**Name (netid):** Rahul Grover (rgrover4)
**CS 445 - Project 3: Gradient Domain Fusion**

Complete the claimed points and sections below.

| | |
|---|---|
| **Total Points Claimed** | **[100] / 160** |

**Core**

| | |
|---|---|
| 1. Toy Problem | [20] / 20 |
| 2. Poisson blending | [50] / 50 |
| 3. Mixed gradients | [20] / 20 |
| 4. Quality of results / report | [10] / 10 |

**B&W**

| | |
|---|---|
| 5. Color2Gray | [0] / 20 |
| 6. Laplacian Pyramid Blending | [0] / 20 |
| 7. More gradient domain processing | [0] / 20 |

### 1. Toy problem

```
Max error is:  8.073677303210847e-06
```

### 2. Poisson blending

**Background Image**

**Object Image**

**Pasted image with source pixels directly on background**

**Final blend result**

**Background Image**

**Object Image**

**Pasted image with source pixels directly copied onto target**

**Final blend result**

## Failure Case:

**Background Image**

**Object Image**

**Pasted image with source pixels directly copied onto target**

**Final blend result**

This last case failed mainly because the background of our object image was very different in both texture and color from that of our background image. The sand is very dry and moving whereas the sand on the crab is wet and still. As a result, the gradients among the rows and columns of our object image compared with the background result in an image that is not blended together very well.

**3. Mixed gradients**

**Background Image**


**Object Image**


**Pasted image with source pixels directly copied onto target**


**Final blend result**

**Acknowledgments / Attribution**

**Sky image:** https://www.istockphoto.com/photos/sky
**Jet image:** https://www.aerotime.aero/articles/best-fighter-jets
**Alligator image:** https://www.istockphoto.com/photos/alligator-in-water?page=2
**Infinity pool image:** https://en.wikipedia.org/wiki/Infinity_pool
**Sand image:** https://www.cnbc.com/2021/03/05/sand-shortage-the-world-is-running-out-of-a-crucial-commodity.html
**Sand crab image:** https://dtmag.com/thelibrary/living-in-the-middle-of-nowhere-creatures-of-the-sand-and-rubble/
**Brown background image:** https://www.pexels.com/search/plain%20backgrounds/
**Woohoo image:** https://www.pinterest.com/itsmeashakaur/one-word-white-background/

# CS 445: Computational Photography

## Programming Project #3: Gradient Domain Fusion

```
from google.colab import drive
drive.mount('/content/drive', force_remount=True)
```

