CS 445: Computational Photography

Programming Project #3: Gradient Domain Fusion

In [1]:

```
import cv2
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import os
from random import random
import time
import scipy
import scipy.sparse.linalg
import utils
```

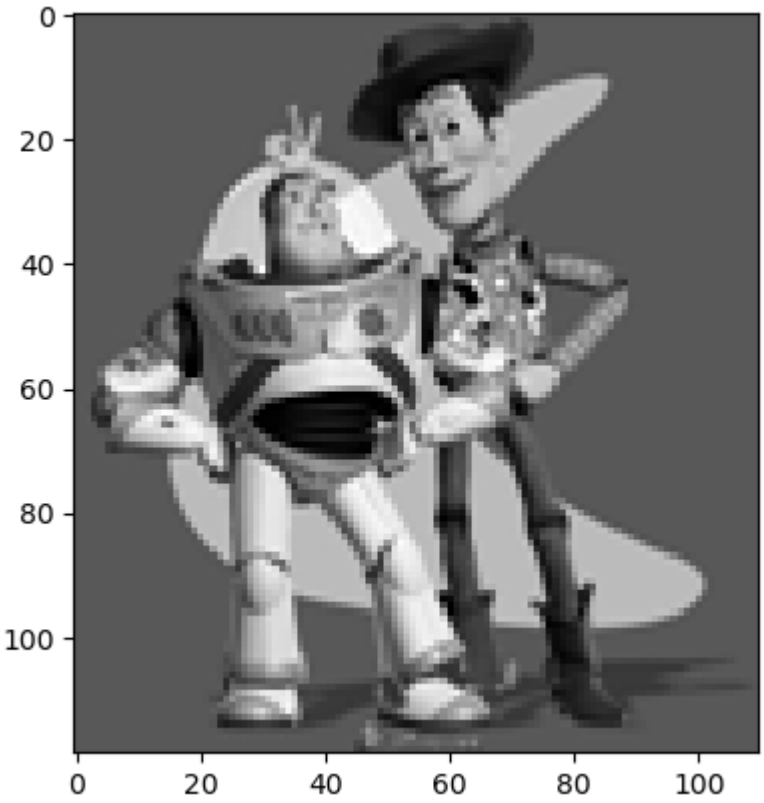
Part 1 Toy Problem (20 pts)

In [74]:

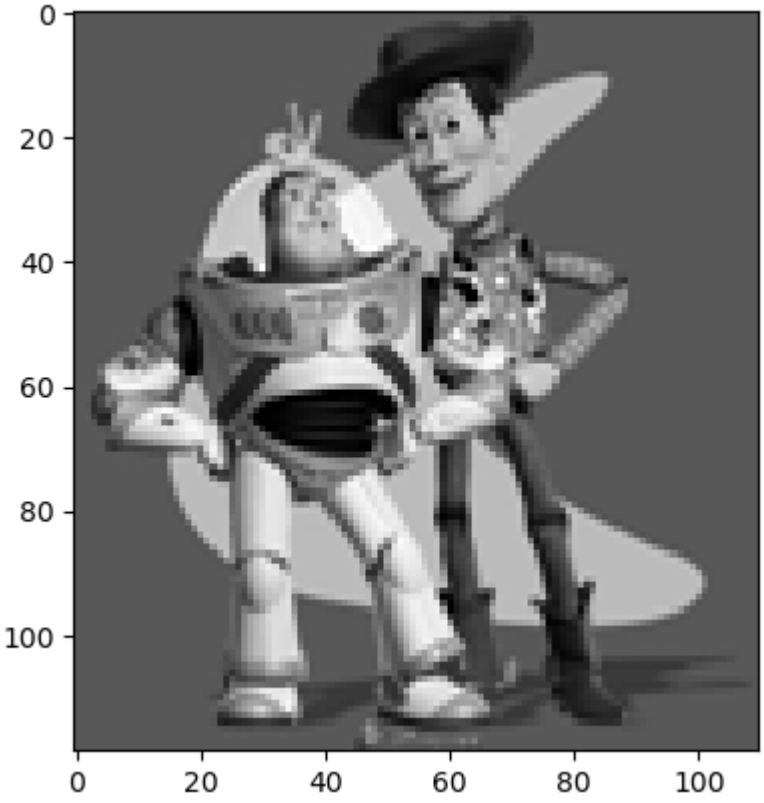
```python
def toy_reconstruct(img):
    """
    The implementation for gradient domain processing is not complicat
    1. minimize (v(x+1,y)-v(x,y) - (s(x+1,y)-s(x,y)))^2
    2. minimize (v(x,y+1)-v(x,y) - (s(x,y+1)-s(x,y)))^2
    Note that these could be solved while adding any constant value to
    3. minimize (v(1,1)-s(1,1))^2

    :param toy_img: numpy.ndarray
    """

    im_h, im_w = img.shape
    im2var = np.arange(im_h * im_w).reshape(im_h, im_w)

    neq = im_h * (im_w-1) + (im_h-1) * im_w + 1
    A = scipy.sparse.lil_matrix((neq, im_h * im_w), dtype='double')
    b = np.zeros((neq, 1), dtype='double')

    e = 0

    for y in range(im_w):
        for x in range(im_h - 1):
            A[e, im2var[x+1, y]] = 1
            A[e, im2var[x, y]] = -1
            b[e] = img[x+1, y] - img[x, y]
            e += 1


    for y in range(im_w - 1):
        for x in range(im_h):
            A[e, im2var[x, y+1]] = 1
            A[e, im2var[x, y]] = -1
            b[e] = img[x, y+1] - img[x, y]
            e += 1

    A[e, im2var[0, 0]] = 1
    b[e] = img[0, 0]

    v = scipy.sparse.linalg.lsqr(A.tocsr(), b) # solve w/ csr

    im_re = np.zeros((im_h, im_w), dtype='double')
    for x in range(im_h):
        for y in range(im_w):
            im_re[x, y] = v[0][im2var[x, y]]

    return im_re

```

In [344]:

```
1 toy_img = cv2.cvtColor(cv2.imread('samples/toy_problem.png'), cv2.COLO
2 plt.imshow(toy_img, cmap="gray")
3 plt.show()
4
5 im_out = toy_reconstruct(toy_img)
6 plt.imshow(im_out, cmap="gray")
7 plt.show()
8 print("Max error is: ", np.sqrt(((im_out - toy_img)**2).max()))
```



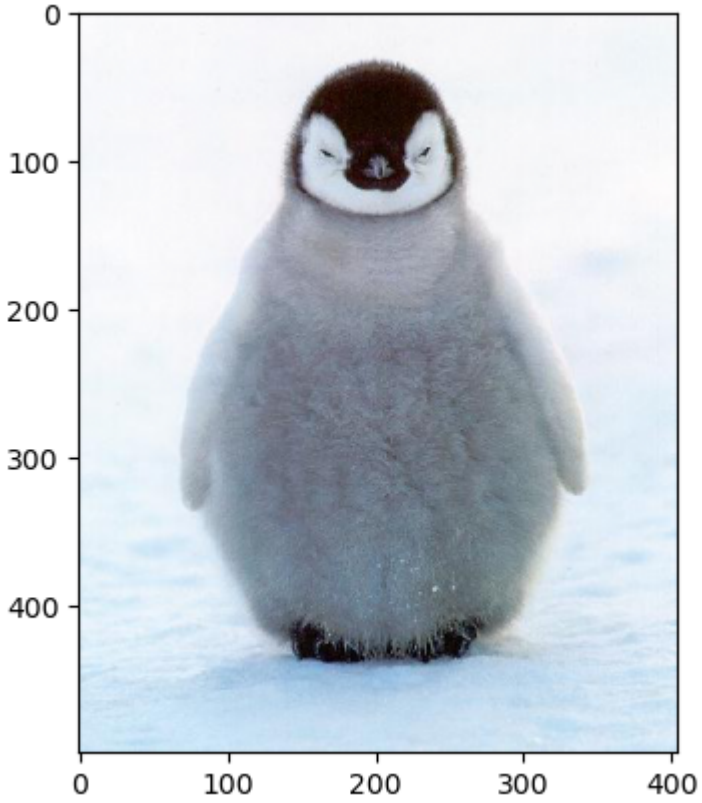
Pre

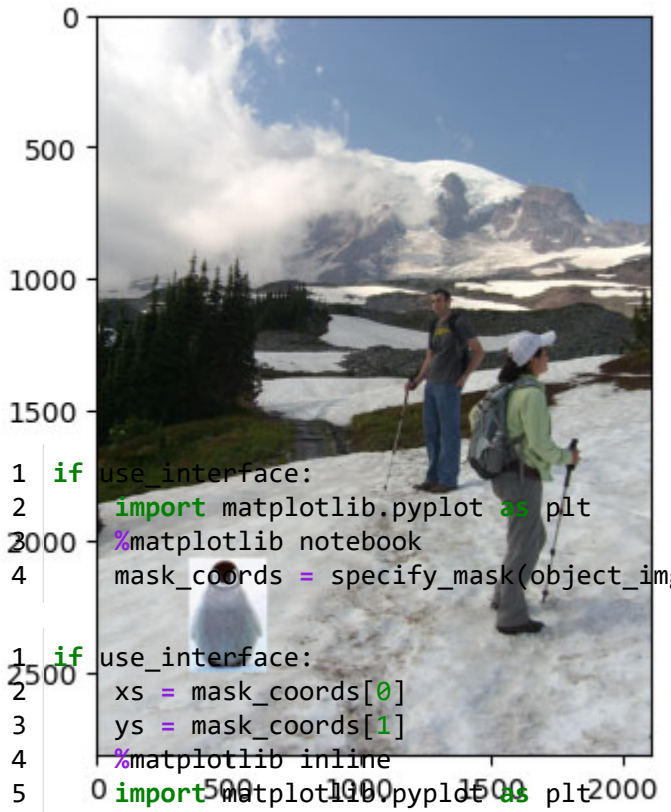



```
Max error is:  8.07367729038777e-06
```

