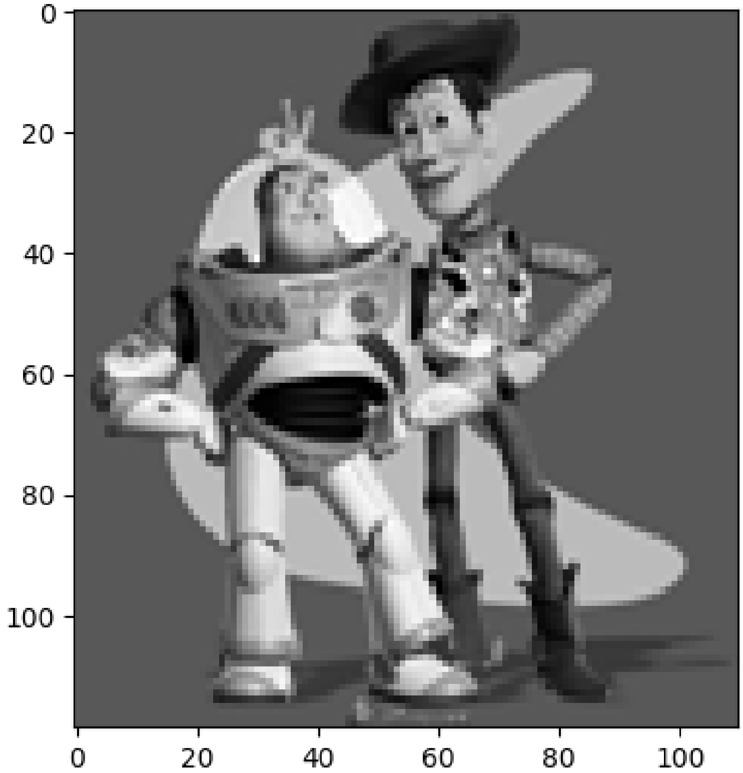
CS 445: Computational Photography

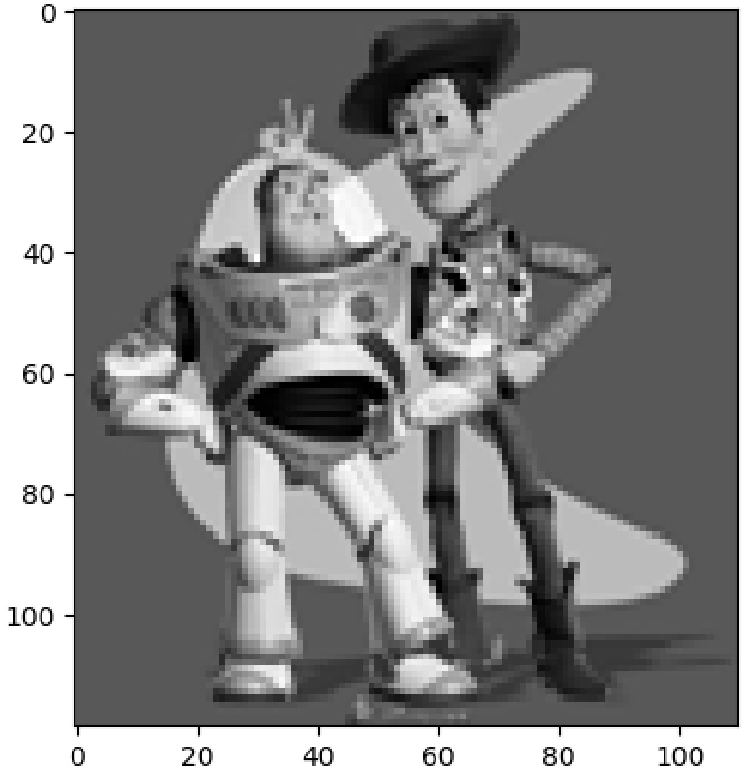
Programming Project #3: Gradient Domain Fusion

```python
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)

```python
def toy_reconstruct(img):
    """
    The implementation for gradient domain processing is not
complicated, but it is easy to make a mistake, so let's start with a
toy example. Reconstruct this image from its gradient values, plus one
pixel intensity. Denote the intensity of the source image at (x, y) as
s(x,y) and the value to solve for as v(x,y). For each pixel, then, we
have two objectives:
    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
v, so we will add one more objective:
    3. minimize (v(1,1)-s(1,1))^2

    :param toy_img: numpy.ndarray
    """