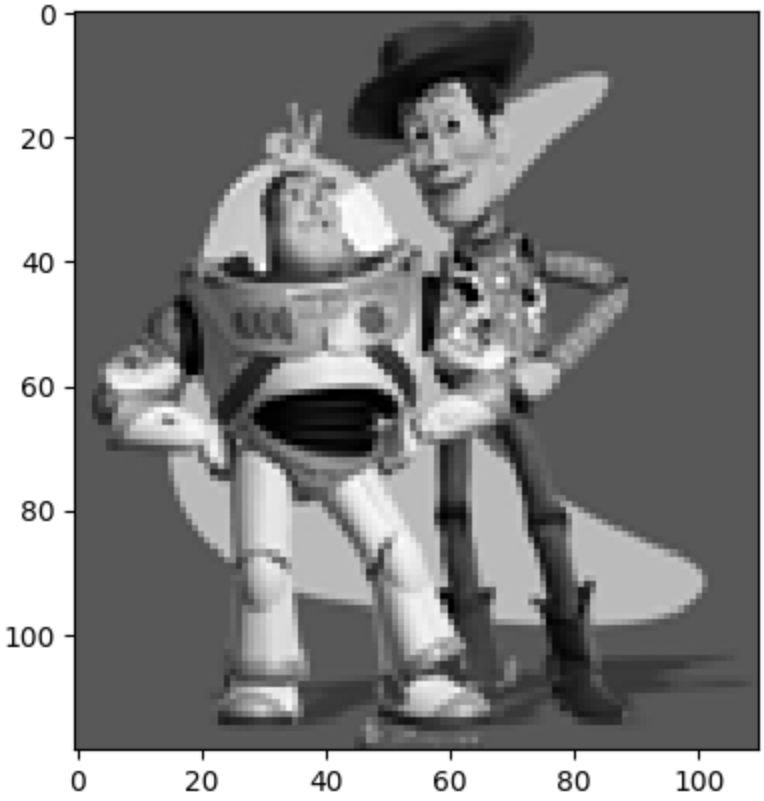
```
Mounted at /content/drive
```

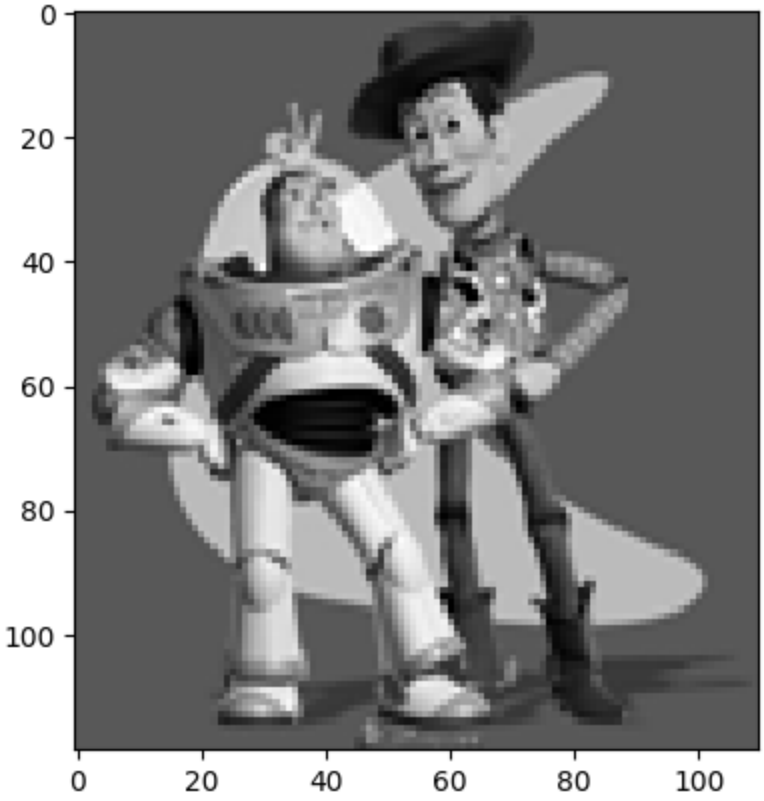
```
import cv2
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
import os
from random import random
import time
import scipy
import scipy.sparse.linalg

# modify to where you store your project data including utils.py
datadir = "/content/drive/My Drive/GradientDomainFunction/cs445_proj3_starter_code3/

utilfn = datadir + "utils.py"
!cp "$utilfn" .
samplesfn = datadir + "samples"
!cp -r "$samplesfn" .
import utils
```

## Part 1 Toy Problem (20 pts)

```
def toy_reconstruct(img):
    """
    The implementation for gradient domain processing is not complicated, but it is
    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
    3. minimize (v(1,1)-s(1,1))^2

    :param toy_img: numpy.ndarray
    """
    # Rows, columns, im2var
    r, c = img.shape
    im2var = np.arange(r*c).reshape(r, c)
```

```
    # Take the gradients of row, row+1 and col,col+1 (2*r*c gradients). Skip last ro
    neq = 1 + 2*r*c - r - c

    # Set up our matrices
    A = scipy.sparse.lil_matrix((neq, r*c), dtype='double')
    b = np.zeros((neq, 1), dtype='double')

    # Equation counter, Obj 3 (minimize start)
    e = 0
    A[e, im2var[0, 0]] = 1
    b[e] = img[0, 0]

    # Obj 1 (exclude last column)
    for i in range(r):
      for j in range(c - 1):
        e += 1
        A[e, im2var[i, j+1]] = 1
        A[e, im2var[i, j]] = -1
        b[e] = img[i, j+1] - img[i, j]

    # Obj 2 (exclude last row)
    for i in range(r - 1):
      for j in range(c):
        e += 1
        A[e, im2var[i+1, j]] = 1
        A[e, im2var[i, j]] = -1
        b[e] = img[i+1, j] - img[i, j]

    v = scipy.sparse.linalg.lsqr(A.tocsr(), b, atol=1e-8, btol=1e-8)[0]
    return v.reshape(r, c)


toy_img = cv2.cvtColor(cv2.imread('samples/toy_problem.png'), cv2.COLOR_BGR2GRAY).as
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()))
```