In [220]:

```
background_img = cv2.cvtColor(cv2.imread('samples/im2.JPG'), cv2.COLOR
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('samples/penguin-chick.jpeg'), cv
plt.imshow(object_img)
plt.show()

use_interface = False  # set to true if you want to use the interface
if not use_interface:
    xs = (65, 359, 359, 65)
    ys = (24, 24, 457, 457)
    object_mask = utils.get_mask(ys, xs, object_img)
    bottom_center = (500, 2500) # (x,y)

    object_img, object_mask = utils.crop_object_img(object_img, object
    bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
    plt.imshow(utils.get_combined_img(background_img, object_img, obje
```





In [149]:
```
if use_interface:
    import matplotlib.pyplot as plt
    %matplotlib notebook
    mask_coords = specify_mask(object_img)
```

In [150]:
```
if use_interface:
    xs = mask_coords[0]
    ys = mask_coords[1]
    %matplotlib inline
    import matplotlib.pyplot as plt
    plt.figure()
    object_mask = get_mask(ys, xs, object_img)
```

In [151]:

```
if use_interface:
    %matplotlib notebook
    import matplotlib.pyplot as plt
    bottom_center = specify_bottom_center(background_img)
    %matplotlib inline
    import matplotlib.pyplot as plt

    object_img, object_mask = utils.crop_object_img(object_img, object
    bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
    plt.imshow(utils.get_combined_img(background_img, object_img, obje
```

Part 2 Poisson Blending (50 pts)

In [52]:

```python
def poisson_blend(object_img, object_mask, bg_img, bg_ul):
    """
    Returns a Poisson blended image with masked object_img over the bg
    Can be implemented to operate on a single channel or multiple chan
    :param object_img: the image containing the foreground object
    :param object_mask: the mask of the foreground object in object_im
    :param background_img: the background image
    :param bg_ul: position (row, col) in background image correspondin
    """

    # extract the background patch that overlaps with the aligned obje
    bg = bg_img.copy()
    x, y = bg_ul[0], bg_ul[1]
    h, w = object_img.shape
    img = bg[x:x+h, y:y+w]

    im_h, im_w = img.shape
    im2var = np.arange(im_h * im_w).reshape(im_h, im_w)

    # for each pixel where mask == 1 4 eqns else 1 per pixel
    nz = np.count_nonzero(object_mask == 1)
    neq = 4 * nz + len(object_mask) - nz

    # initialize linear equation matrices A and b
    A = scipy.sparse.lil_matrix((neq, im_h * im_w), dtype='double')
    b = np.zeros((neq, 1), dtype='double')

    # calculate poisson blending
    e = 0

    for y in range(w):
        for x in range(h - 1):
            e += 1
            if object_mask[x, y] == 1:
                A[e, im2var[x+1, y]] = 1
                A[e, im2var[x, y]] = -1
                b[e] = object_img[x+1, y] - object_img[x, y]
            else:
                A[e, im2var[x+1, y]] = 1
                b[e] = object_img[x+1, y] - object_img[x, y] + img[x,

    for y in range(w - 1):
        for x in range(h):
            e += 1
            if object_mask[x, y] == 1:
                A[e, im2var[x, y+1]] = 1
                A[e, im2var[x, y]] = -1
                b[e] = object_img[x, y+1] - object_img[x, y]
            else:
                A[e, im2var[x, y+1]] = 1
                b[e] = object_img[x, y+1] - object_img[x, y] + img[x,

    v = scipy.sparse.linalg.lsqr(A.tocsr(), b) # solve w/ csr

    # modify the patch
```

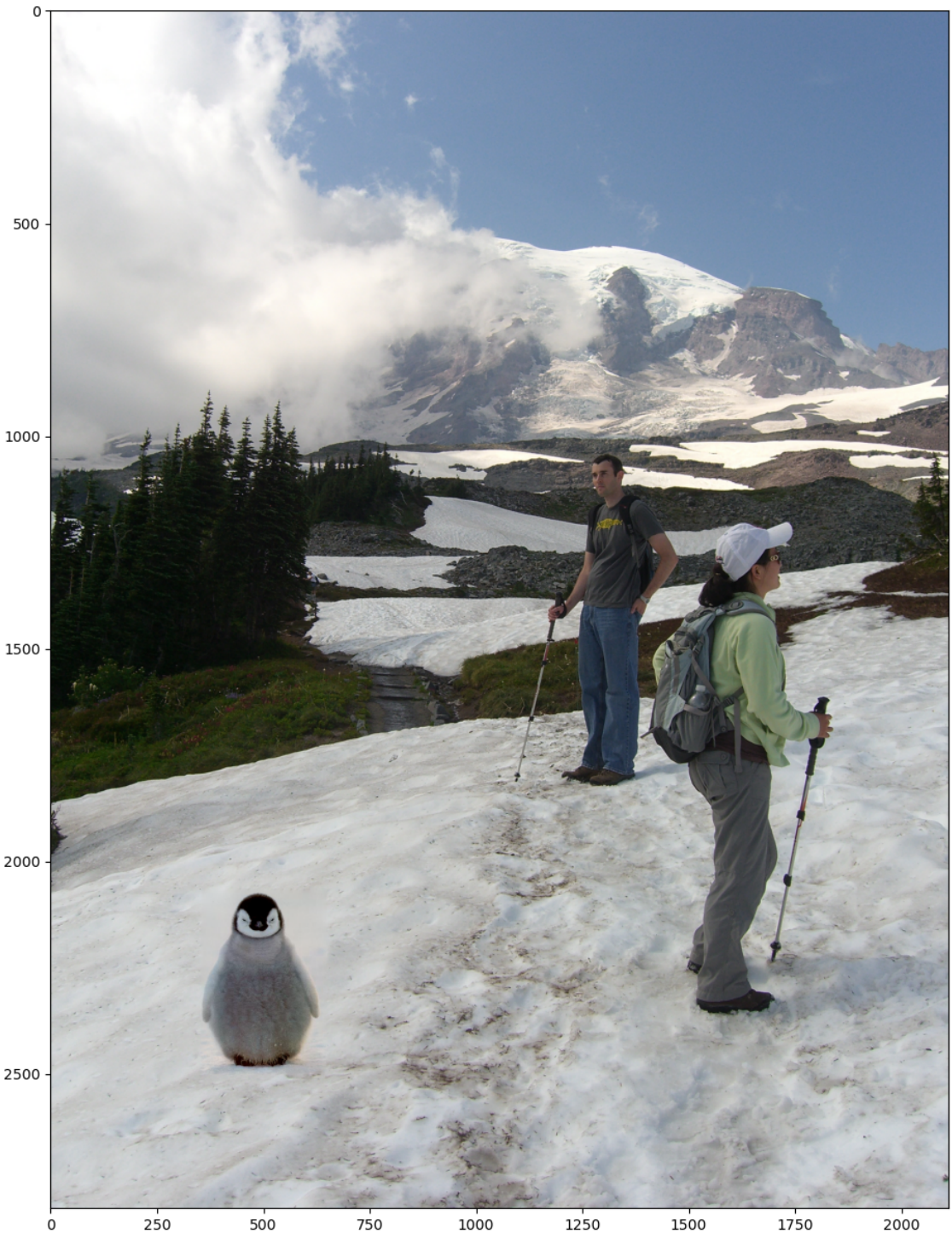
```
    for x in range(im_h):
        for y in range(im_w):
            img[x, y] = v[0][im2var[x, y]]

    # copy the patch back into the background image
    x, y = bg_ul[0], bg_ul[1]
    bg_img[x:x+im_h, y:y+im_w] = img

    return bg_img
```

In [429]:

```
im_blend = np.zeros(background_img.shape)
for b in np.arange(3):
    im_blend[:,:,b] = poisson_blend(object_img[:,:,b], object_mask, ba

plt.figure(figsize=(15,15))
plt.imshow(im_blend)
```