    # Initialization
    H, W = img.shape
    im2var = np.arange(H*W).reshape(H, W)

    total = 2*(H-1)*(W-1)+W+H-1
    A = np.zeros((total, H*W))
    b = np.zeros(total)
    e = 0

    # object 3
    A[e][im2var[0][0]] = 1
    b[e] = img[0][0]
    e += 1
    for x in range(W):
        for y in range(H):

            # object 1
            if x < W - 1:
                A[e][im2var[y][x+1]] = 1
                A[e][im2var[y][x]] = -1
                b[e] = img[y][x+1] - img[y][x]
                e += 1

            # object 2
            if y < H - 1:
                A[e][im2var[y+1][x]] = 1
                A[e][im2var[y][x]] = -1
                b[e] = img[y+1][x] - img[y][x]
                e += 1

    v = scipy.sparse.linalg.lsqr(A, b, atol=1e-14, btol=1e-14)[0]
    return v.reshape(H, W)

toy_img = cv2.cvtColor(cv2.imread('samples/toy_problem.png'),
cv2.COLOR_BGR2GRAY).astype('double') / 255.0
plt.imshow(toy_img, cmap="gray")
plt.show()

im_out = toy_reconstruct(toy_img)
plt.imshow(im_out, cmap="gray")
plt.show()
print("Max error is: ", np.sqrt(((im_out - toy_img)**2).max()))
```





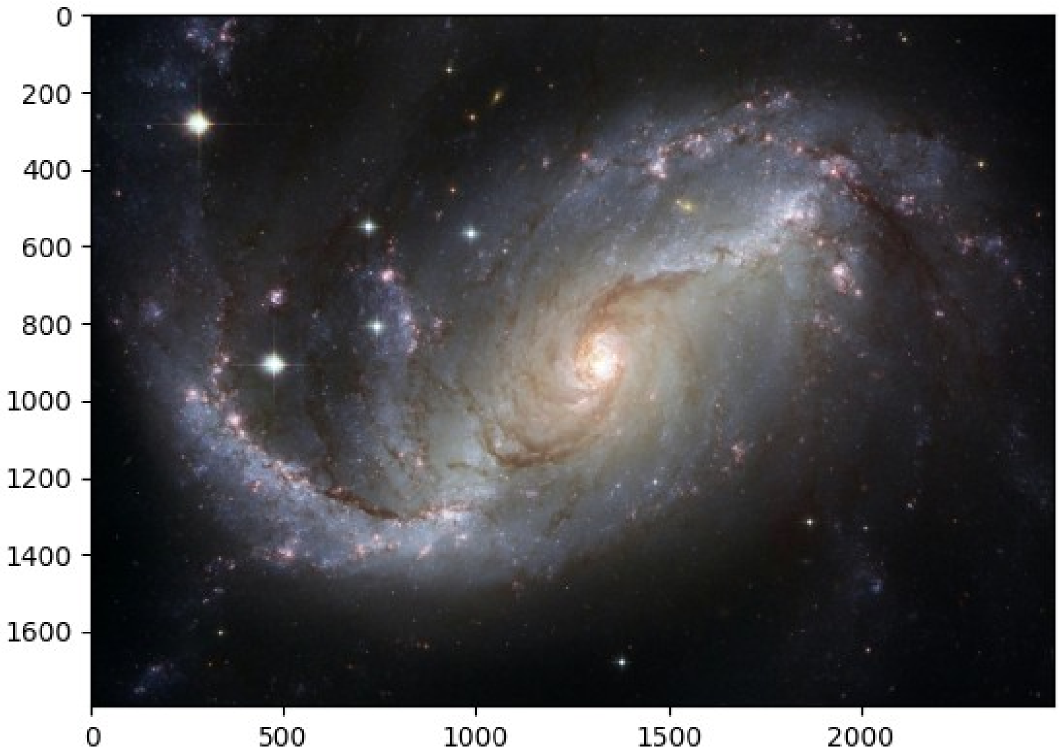
```
Max error is:  7.420508651989621e-12
```

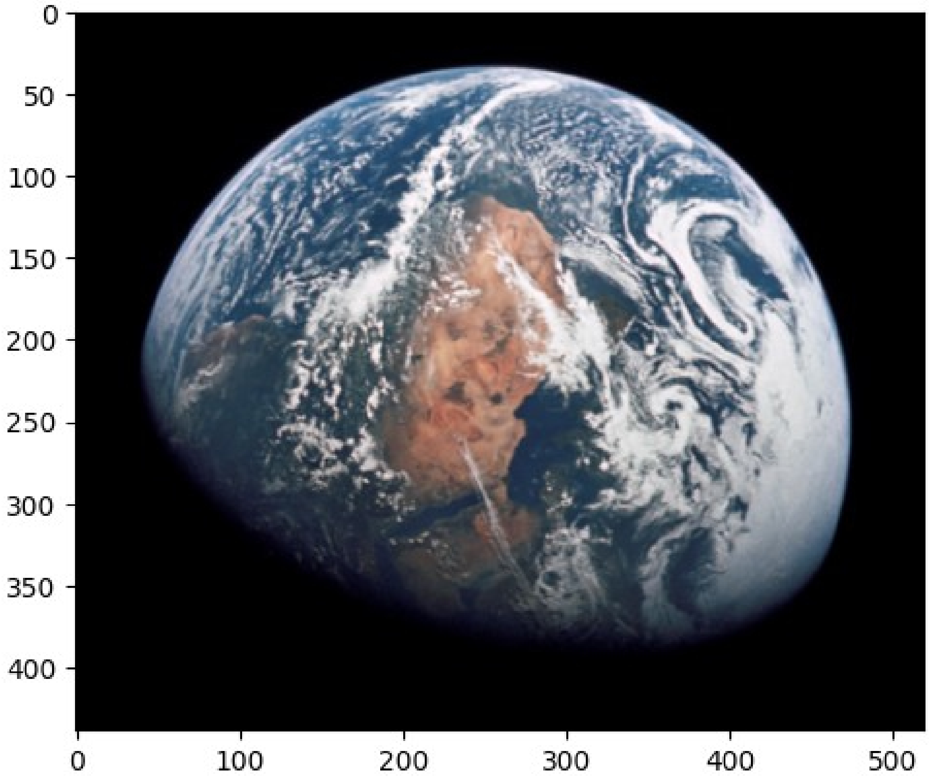
Part 2 Poisson Blending (50 pts)

Preparation

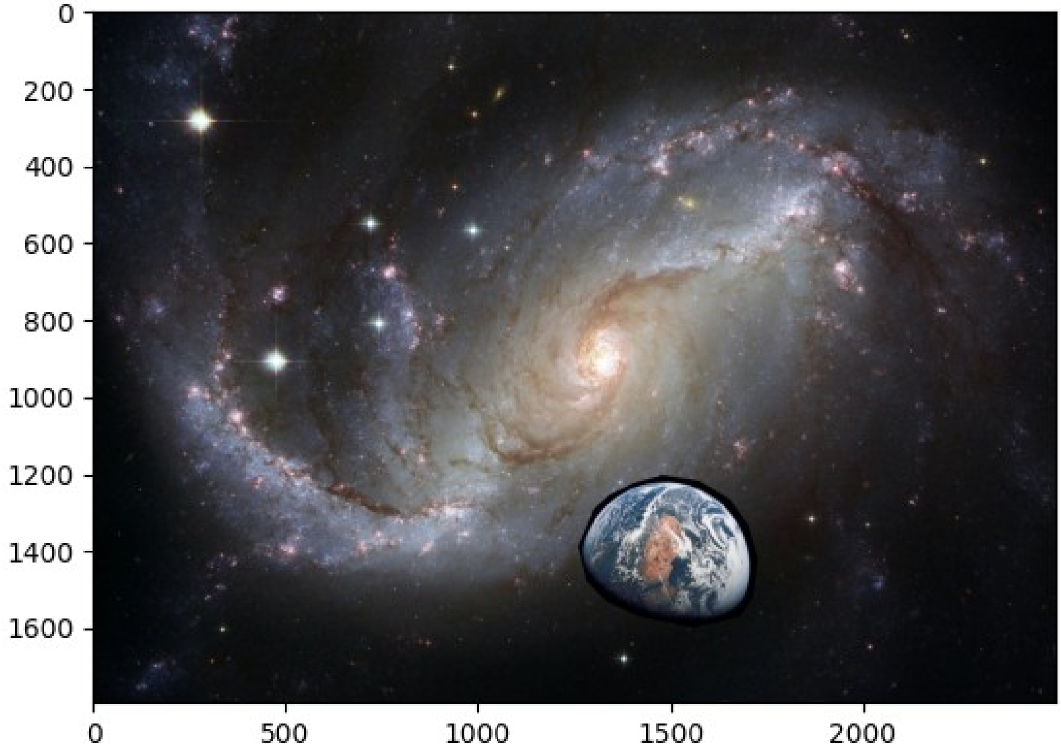
```
background_img = cv2.cvtColor(cv2.imread('samples/universe.jpg'),
cv2.COLOR_BGR2RGB).astype('double') / 255.0
# background_img = cv2.cvtColor(cv2.imread('samples/horizon.jpg'),
cv2.COLOR_BGR2RGB).astype('double') / 255.0
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('samples/earth.png'),
cv2.COLOR_BGR2RGB).astype('double') / 255.0
# object_img = cv2.cvtColor(cv2.imread('samples/dophin2.png'),
cv2.COLOR_BGR2RGB).astype('double') / 255.0
# object_img = cv2.cvtColor(cv2.imread('samples/dophin.png'),
cv2.COLOR_BGR2RGB).astype('double') / 255.0
plt.imshow(object_img)
plt.show()

