 0] = mean_value
    mos_img[:, :, 1] = green_channel

    return mos_img


def demosaicNN(img):
    '''Nearest neighbor demosaicing.

    Args:
        img: np.array of size NxM.

    Returns:
        Color image of size NxMx3 demosaiced using the nearest neighbor
        algorithm.
    '''

    # Check if image has odd height or width
    image_height, image_width = img.shape
    is_odd_height = 0 if image_height % 2 == 0 else 1
    is_odd_width = 0 if image_width % 2 == 0 else 1

    # new height and width
    nH = image_height - 1 if is_odd_height == 1 else image_height
    nW = image_width - 1 if is_odd_width == 1 else image_width

    # empty array for return
    result = np.empty((image_height, image_width, 3))


    ### RED ###

    # 1. retrieve original R value
    # Position: X O
    #           O O
    result[:nH:2, :nW:2, 0] = img[:nH:2, :nW:2]

    # 2. Filling in missing values
    result[:nH:2, 1:nW:2, 0] = img[:nH:2, :nW:2] # upper right - copy from upper left
    result[1:nH:2, 1:nW:2, 0] = img[:nH:2, :nW:2] # lower right - copy from upper left
    result[1:nH:2, :nW:2, 0] = img[:nH:2, :nW:2] # lower left - copy from upper left
    # 3. Handle Egde Cases
    if is_odd_height:
        result[-1, ::, 0] = result[-2, ::, 0]
    if is_odd_width:
```

```
    result[:, -1, 0] = result[:, -2, 0]


### BLUE ###
# 1. retrieve original B value
# Position: O O
#           O X
result[1:nH:2, 1:nW:2, 1] = img[1:nH:2, 1:nW:2]

# 2. filling in missing values
result[1:nH:2, 0:nW:2, 1] = img[1:nH:2, 1:nW:2] # lower left - copy from lower right
result[:nH:2, :nW:2, 1] = img[1:nH:2, 1:nW:2] # upper left - copy from lower right
result[:nH:2, 1:nW:2, 1] = img[1:nH:2, 1:nW:2] # upper right - copy from lower right
# 3. Handle Edge Cases
if is_odd_height:
    result[-1, ::, 1] = result[-2, ::, 1]
if is_odd_width:
    result[::, -1, 1] = result[::, -2, 1]


### GREEN ###
# 1. retrieve original B value
# Position: O O
#           X O
result[1:nH:2, 0:nW:2, 2] = img[1:nH:2, 0:nW:2]
# Position: O X
#           O O
result[0:nH:2, 1:nW:2, 2] = img[0:nH:2, 1:nW:2]
# 2. filling in missing values
result[:nH:2, :nW:2, 2] = img[:nH:2, 1:nW:2] # upper left - copy from upper right
result[1:nH:2, 1:nW:2, 2] = img[1:nH:2, :nW:2] # lower right - copy from lower left
# 3. Handle edge cases
if is_odd_height:
    result[-1, ::, 2] = result[-2, ::, 2]
if is_odd_width:
    result[::, -1, 2] = result[::, -2, 2]

return result
```