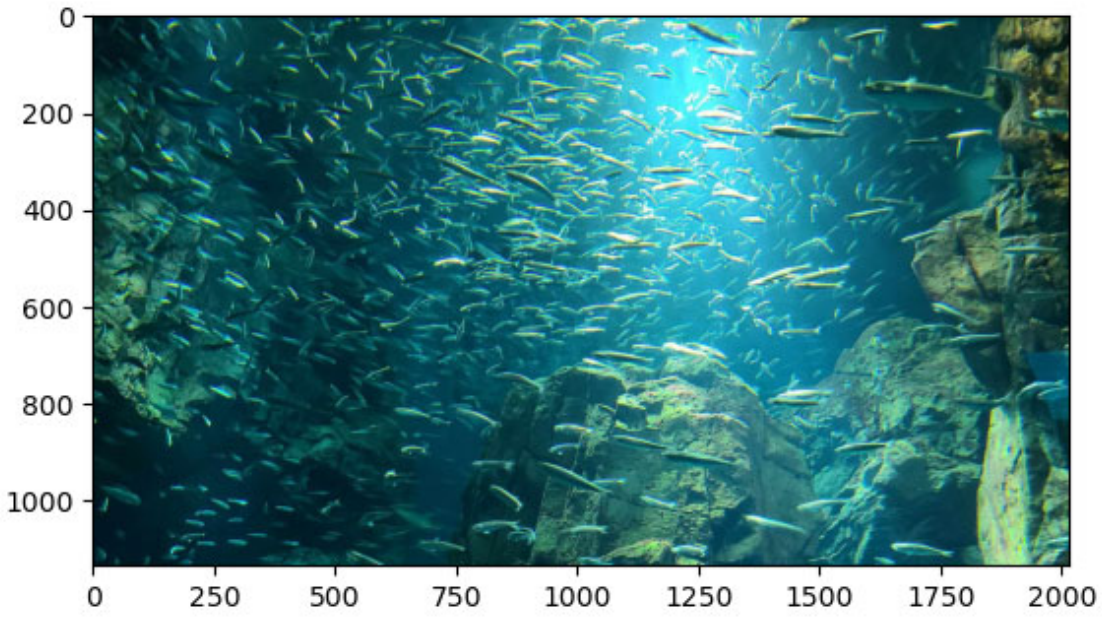
```
Clipping input data to the valid range for imshow with RGB data ([0..1] f
or floats or [0..255] for integers).
```

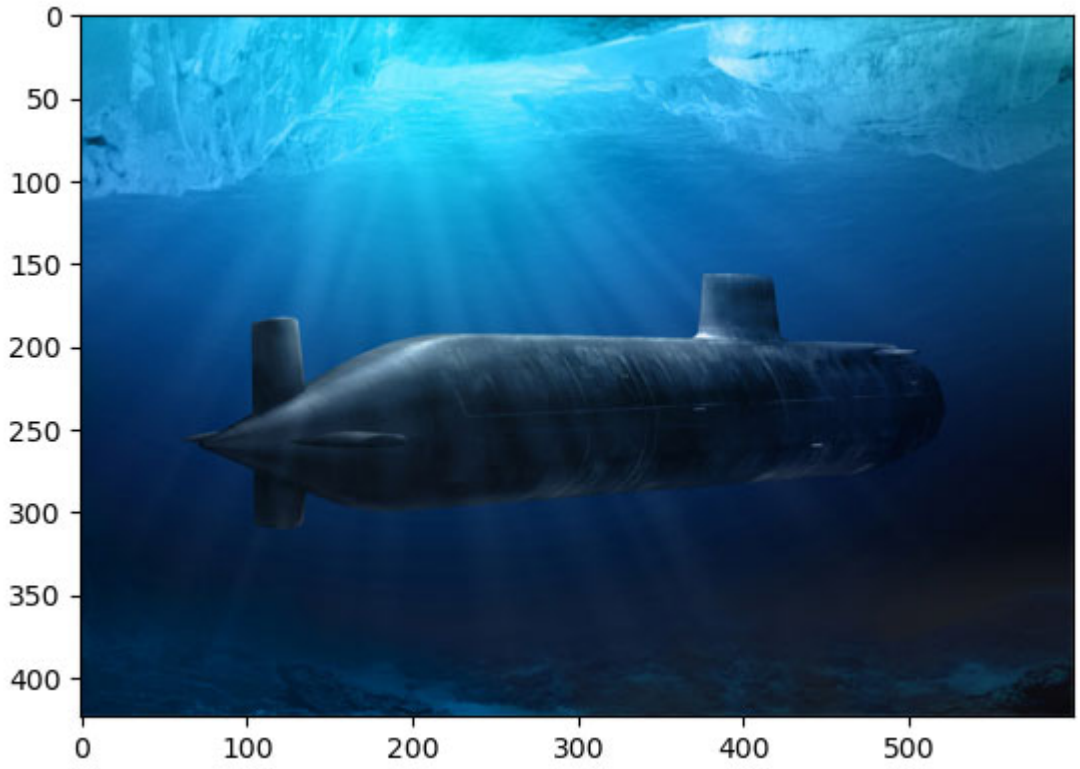
Out[429]: <matplotlib.image.AxesImage at 0x1aff196c2c8>



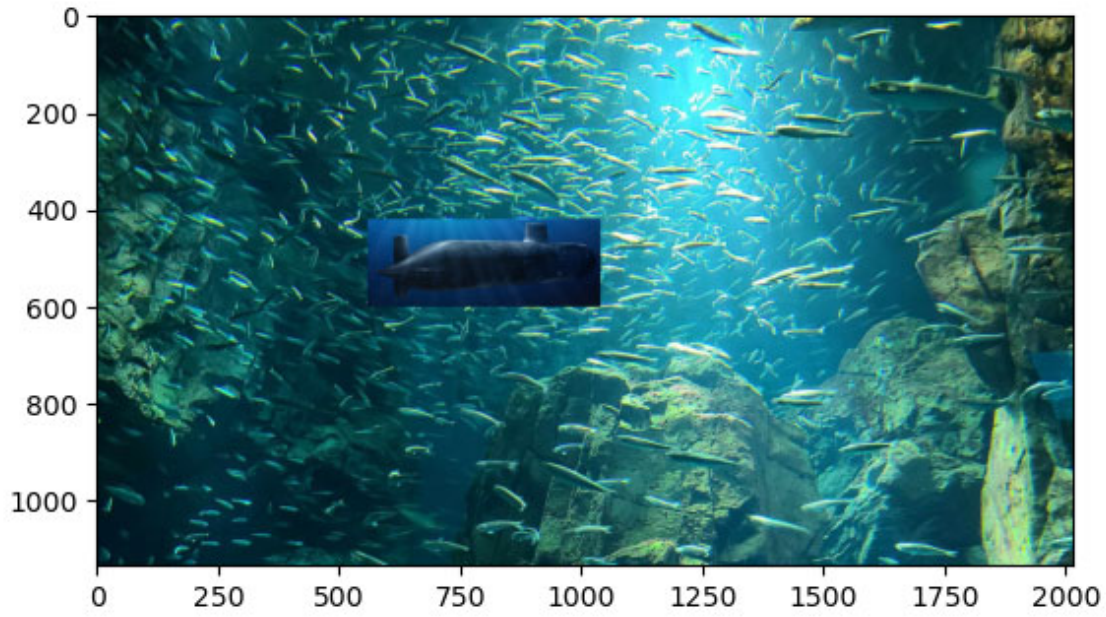
In [440]:

```
background_img = cv2.cvtColor(cv2.imread('aquarium.JPG'), cv2.COLOR_BG
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('submarine.JPG'), cv2.COLOR_BGR2R
plt.imshow(object_img)
plt.show()

xs = (50, 530, 530, 50)
ys = (150, 150, 330, 330)
object_mask = utils.get_mask(ys, xs, object_img)
bottom_center = (800, 600) # (x,y)

object_img, object_mask = utils.crop_object_img(object_img, object_mas
bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
plt.imshow(utils.get_combined_img(background_img, object_img, object_m
```





Out[440]: <matplotlib.image.AxesImage at 0x1afbde8aac8>



In [441]:

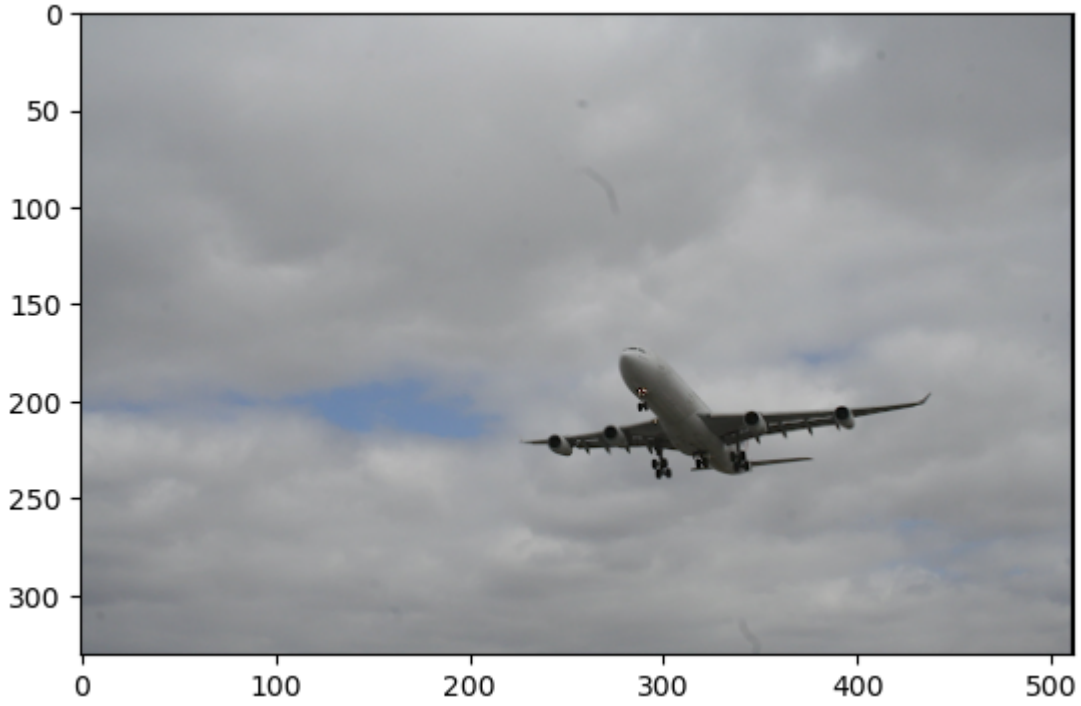
```
im_blend = np.zeros(background_img.shape)
for b in np.arange(3):
    im_blend[:,:,b] = poisson_blend(object_img[:,:,b], object_mask, ba

plt.figure(figsize=(15,15))
plt.imshow(im_blend)
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] f
or floats or [0..255] for integers).
```