use_interface = False  # set to true if you want to use the interface
to choose points (might not work in Colab)
if not use_interface:
    # result 1
    xs = (174, 110, 67, 29, 50, 102, 189, 329, 450, 482, 495, 470,
424, 342, 247)
    ys = (35, 66, 106, 200, 290, 343, 383, 411, 383, 332, 232, 144,
78, 29, 15)
    bottom_center = (1500, 1600) # (x,y)

    # result 2
    # xs = (62, 36, 8, 10, 41, 57, 84, 116, 175, 186, 210, 213, 222,
188, 160, 163, 150, 117, 89)
    # ys = (7, 21, 30, 43, 56, 77, 81, 80, 99, 126, 130, 108, 77, 74,
58, 38, 19, 6, 4)
    # bottom_center = (150, 530) # (x,y)

    # result 3
    # xs = (60, 46, 27, 19, 4, 4, 25, 53, 60, 81, 97, 128, 130, 118,
113, 104, 101, 107, 127, 114, 124, 140, 136, 117, 89)
    # ys = (8, 21, 47, 59, 72, 85, 97, 130, 151, 164, 176, 175, 166,
161, 143, 115, 98, 79, 78, 51, 38, 25, 9, 5, 2)
    # bottom_center = (700, 530) # (x,y)

    object_mask = utils.get_mask(ys, xs, object_img)
    object_img, object_mask = utils.crop_object_img(object_img,
object_mask)
    bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
    combined_img = utils.get_combined_img(background_img, object_img,
object_mask, bg_ul)
```

```
plt.imshow(combined_img)
# plt.imsave("./results/part2_simple_result1.png", combined_img)
```





0
50
100
150
200
250
300
350
400
0
100
200
300
400
500



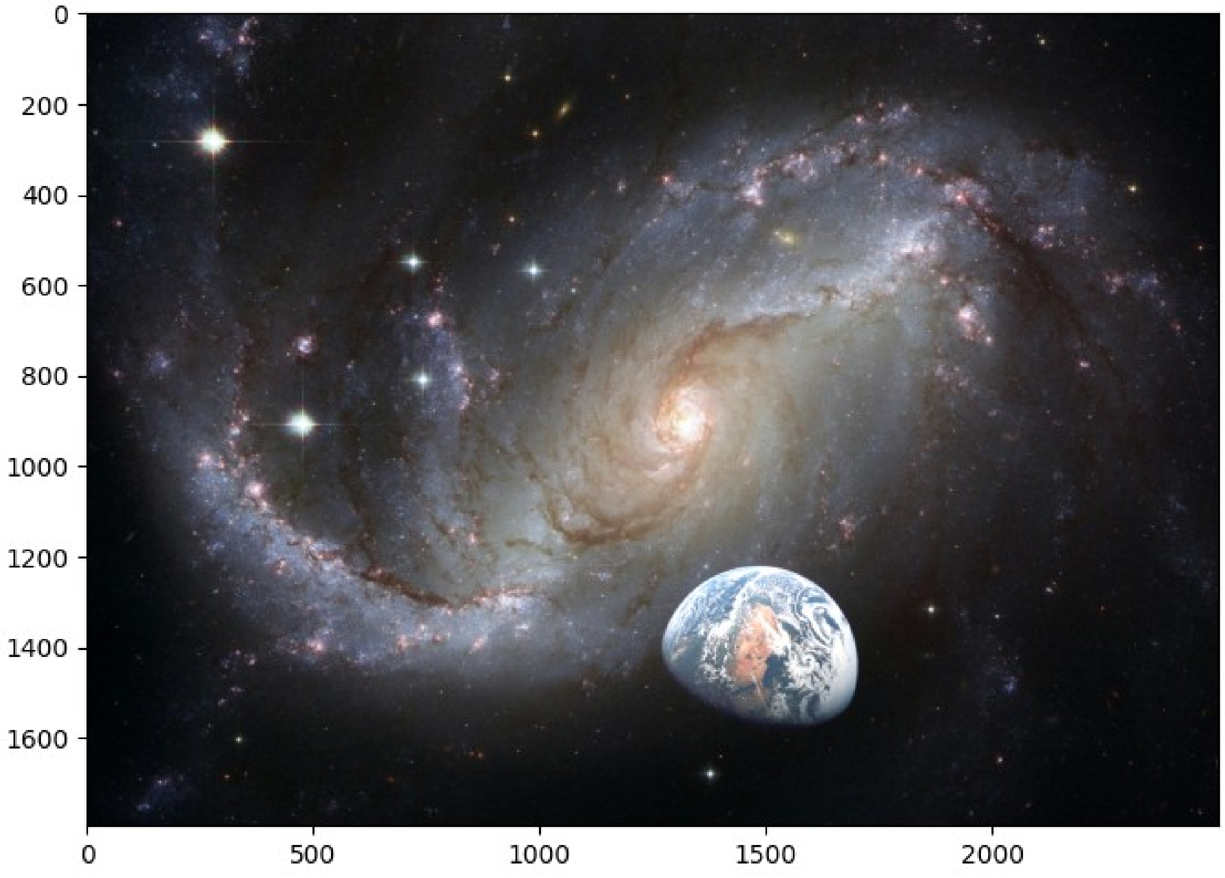
0
200
400
600
800
1000
1200
1400
1600
0
500
1000
1500
2000

Poisson Blending