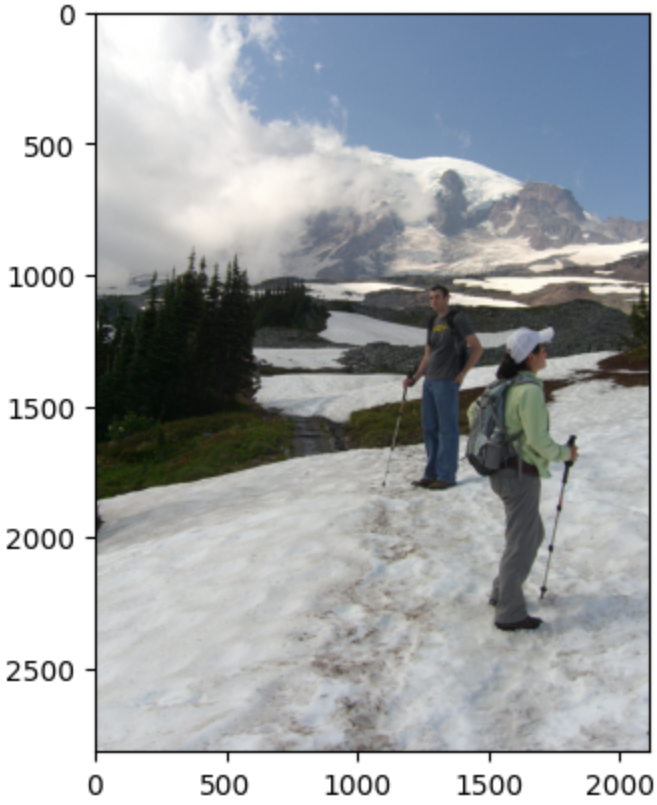


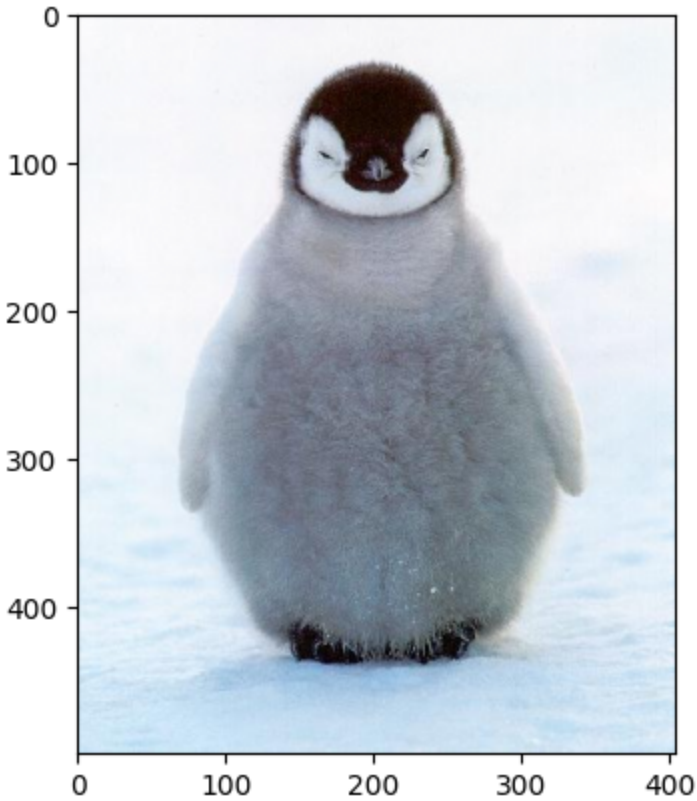




```
Max error is:  8.073677303210847e-06
```