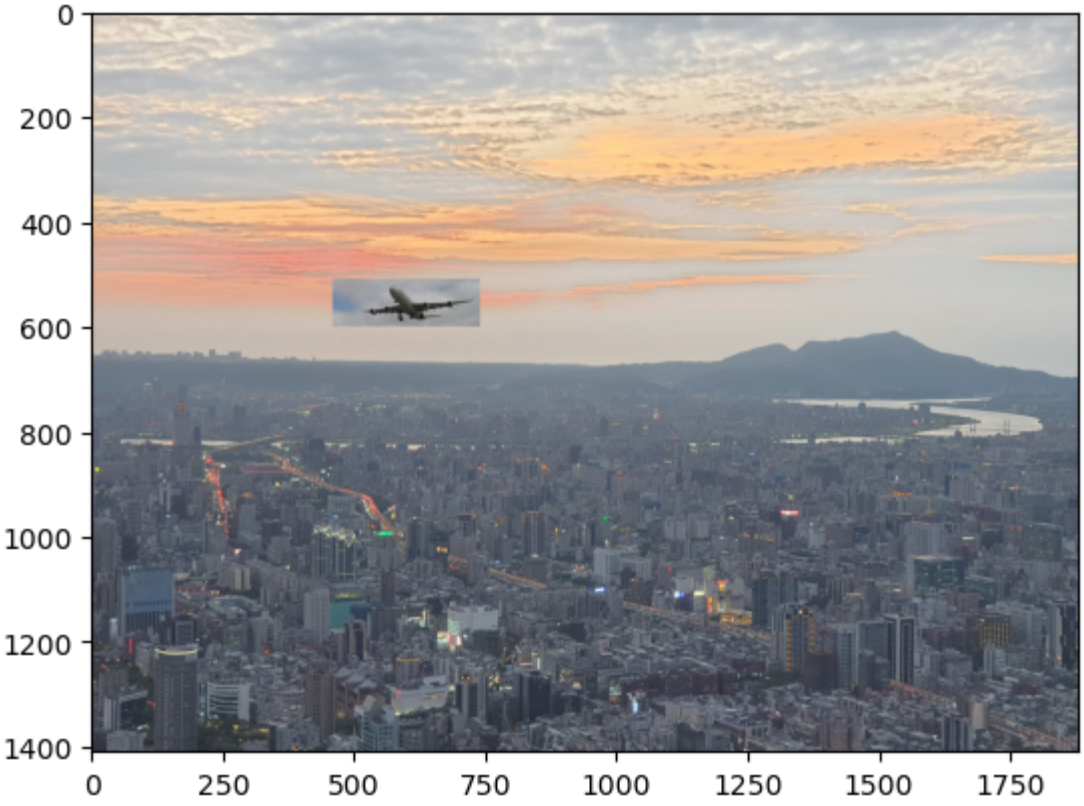
Out[441]: <matplotlib.image.AxesImage at 0x1af97807888>

In [451]:

```
background_img = cv2.cvtColor(cv2.imread('101.PNG'), cv2.COLOR_BGR2RGB
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('plane.PNG'), cv2.COLOR_BGR2RGB).
plt.imshow(object_img)
plt.show()

xs = (170, 450, 450, 170)
ys = (160, 160, 250, 250)
object_mask = utils.get_mask(ys, xs, object_img)
bottom_center = (600, 600) # (x,y)

object_img, object_mask = utils.crop_object_img(object_img, object_mas
bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
plt.imshow(utils.get_combined_img(background_img, object_img, object_m
```



Out[451]: <matplotlib.image.AxesImage at 0x1afdc46d608>



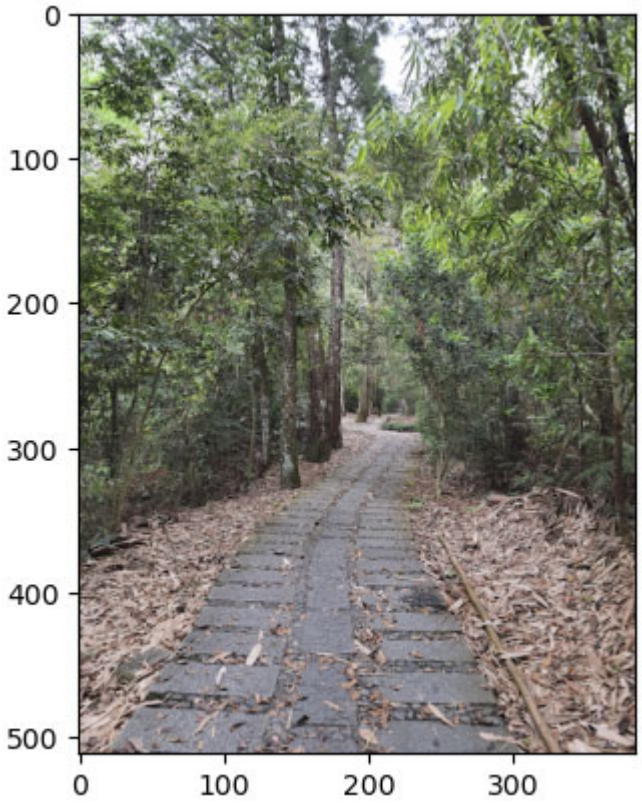
In [452]:

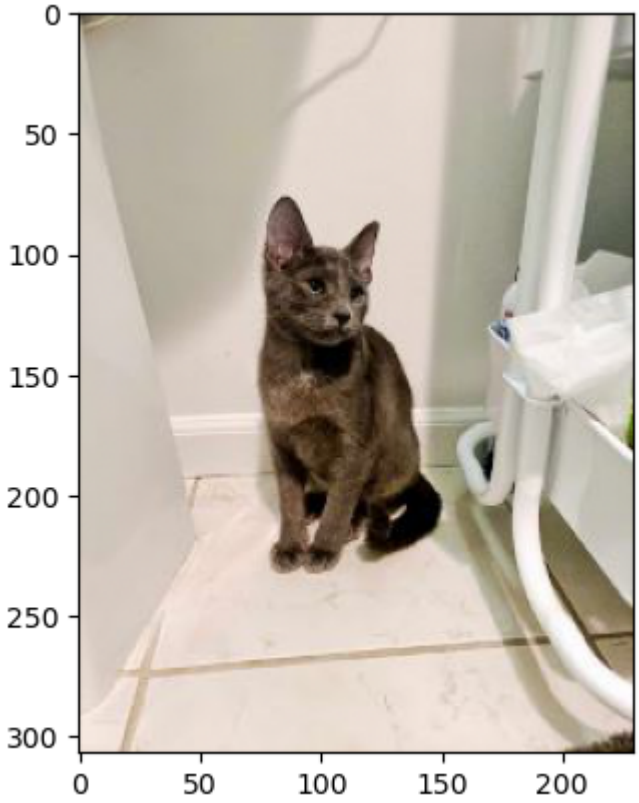
```
im_blend = np.zeros(background_img.shape)
for b in np.arange(3):
    im_blend[:,:,b] = poisson_blend(object_img[:,:,b], object_mask, ba

plt.figure(figsize=(15,15))
plt.imshow(im_blend)
```

Out[452]: <matplotlib.image.AxesImage at 0x1aff1b58848>

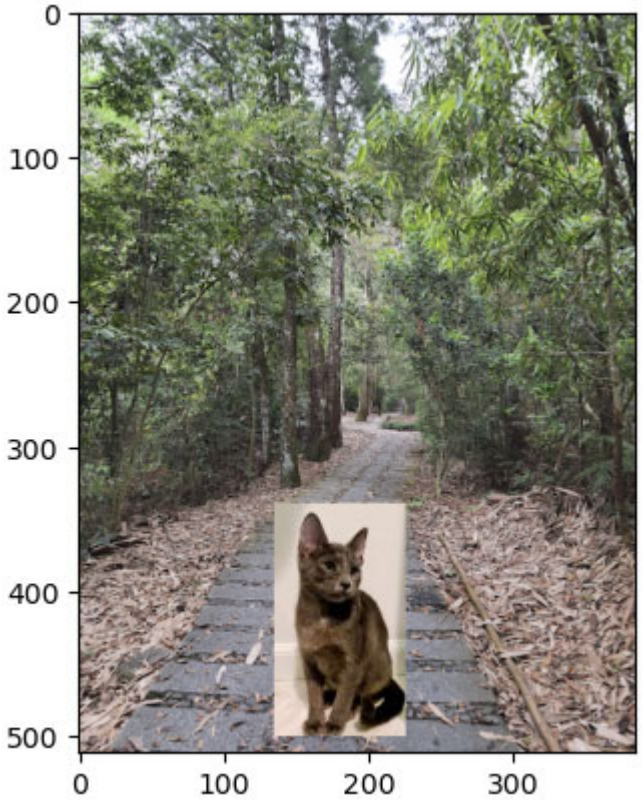
In [472]:

```
background_img = cv2.cvtColor(cv2.imread('path.PNG'), cv2.COLOR_BGR2RG
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('misha.JPG'), cv2.COLOR_BGR2RGB).
plt.imshow(object_img)
plt.show()

xs = (60, 150, 150, 60)
ys = (70, 70, 230, 230)
object_mask = utils.get_mask(ys, xs, object_img)
bottom_center = (180, 500) # (x,y)

object_img, object_mask = utils.crop_object_img(object_img, object_mas
bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
plt.imshow(utils.get_combined_img(background_img, object_img, object_m
```