```
def poisson_blend(object_img, object_mask, bg_img, bg_ul):
    """
    Returns a Poisson blended image with masked object_img over the
bg_img at position specified by bg_ul.
    Can be implemented to operate on a single channel or multiple
channels
    :param object_img: the image containing the foreground object
    :param object_mask: the mask of the foreground object in
object_img
    :param background_img: the background image
    :param bg_ul: position (row, col) in background image
corresponding to (0,0) of object_img
    """
    # get all nonzeros indices
    rows, cols = np.nonzero(object_mask)

    # construct im2var
    im2var = np.full(object_mask.shape,-1,dtype=int)
    for i, (r, c) in enumerate(zip(rows, cols)):
        im2var[r][c] = i

    data, row_ind, col_ind = [], [], []
    b = np.zeros(4*len(rows))
    e = 0
    increments = [(-1,0), (1,0), (0,-1), (0,1)]

    for r, c in zip(rows, cols):
        for inc in increments:
            nr, nc = r+inc[0], c+inc[1]

            row_ind.append(e)
            col_ind.append(im2var[r][c])
            data.append(1)

            if object_mask[nr][nc]:
                row_ind.append(e)
                col_ind.append(im2var[nr][nc])
                data.append(-1)
                b[e] = object_img[r][c] - object_img[nr][nc]
            else:
                tnr, tnc = bg_ul[0]+nr-1, bg_ul[1]+nc-1
                b[e] = bg_img[tnr][tnc] + object_img[r][c] -
object_img[nr][nc]

            e += 1

    A = scipy.sparse.csr_matrix((data, (row_ind, col_ind)), shape=(e,
len(rows)))
```

```
    v = scipy.sparse.linalg.lsqr(A, b, atol=1e-14, btol=1e-14)[0]
    v = np.clip(v, 0.0, 1.0)

    # paste to background image
    for i, (r, c) in enumerate(zip(rows, cols)):
        tr, tc = bg_ul[0]+r-1, bg_ul[1]+c-1
        bg_img[tr][tc] = v[i]