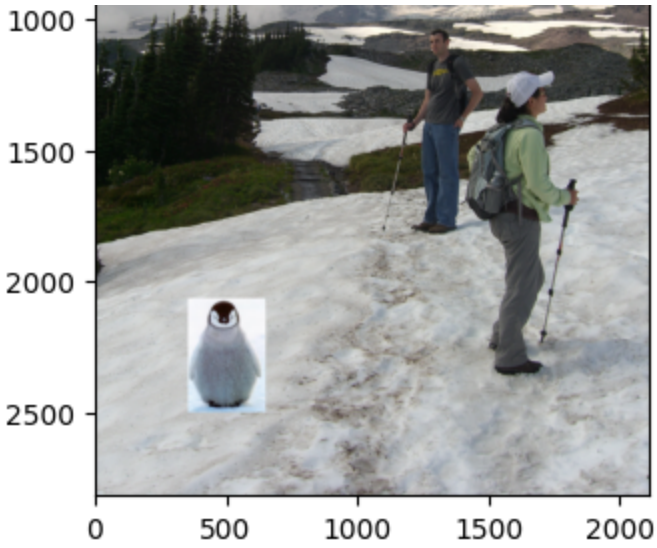
## Preparation

```
background_img = cv2.cvtColor(cv2.imread('samples/im2.JPG'), cv2.COLOR_BGR2RGB).asty
plt.figure()
plt.imshow(background_img)
plt.show()
object_img = cv2.cvtColor(cv2.imread('samples/penguin-chick.jpeg'), cv2.COLOR_BGR2RG
plt.imshow(object_img)
plt.show()

use_interface = False  # set to true if you want to use the interface to choose poin
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_mask)
  bg_ul = utils.upper_left_background_rc(object_mask, bottom_center)
  plt.imshow(utils.get_combined_img(background_img, object_img, object_mask, bg_ul))
```


0
500
1000
1500
2000
2500
0
500
1000
1500
2000


0
100
200
300
400
0
100
200
300
400


0
500




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

```
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)
```