Out[472]: <matplotlib.image.AxesImage at 0x1afbcf52d88>

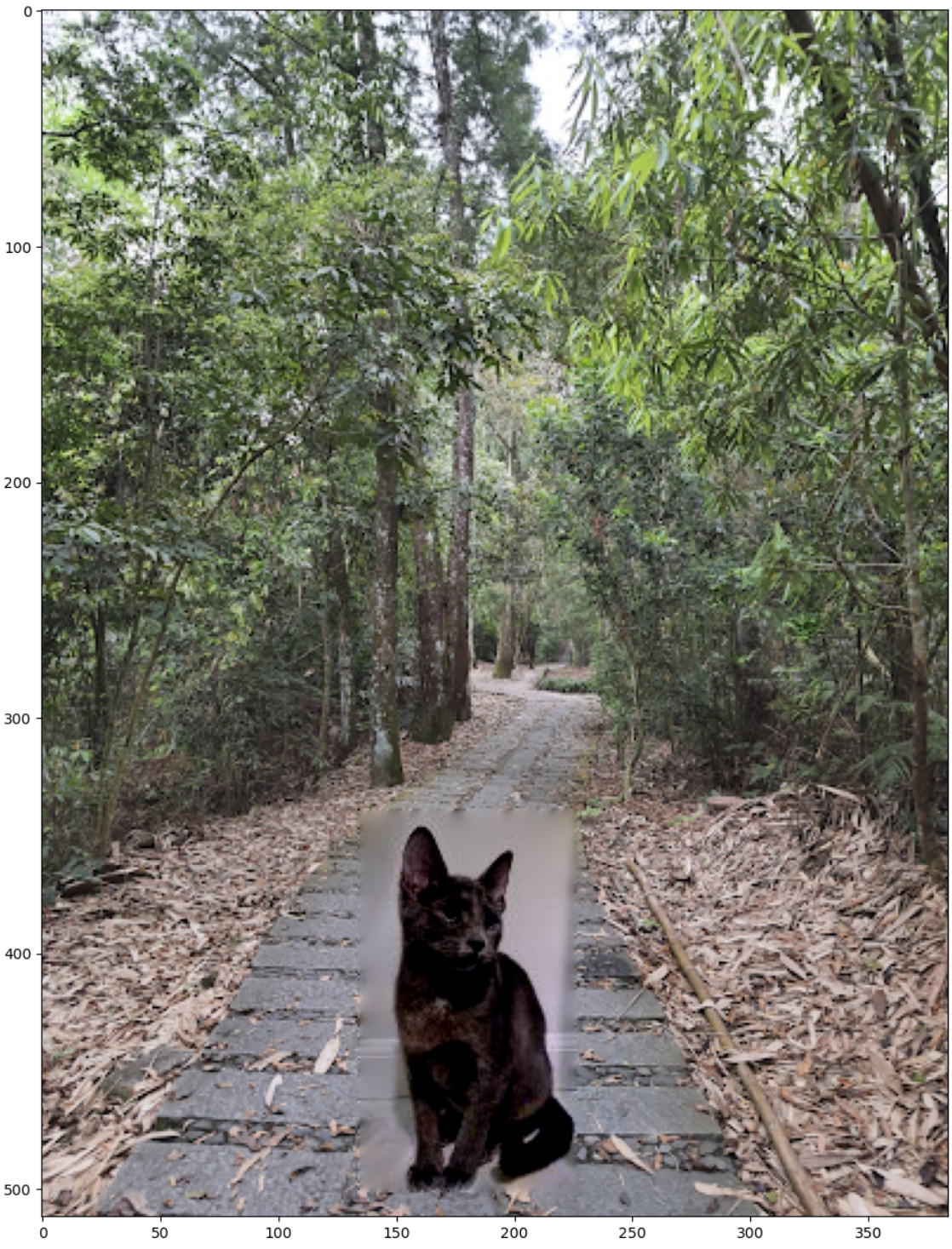


In [473]:

```
im_blend = np.zeros(background_img.shape)
for b in np.arange(3):
    im_blend[:,:,b] = poisson_blend(object_img[:,:,b], object_mask, ba

plt.figure(figsize=(15,15))
plt.imshow(im_blend)
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] f
or floats or [0..255] for integers).
```

Out[473]: <matplotlib.image.AxesImage at 0x1afbf0e3b88>



Part 3 Mixed Gradients (20 pts)

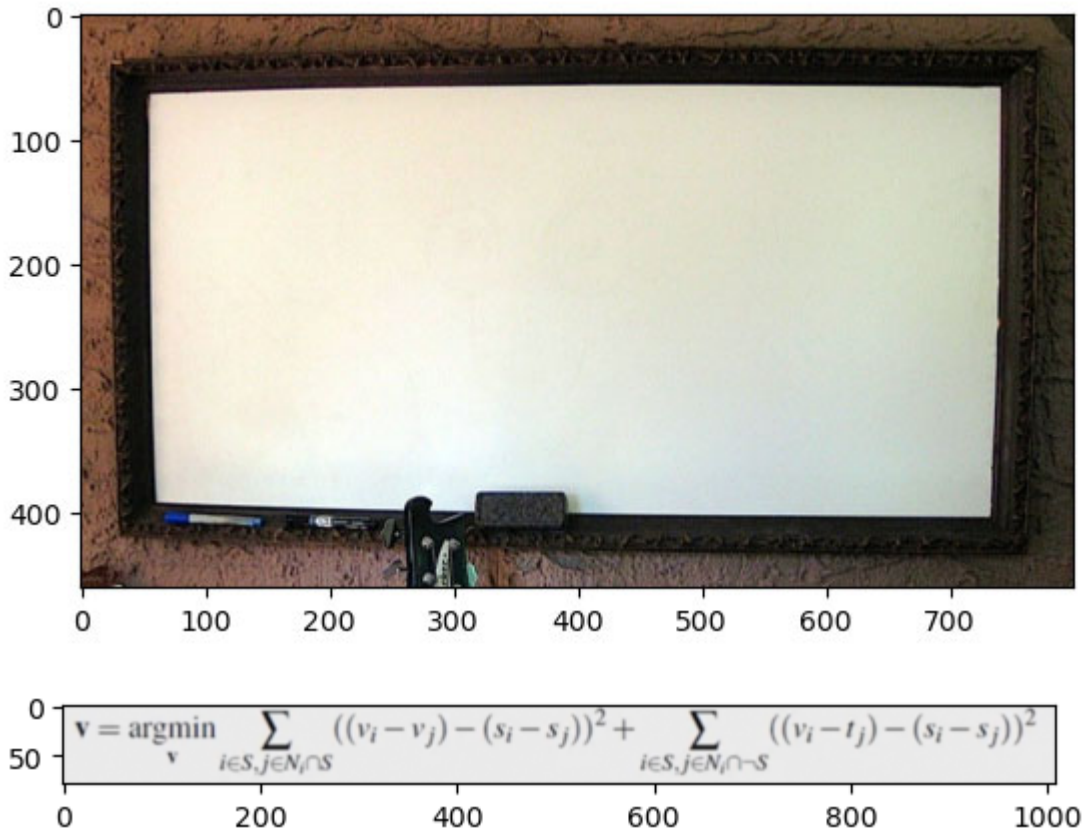
In [68]:

```python
def mixed_blend(object_img, object_mask, bg_img, bg_ul):
    """
    Returns a mixed gradient blended image with masked object_img over
    Can be implemented to operate on a single channel or multiple chan
    :param object_img: the image containing the foreground object
    :param object_mask: the mask of the foreground object in object_im
    :param background_img: the background image
    :param bg_ul: position (row, col) in background image correspondin
    """

    # extract the background patch that overlaps with the aligned obje
    bg = bg_img.copy()
    x, y = bg_ul[0], bg_ul[1]
    h, w = object_img.shape
    img = bg[x:x+h, y:y+w]

    im_h, im_w = img.shape
    im2var = np.arange(im_h * im_w).reshape(im_h, im_w)

    # for each pixel where mask == 1 4 eqns else 1 per pixel
    nz = np.count_nonzero(object_mask == 1)
    neq = 4 * nz + len(object_mask) - nz

    # initialize linear equation matrices A and b
    A = scipy.sparse.lil_matrix((neq, im_h * im_w), dtype='double')
    b = np.zeros((neq, 1), dtype='double')

    # calculate poisson blending
    e = 0

    for y in range(w):
        for x in range(h - 1):
            e += 1
            A[e, im2var[x+1, y]] = 1

            # compare gradient magnitudes from source and target
            d_source = object_img[x+1, y] - object_img[x, y]
            d_target = img[x+1, y] - img[x, y]

            if object_mask[x, y] == 1:
                A[e, im2var[x, y]] = -1
                b[e] = max([d_source, d_target], key=abs)
            else:
                b[e] = max([d_source, d_target], key=abs) + img[x, y]

    for y in range(w - 1):
        for x in range(h):
            e += 1
            A[e, im2var[x, y+1]] = 1

            # compare gradient magnitudes from source and target
            d_source = object_img[x, y+1] - object_img[x, y]
            d_target = img[x, y+1] - img[x, y]

            if object_mask[x, y] == 1:
```

```
                A[e, im2var[x, y]] = -1
                b[e] = max([d_source, d_target], key=abs)
            else:
                b[e] = max([d_source, d_target], key=abs) + img[x, y]

    v = scipy.sparse.linalg.lsqr(A.tocsr(), b) # solve w/ csr

    # modify the patch
    for x in range(im_h):
        for y in range(im_w):
            img[x, y] = v[0][im2var[x, y]]

    # copy the patch back into the background image
    x, y = bg_ul[0], bg_ul[1]
    bg_img[x:x+im_h, y:y+im_w] = img

    return bg_img
```