    return bg_img

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

plt.figure(figsize=(8,8))
plt.imshow(im_blend)
```

```
<matplotlib.image.AxesImage at 0x762e2bb25d80>
```

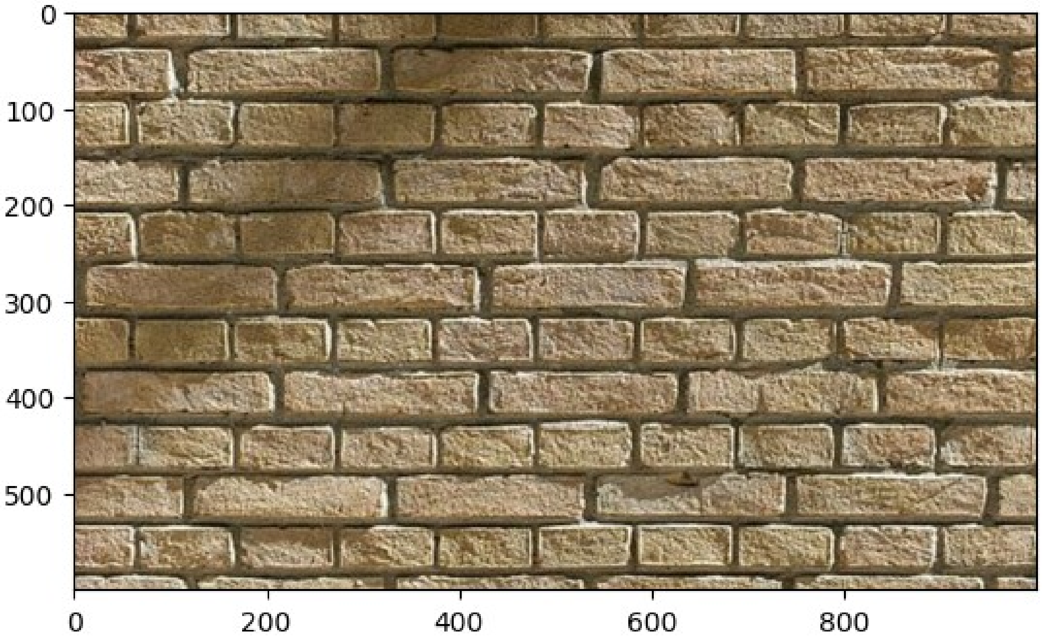


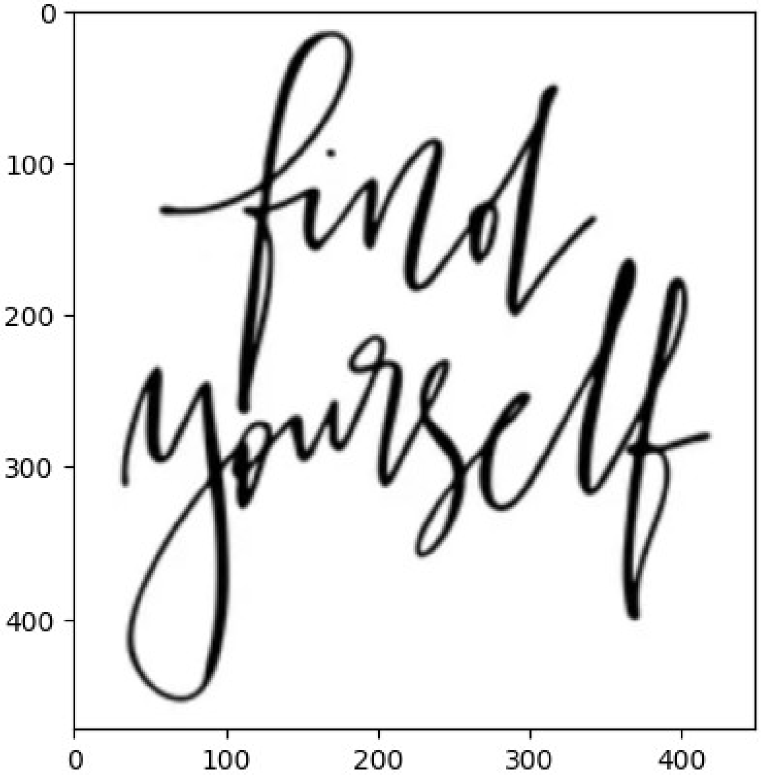
```
# plt.imsave("./results/part2_result1.png", im_blend)
```

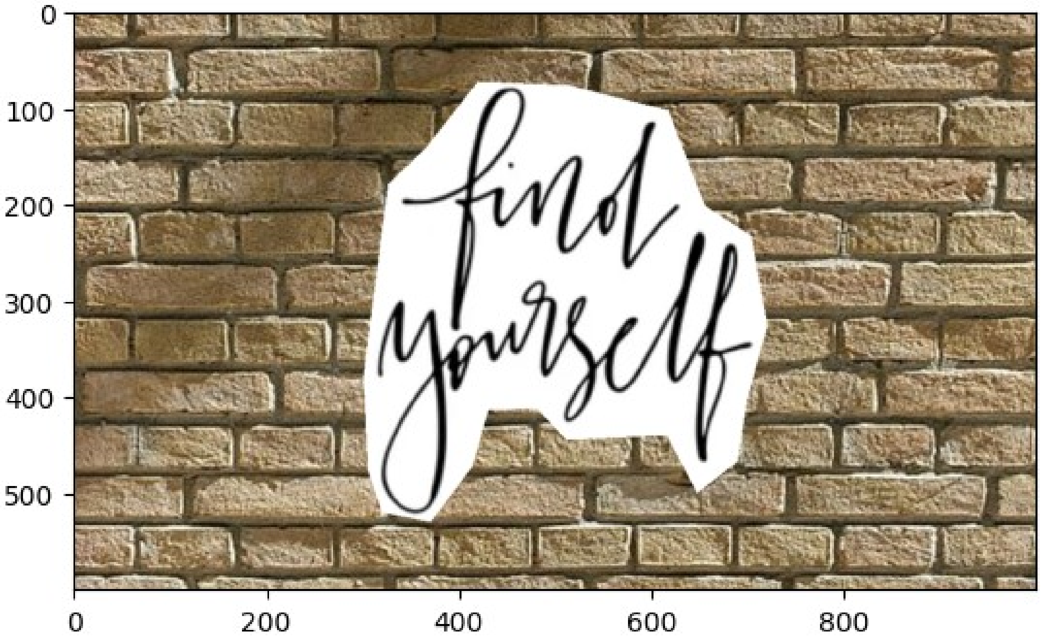
Part 3 Mixed Gradients (20 pts)

Preparation