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

```
if use_interface:
  %matplotlib inline
  import matplotlib.pyplot as plt

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

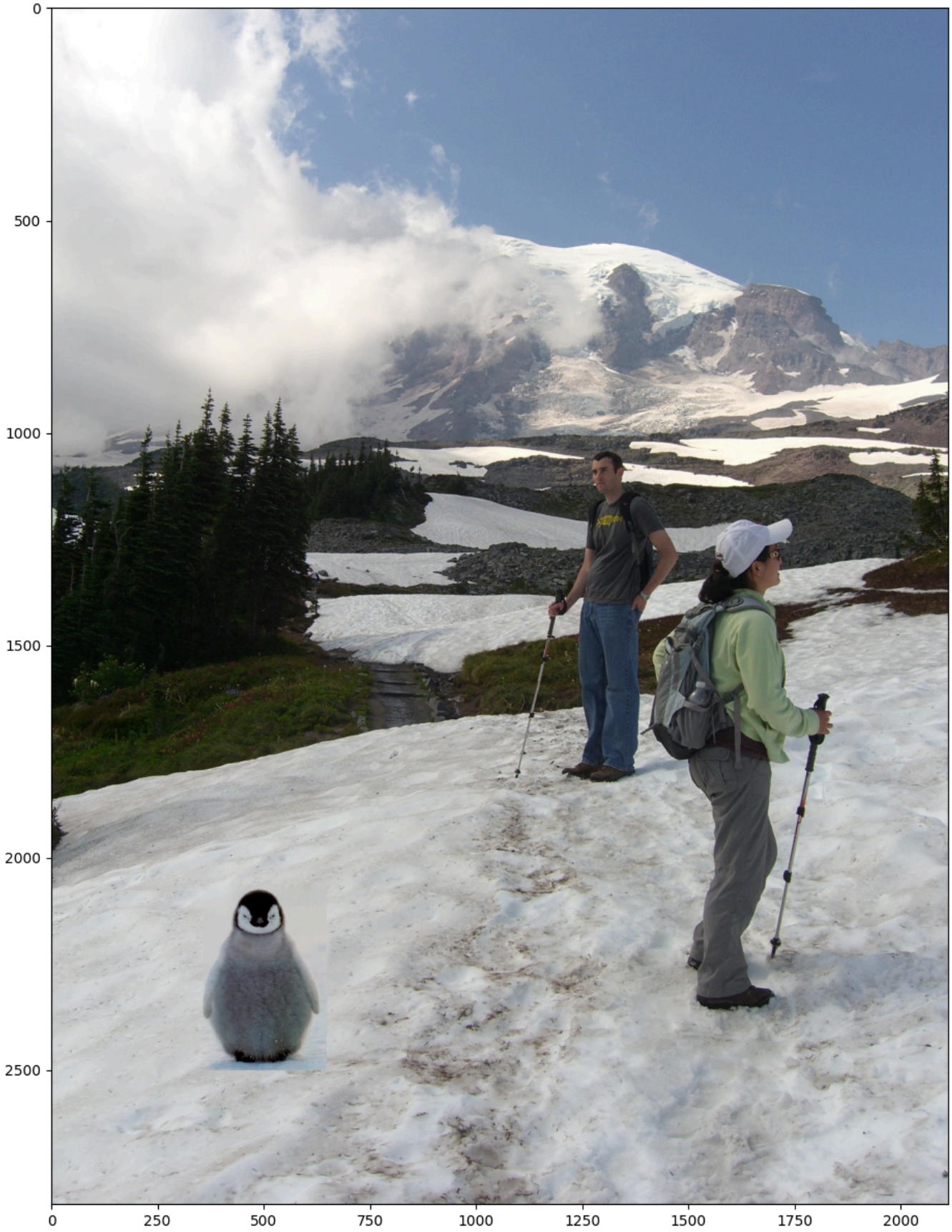
## Part 2 Poisson Blending (50 pts)

```
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 positi
    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 bg_img: the background image
    :param bg_ul: position (row, col) in background image corresponding to (0,0) of
    """
    # Size of our object image
    r, c = object_img.shape
    # Get x and y coords of where (0, 0) of object_img will be placed in bg_img
    xPos, yPos = bg_ul
    # Patch we are going to replace in bg image
    patch = bg_img[xPos:xPos + r, yPos:yPos + c]

    # Set up im2var
    im2var = np.arange(r*c).reshape(r, c)

    # Take the gradients of row, row+1 and col,col+1 (2*r*c gradients). Skip last ro
    neq = 2*r*c - r - c

    # Set up our matrices and equation counter
    A = scipy.sparse.lil_matrix((neq, r*c), dtype='double')
    b = np.zeros((neq, 1), dtype='double')
    e = 0

    # Obj 1 (exclude last column)
    for i in range(r):
      for j in range(c - 1):
        # If it is in our mask and equals 1, we need 2 equations
        if(object_mask[i][j] and object_mask[i][j+1] and object_mask[i][j] == 1):
          A[e, im2var[i, j+1]] = 1
          A[e, im2var[i, j]] = -1
          b[e] = object_img[i, j+1] - object_img[i, j]
        else:
          A[e, im2var[i, j+1]] = 1
          b[e] = object_img[i, j+1] - object_img[i, j] + patch[i, j]
        e += 1