In [69]:

```
background_img = cv2.cvtColor(cv2.imread('whiteboard.JPG'), cv2.COLOR_
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('eqn.PNG'), cv2.COLOR_BGR2RGB).as
plt.imshow(object_img)
plt.show()

xs = (1, 400, 400, 1)
ys = (1, 1, 70, 70)
object_mask = utils.get_mask(ys, xs, object_img)
bottom_center = (400, 300) # (x,y)

object_img, object_mask = utils.crop_object_img(object_img, object_mas
bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
plt.imshow(utils.get_combined_img(background_img, object_img, object_m
```

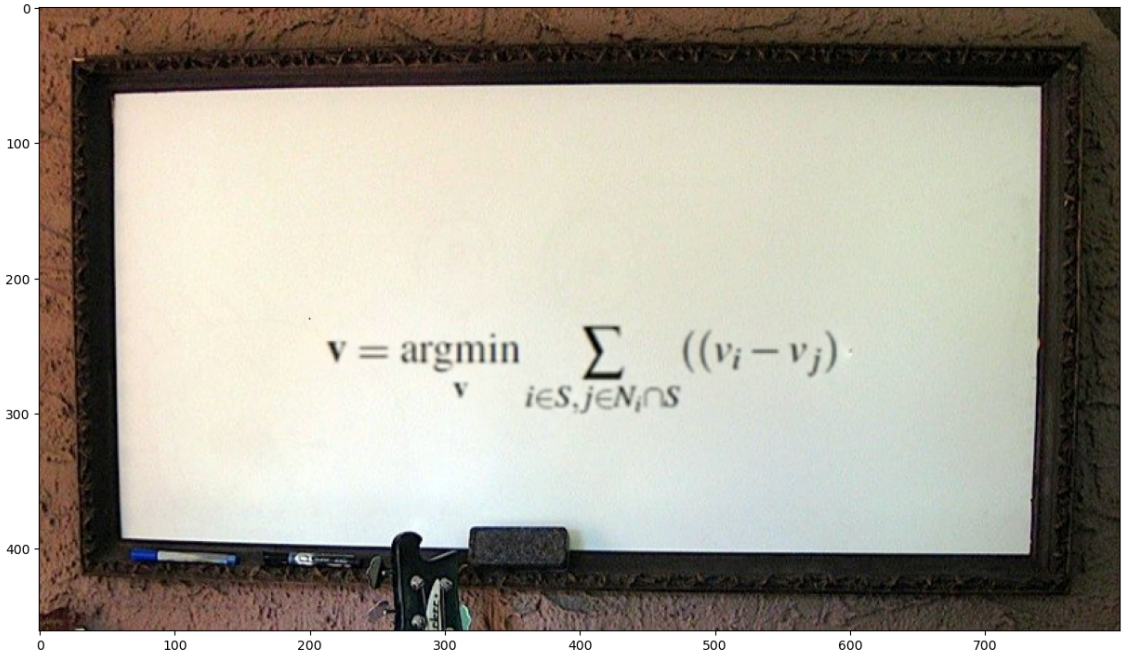


Out[69]: <matplotlib.image.AxesImage at 0x280be832508>

In [70]:
```
im_mix = np.zeros(background_img.shape)
for b in np.arange(3):
    im_mix[:,:,b] = mixed_blend(object_img[:,:,b], object_mask, backgr

plt.figure(figsize=(15,15))
plt.imshow(im_mix)
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] f
or floats or [0..255] for integers).
```

Out[70]: <matplotlib.figure.AxesImage at 0x280bf2f59c8>



Bells & Whistles (Extra Points)

Color2Gray (20 pts)

In [135]:

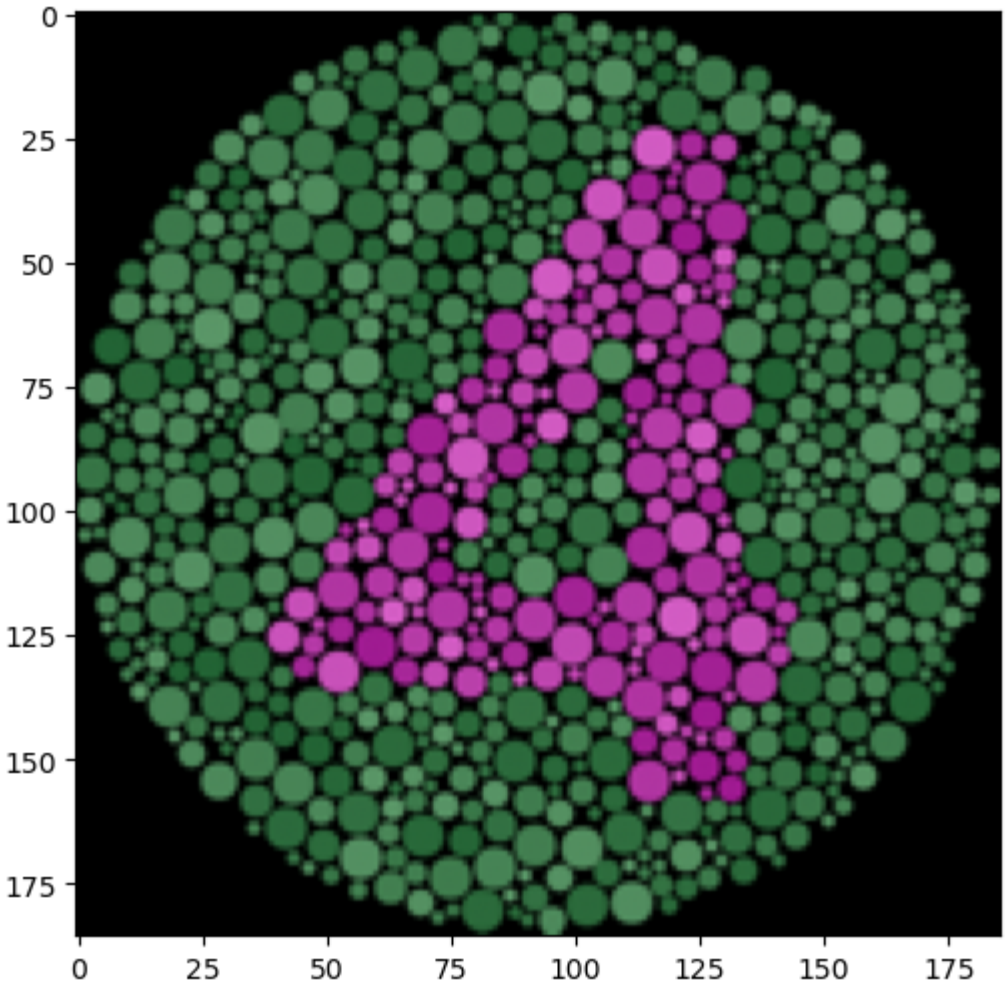
```
def color2gray(img):

    gray = cv2.cvtColor(np.float32(img), cv2.COLOR_BGR2GRAY).astype('d
    mask = np.zeros_like(gray)
    mask[gray != 0] = 1

    im_h, im_w, _ = img.shape
    im2var = np.arange(im_h * im_w).reshape(im_h, im_w)

    im_re = mask

    nz = np.count_nonzero(mask == 1)
    neq = 4 * nz + len(mask) - nz

    # initialize linear equation matrices A and b
    A = scipy.sparse.lil_matrix((neq, im_h * im_w), dtype='double')
    b = np.zeros((neq, 1), dtype='double')

    e = 0

    for y in range(im_w):
        for x in range(im_h - 1):
            A[e, im2var[x+1, y]] = 1

            # compare gradient magnitudes from source and target
            im_r, im_g, im_b = img[:,:,0], img[:,:,1], img[:,:,2]

            d_r = im_r[x+1, y] - im_r[x, y]
            d_g = im_g[x+1, y] - im_g[x, y]
            d_b = im_b[x+1, y] - im_b[x, y]

            if mask[x, y] == 1:
                A[e, im2var[x, y]] = -1
                b[e] = max([d_r, d_g, d_b], key=abs) + gray[x, y]

#             print(d_r, d_g, d_b, b[e])
            e += 1

    for y in range(im_w - 1):
        for x in range(im_h):
            A[e, im2var[x, y+1]] = 1

            # compare gradient magnitudes between channels
            im_r, im_g, im_b = img[:,:,0], img[:,:,1], img[:,:,2]
            d_r = im_r[x, y+1] - im_r[x, y]
            d_g = im_g[x, y+1] - im_g[x, y]
            d_b = im_b[x, y+1] - im_b[x, y]

            if mask[x, y] == 1:
                A[e, im2var[x, y]] = -1
                b[e] = max([d_r, d_g, d_b], key=abs) + gray[x, y]
            e += 1

    v = scipy.sparse.linalg.lsqr(A.tocsr(), b) # solve w/ csr