```
background_img = cv2.cvtColor(cv2.imread('samples/wall.jpg'),
cv2.COLOR_BGR2RGB).astype('double') / 255.0
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('samples/writing.png'),
cv2.COLOR_BGR2RGB).astype('double') / 255.0
plt.imshow(object_img)
plt.show()

use_interface = False  # set to true if you want to use the interface
to choose points (might not work in Colab)
if not use_interface:
    # result 1
    xs = (135, 80, 42, 33, 16, 21, 35, 86, 129, 146, 196, 227, 331,
363, 405, 415, 436, 419, 371, 333, 230)
    ys = (7, 77, 113, 180, 313, 410, 454, 464, 407, 348, 346, 379,
374, 434, 401, 336, 260, 167, 136, 37, 11)
    bottom_center = (500, 530) # (x,y)

    object_mask = utils.get_mask(ys, xs, object_img)
    object_img, object_mask = utils.crop_object_img(object_img,
object_mask)
    bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
    combined_img = utils.get_combined_img(background_img, object_img,
object_mask, bg_ul)
    plt.imshow(combined_img)
    plt.imsave("./results/part3_simple_result.png", combined_img)
```


0
100
200
300
400
500
0
200
400
600
800

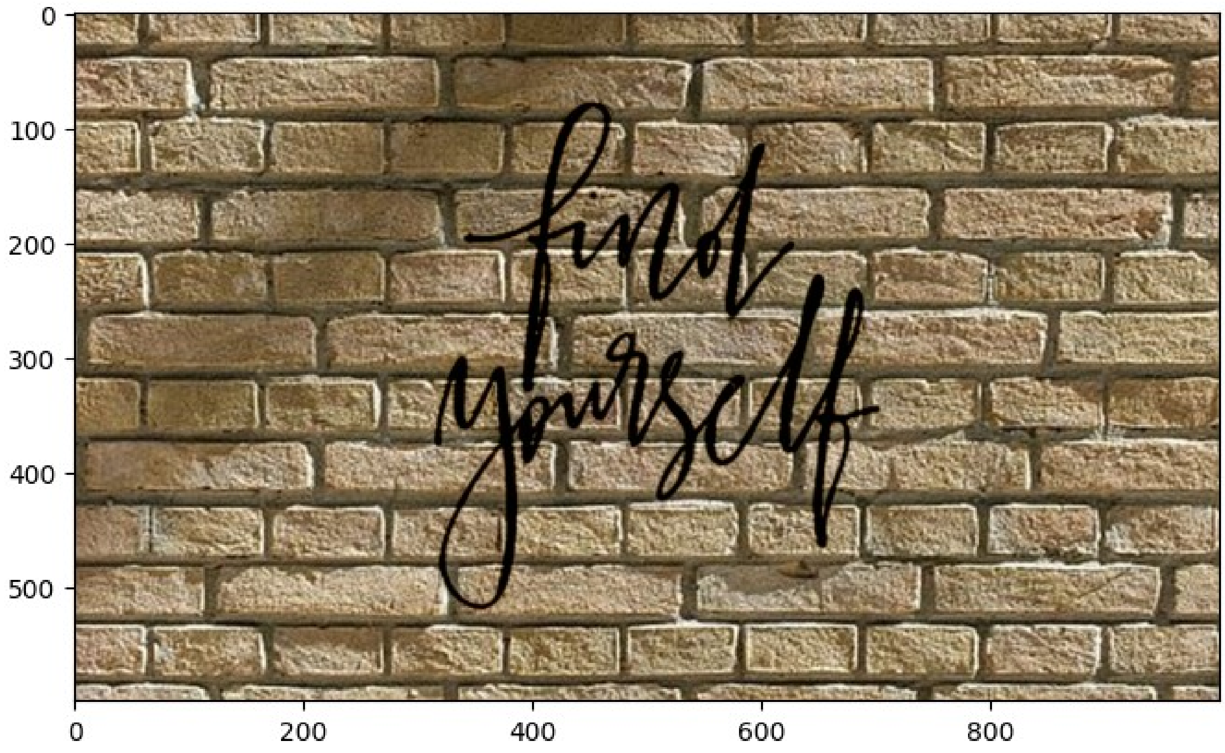

find yourself
0
100
200
300
400
0
100
200
300
400



Mixed Gradients Blending