    # Obj 2 (exclude last row)
    for i in range(r - 1):
      for j in range(c):
        # If it is in our mask, we need 2 equations
        if(object_mask[i][j] and object_mask[i+1][j] and object_mask[i][j] == 1):
          A[e, im2var[i+1, j]] = 1
          A[e, im2var[i, j]] = -1
          b[e] = object_img[i+1, j] - object_img[i, j]
        else:
          A[e, im2var[i+1, j]] = 1
          b[e] = object_img[i+1, j] - object_img[i, j] + patch[i, j]
        e += 1
```

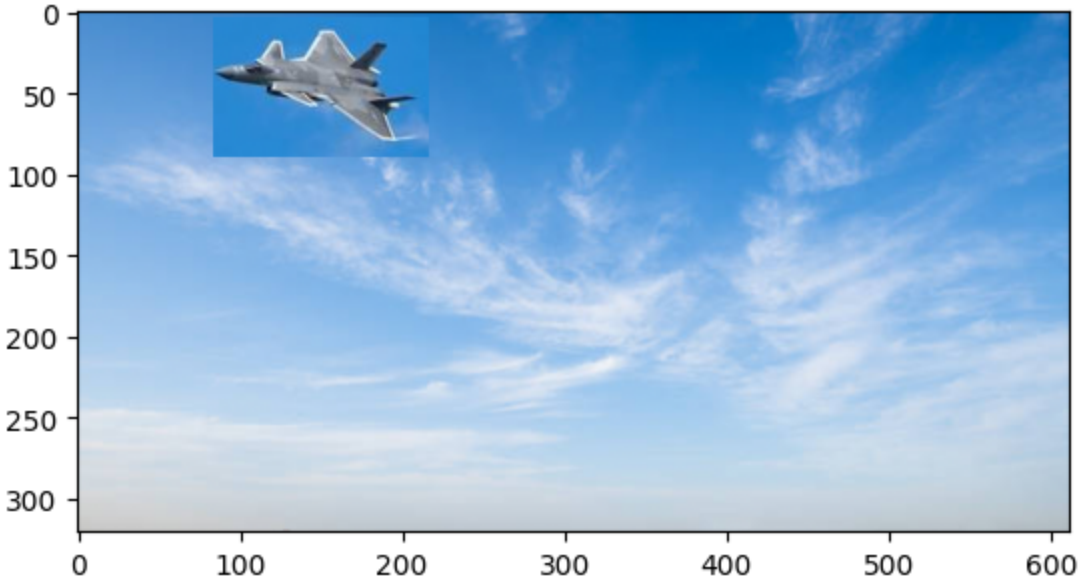
```
        v = scipy.sparse.linalg.lsqr(A.tocsr(), b, atol=1e-8, btol=1e-8)[0].reshape(r, c
        bg_img[xPos:xPos + r, yPos:yPos + c] = v
        return bg_img


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[:,:

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

```
WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
<matplotlib.image.AxesImage at 0x7800cb98b880>
```



```
background_img = cv2.cvtColor(cv2.imread('samples/sky.jpg'), cv2.COLOR_BGR2RGB).asty
plt.figure()
object_img = cv2.cvtColor(cv2.imread('samples/jet.jpg'), cv2.COLOR_BGR2RGB).astype('

use_interface = False  # set to true if you want to use the interface to choose poin
if not use_interface:
  xs = (5, 140, 140, 5)
  ys = (5, 5, 90, 90)
  object_mask = utils.get_mask(ys, xs, object_img)
  bottom_center = (150, 90) # (x,y)

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

```
<Figure size 640x480 with 0 Axes>
```




```
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[:,:
```

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

```
WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
<matplotlib.image.AxesImage at 0x7800bb3f92a0>
```


```
background_img = cv2.cvtColor(cv2.imread('samples/pool.jpg'), cv2.COLOR_BGR2RGB).ast
plt.figure()
object_img = cv2.cvtColor(cv2.imread('samples/alligator.jpg'), cv2.COLOR_BGR2RGB).as

use_interface = False  # set to true if you want to use the interface to choose poin
if not use_interface:
  xs = (85, 359, 359, 85)
  ys = (75, 75, 500, 500)
  object_mask = utils.get_mask(ys, xs, object_img)
  bottom_center = (250, 975) # (x,y)