```

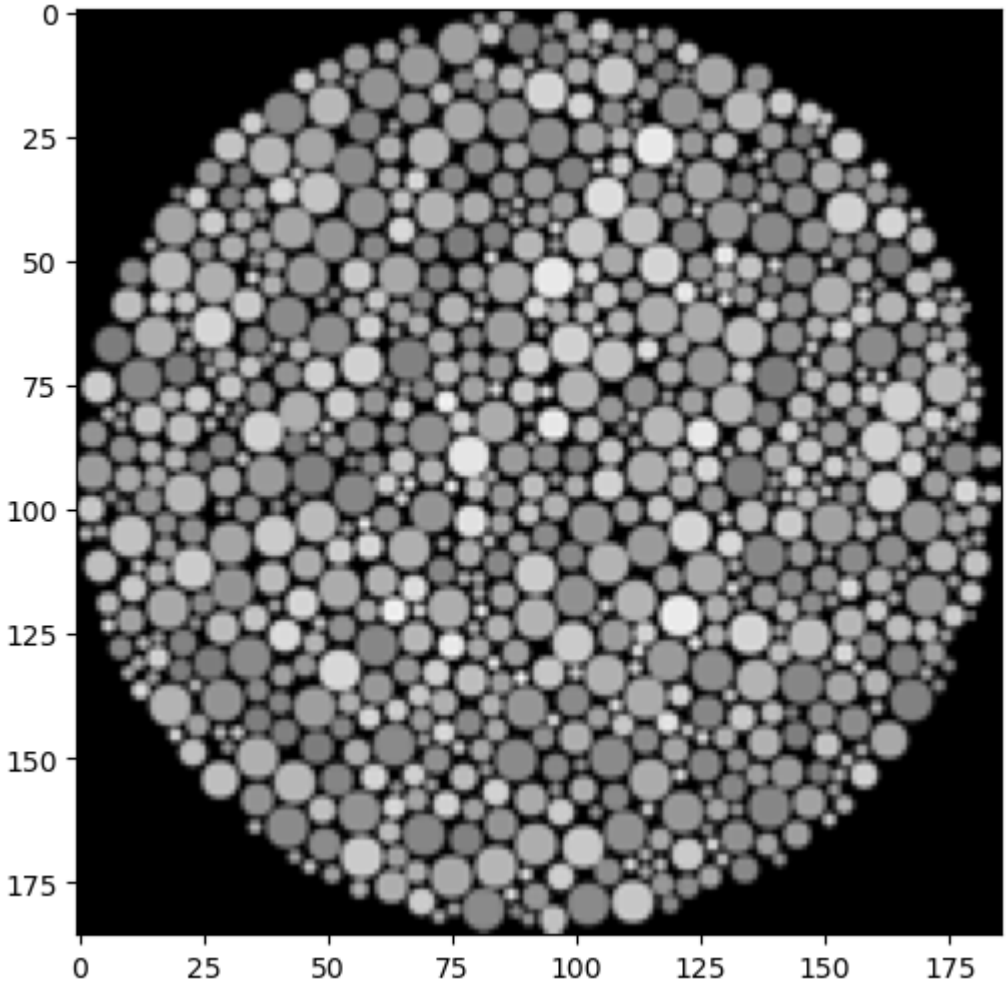
```
    # modify the patch
    for x in range(im_h):
        for y in range(im_w):
            im_re[x, y] = v[0][im2var[x, y]]

    return im_re
```

In [136]:

```
cb4 = cv2.cvtColor(cv2.imread('samples/colorBlind4.png'), cv2.COLOR_BG
plt.figure(figsize=(6,6))
plt.imshow(cb4)

gray = cv2.cvtColor(cv2.imread('samples/colorBlind4.png'), cv2.COLOR_B
plt.figure(figsize=(6,6))
plt.imshow(gray, cmap="gray")

im_re4 = color2gray(cb4)
plt.figure(figsize=(6,6))
plt.imshow(im_re4, cmap="gray")
```