```
def mixed_blend(object_img, object_mask, bg_img, bg_ul):
    """
    Returns a mixed gradient blended image with masked object_img over
the bg_img at position specified by bg_ul.
    Can be implemented to operate on a single channel or multiple
channels
    :param object_img: the image containing the foreground object
    :param object_mask: the mask of the foreground object in
object_img
    :param background_img: the background image
    :param bg_ul: position (row, col) in background image
corresponding to (0,0) of object_img
    """
    def get_grad(r, c, nr, nc):
        s_grad = object_img[r][c] - object_img[nr][nc]

        tr, tc = bg_ul[0]+r-1, bg_ul[1]+c-1
        tnr, tnc = bg_ul[0]+nr-1, bg_ul[1]+nc-1
        t_grad = bg_img[tr][tc] - bg_img[tnr][tnc]

        return s_grad if abs(s_grad) > abs(t_grad) else t_grad

    # get all nonzeros indices
    rows, cols = np.nonzero(object_mask)

    # construct im2var
    im2var = np.full(object_mask.shape,-1,dtype=int)
    for i, (r, c) in enumerate(zip(rows, cols)):
        im2var[r][c] = i

    data, row_ind, col_ind = [], [], []
    b = np.zeros(4*len(rows))
    e = 0
    increments = [(-1,0), (1,0), (0,-1), (0,1)]

    for r, c in zip(rows, cols):
        for inc in increments:
            nr, nc = r+inc[0], c+inc[1]

            row_ind.append(e)
            col_ind.append(im2var[r][c])
            data.append(1)

            grad = get_grad(r, c, nr, nc)

            if object_mask[nr][nc]:
                row_ind.append(e)
                col_ind.append(im2var[nr][nc])
                data.append(-1)
                b[e] = grad
            else:
                tnr, tnc = bg_ul[0]+nr-1, bg_ul[1]+nc-1
                b[e] = bg_img[tnr][tnc] + grad

            e += 1

    A = scipy.sparse.csr_matrix((data, (row_ind, col_ind)), shape=(e,
len(rows)))
    v = scipy.sparse.linalg.lsqr(A, b, atol=1e-14, btol=1e-14)[0]
    v = np.clip(v, 0.0, 1.0)

    # paste to background image
    for i, (r, c) in enumerate(zip(rows, cols)):
        tr, tc = bg_ul[0]+r-1, bg_ul[1]+c-1
        bg_img[tr][tc] = v[i]

    return bg_img

im_mix = np.zeros(background_img.shape)
for b in np.arange(3):
    im_mix[:,:,b] = mixed_blend(object_img[:,:,b], object_mask,
background_img[:,:,b].copy(), bg_ul)

plt.figure(figsize=(8,8))
plt.imshow(im_mix)
```

```
<matplotlib.image.AxesImage at 0x762e85ebeda0>
```



```python
plt.imsave("./results/part3_result.png", im_mix)
```

Bells & Whistles (Extra Points)

Color2Gray (20 pts)

```python
def color2gray(img):
    pass
```

Laplacian pyramid blending (20 pts)

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

More gradient domain processing (up to 20 pts)