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

```
<Figure size 640x480 with 0 Axes>
```


```
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[:,:

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

```
WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
<matplotlib.image.AxesImage at 0x7800ab945480>
```


## Part 3 Mixed Gradients (20 pts)

```
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
    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
    """
    # Size of our object image
    r, c = object_img.shape
```

# CS 445: Computational Photography

## Programming Project #3: Gradient Domain Fusion

[ ] ↳ *2 cells hidden*

## Part 1 Toy Problem (20 pts)

[ ] ↳ *2 cells hidden*

## Preparation

[ ] ↳ *5 cells hidden*

## Part 2 Poisson Blending (50 pts)

↳ *6 cells hidden*

## Part 3 Mixed Gradients (20 pts)

```
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
    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
    """
    # Size of our object image
    r, c = object_img.shape
    # Get x and y coords of where (0, 0) of object_img will be placed in bg_img
    xPos, yPos = bg_ul
    # Patch we are going to replace in bg image
    patch = bg_img[xPos:xPos + r, yPos:yPos + c]

    # Set up im2var
    im2var = np.arange(r*c).reshape(r, c)

    # Take the gradients of row, row+1 and col,col+1 (2*r*c gradients). Skip last ro
```

```
    neq = 2*r*c - r - c

    # Set up our matrices and equation counter
    A = scipy.sparse.lil_matrix((neq, r*c), dtype='double')
    b = np.zeros((neq, 1), dtype='double')
    e = 0

    # Obj 1 (exclude last column)
    for i in range(r):
      for j in range(c - 1):
        # If it is in our mask and equals 1, we need 2 equations
        if(object_mask[i][j] and object_mask[i][j+1] and object_mask[i][j] == 1):
          A[e, im2var[i, j+1]] = 1
          A[e, im2var[i, j]] = -1
          diff1 = object_img[i, j+1] - object_img[i, j]
          diff2 = patch[i, j+1] - patch[i, j]
          if(abs(diff1) > abs(diff2)): b[e] = diff1
          else: b[e] = diff2
        else:
          A[e, im2var[i, j+1]] = 1
          b[e] = object_img[i, j+1] - object_img[i, j] + patch[i, j]
        e += 1

    # Obj 2 (exclude last row)
    for i in range(r - 1):
      for j in range(c):
        # If it is in our mask, we need 2 equations
        if(object_mask[i][j] and object_mask[i+1][j] and object_mask[i][j] == 1):
          A[e, im2var[i+1, j]] = 1
          A[e, im2var[i, j]] = -1
          diff1 = object_img[i+1, j] - object_img[i, j]
          diff2 = patch[i+1, j] - patch[i, j]
          if(abs(diff1) > abs(diff2)): b[e] = diff1
          else: b[e] = diff2
        else:
          A[e, im2var[i+1, j]] = 1
          b[e] = object_img[i+1, j] - object_img[i, j] + patch[i, j]
        e += 1

    v = scipy.sparse.linalg.lsqr(A.tocsr(), b, atol=1e-8, btol=1e-8)[0].reshape(r, c
    bg_img[xPos:xPos + r, yPos:yPos + c] = v
    return bg_img



background_img = cv2.cvtColor(cv2.imread('samples/background.jpg'), cv2.COLOR_BGR2RG
plt.figure()
object_img = cv2.cvtColor(cv2.imread('samples/writing.jpg'), cv2.COLOR_BGR2RGB).asty

use_interface = False  # set to true if you want to use the interface to choose poin
if not use_interface:
```

```
  xs = (55, 185, 185, 55)
  ys = (75, 75, 150, 150)
  object_mask = utils.get_mask(ys, xs, object_img)
  bottom_center = (250, 200) # (x,y)

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

```
<Figure size 640x480 with 0 Axes>
```


```
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].

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

```
WARNING:matplotlib.image:Clipping input data to the valid range for imshow with
<matplotlib.image.AxesImage at 0x7800bb27eb00>
```