Out[136]: <matplotlib.image.AxesImage at 0x1a201bb71c8>

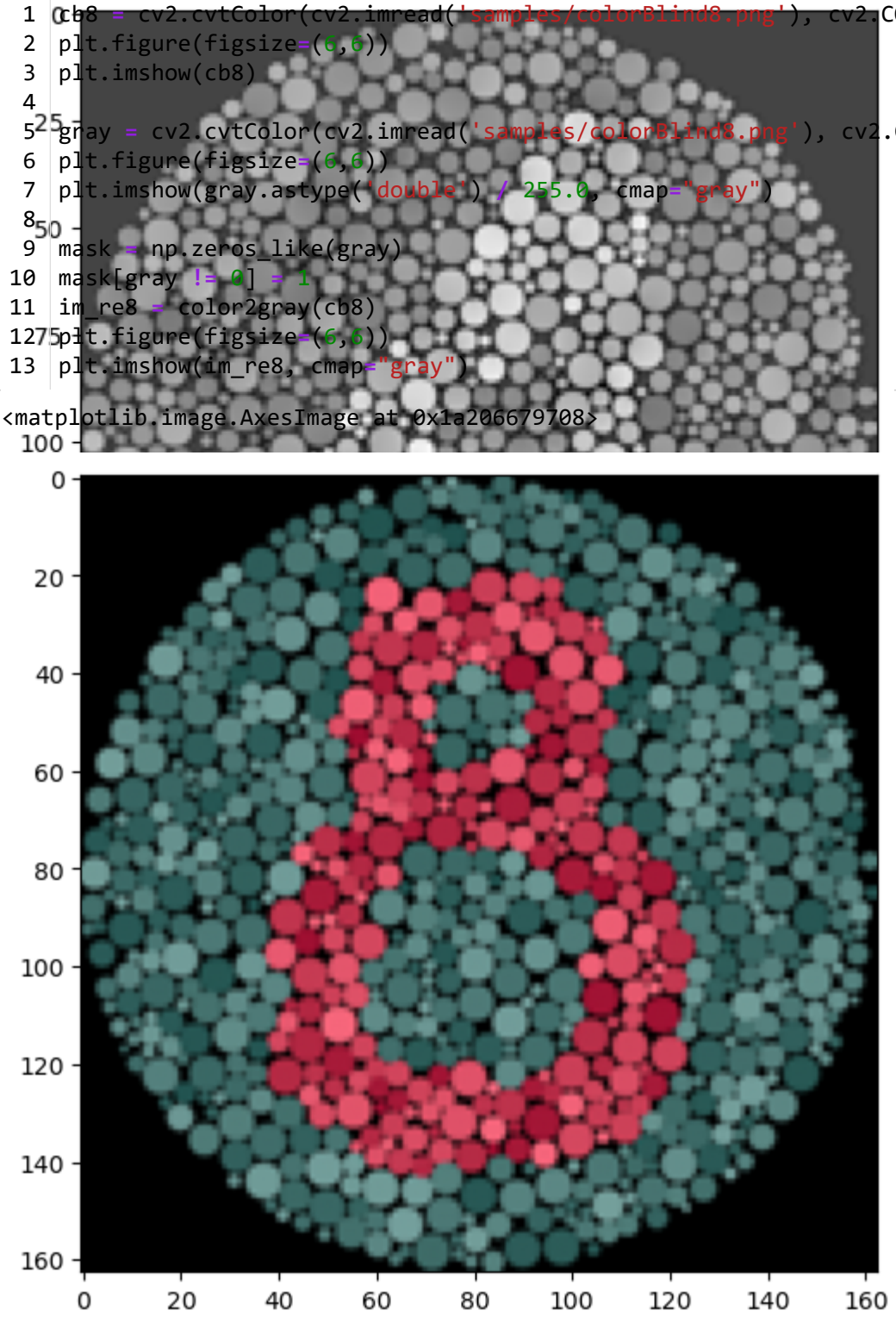


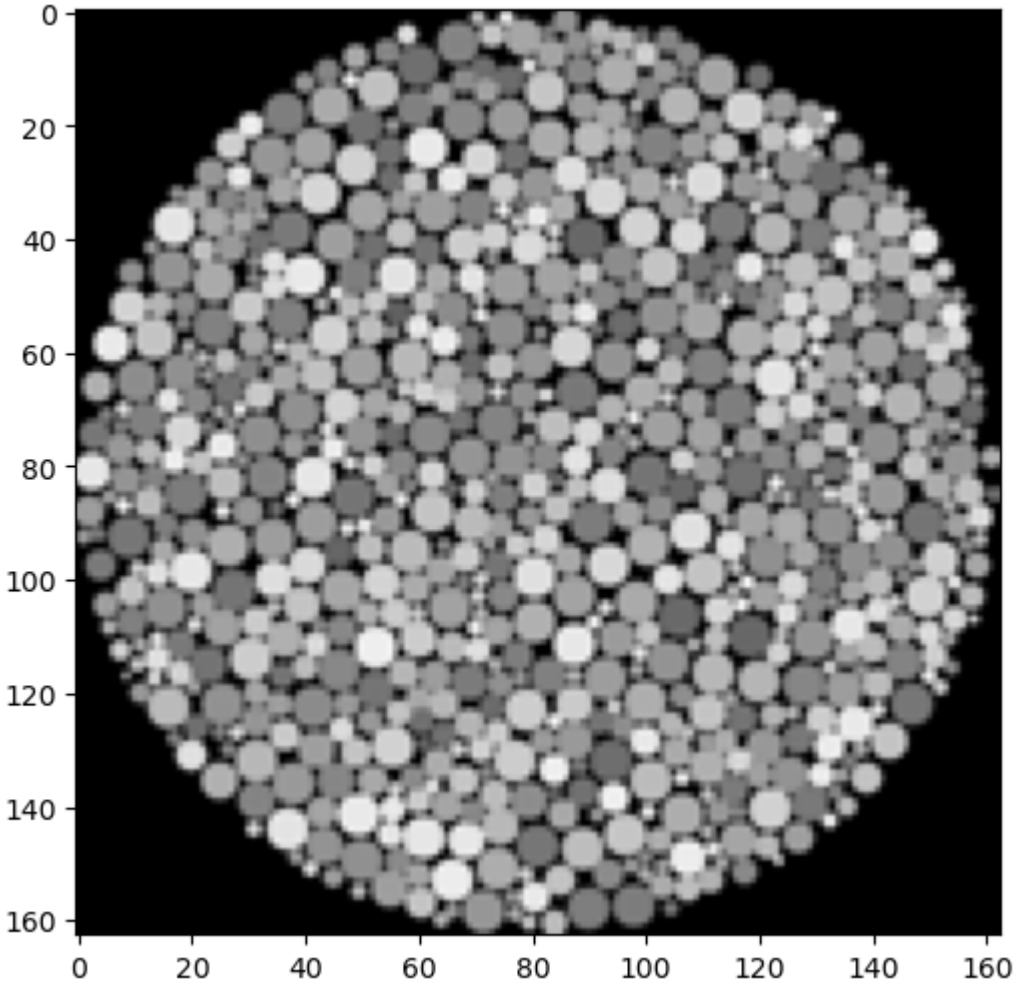

0
25
50
75
100
125
150
175
0
25
50
75
100
125
150
175

In [138]:

```
cb8 = cv2.cvtColor(cv2.imread('samples/colorBlind8.png'), cv2.COLOR_BG
plt.figure(figsize=(6,6))
plt.imshow(cb8)

gray = cv2.cvtColor(cv2.imread('samples/colorBlind8.png'), cv2.COLOR_B
plt.figure(figsize=(6,6))
plt.imshow(gray.astype('double') / 255.0, cmap="gray")

mask = np.zeros_like(gray)
mask[gray != 0] = 1
im_re8 = color2gray(cb8)
plt.figure(figsize=(6,6))
plt.imshow(im_re8, cmap="gray")
```

Out[138]: <matplotlib.image.AxesImage at 0x1a206679708>

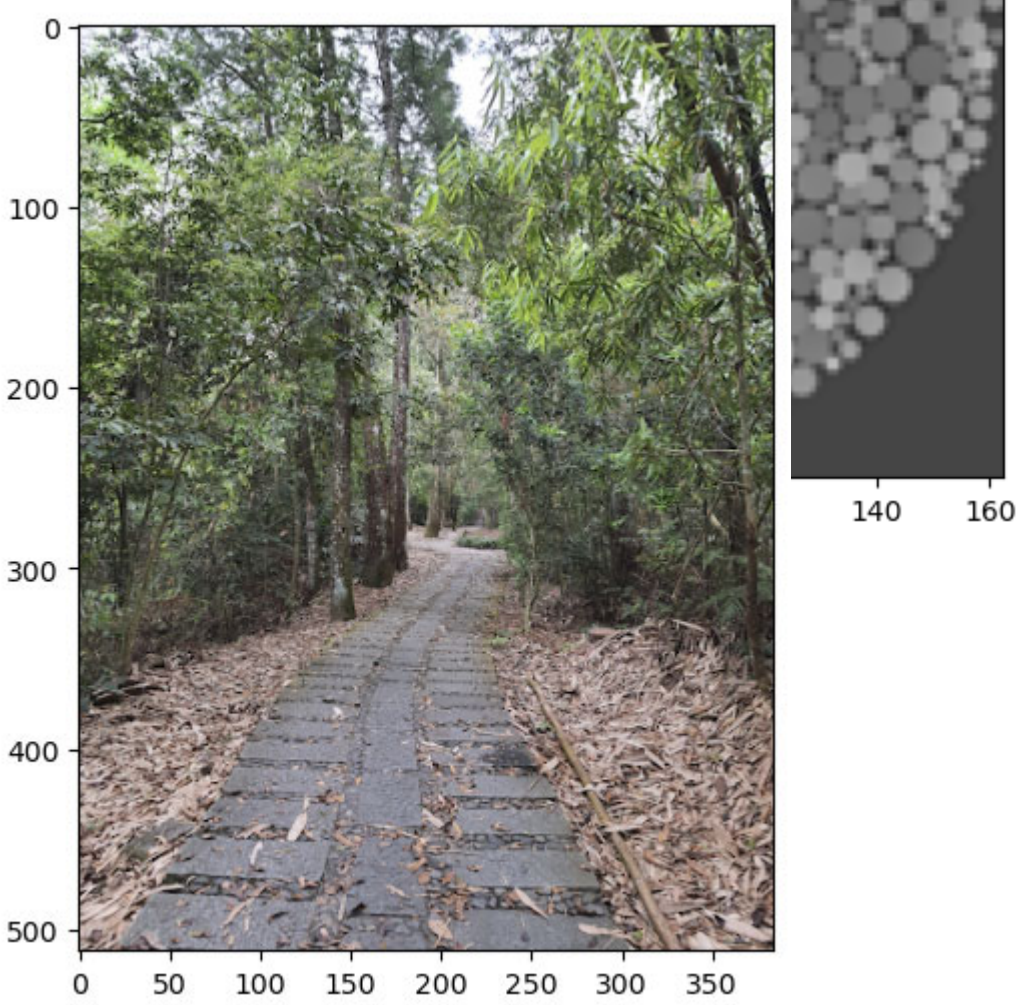


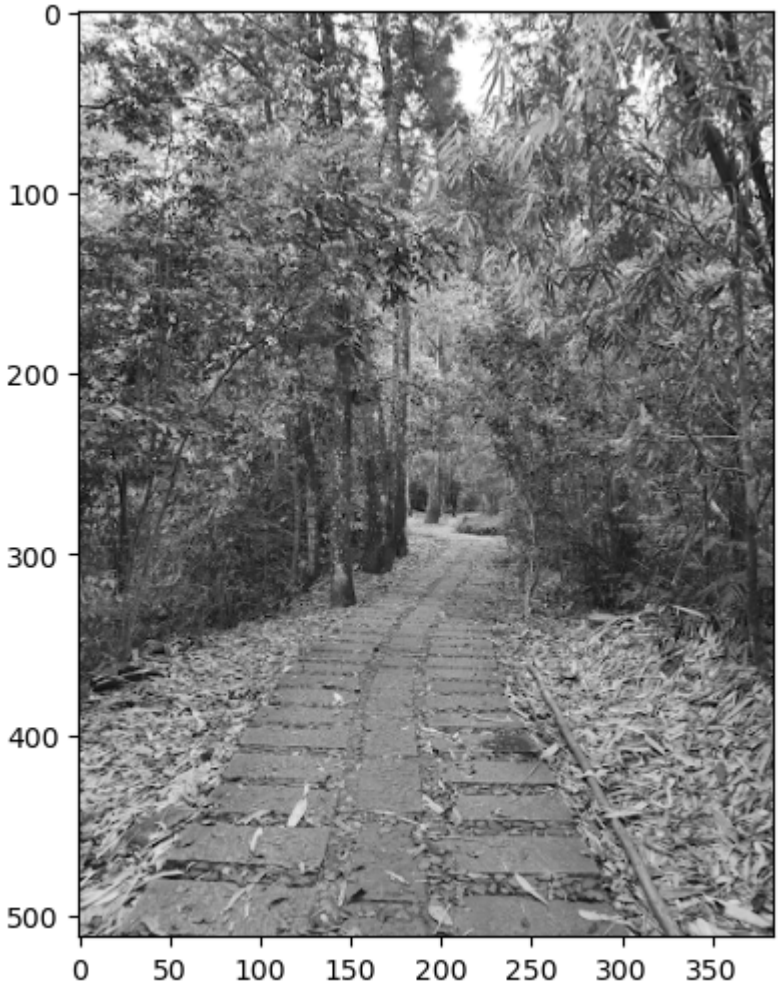

0
20
40
60
80
100
120
140
160
0
20
40
60
80
100
120
140
160

In [140]:

```
path = cv2.cvtColor(cv2.imread('path.png'), cv2.COLOR_BGR2RGB).astype(
plt.figure(figsize=(6,6))
plt.imshow(path)

gray = cv2.cvtColor(cv2.imread('path.png'), cv2.COLOR_BGR2GRAY)
plt.figure(figsize=(6,6))
plt.imshow(gray, cmap="gray")

im_path = color2gray(path)
plt.figure(figsize=(6,6))
plt.imshow(im_path, cmap="gray")
```

Out[140]: <matplotlib.image.AxesImage at 0x1a206045b08>





Laplacian pyramid blending (20 pts)

In [ ]:

```
def laplacian_blend(object_img, object_mask, bg_img, bg_ul):
    # feel free to change input parameters
    pass
```

Mo 20 pts)

In [ ]:

```
1
```