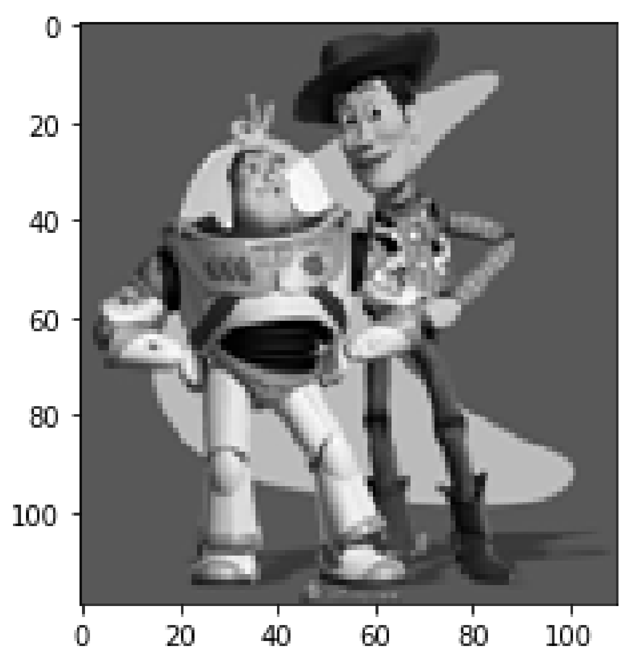
Project3

March 23, 2020

[1]:
```
import cv2
import numpy as np
%matplotlib inline
import matplotlib.pyplot as plt
from utils import *
import os
from numpy.linalg import lstsq
from scipy.sparse.linalg import lsqr, spsolve
from scipy.sparse import csr_matrix, lil_matrix, linalg
```

[2]:
```
toy_img = cv2.cvtColor(cv2.imread('samples/toy_problem.png'), cv2.COLOR_BGR2RGB)
toy_img = cv2.cvtColor(toy_img, cv2.COLOR_BGR2GRAY).astype('double') / 255.0
plt.imshow(toy_img, cmap="gray")
```

[2]: <matplotlib.image.AxesImage at 0x127aece50>



0.1 Part 1 Toy Problem (20 pts)

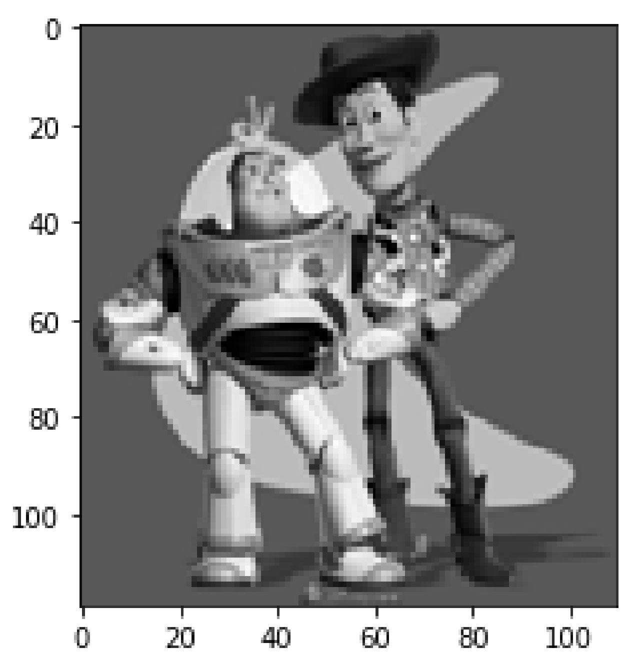
```
[3]: def toy_reconstruct(toy_img):
         """
         The implementation for gradient domain processing is not complicated, but␣
      ↪it is easy to make a mistake, so let's start with a toy example. Reconstruct␣
      ↪this image from its gradient values, plus one pixel intensity. Denote the␣
      ↪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
         """
         im = toy_img
         # Matrix "im2var" maps each pixel to a variable number
         im_h, im_w = im.shape[0], im.shape[1]
         im2var = np.arange(im_h*im_w).reshape(im_w, im_h).T

         # sparse matrixes for A and b to add constraints
         # y*(x-1) + (y-1)*x+1
         n_constraints = im_h*(im_w-1) + (im_h-1)*im_w+1
         total_pixels = im_h*im_w
         # print("Constraints", n_constraints)
         # A = lil_matrix((n_constraints, total_pixels), dtype=np.float64)
         A = np.zeros((n_constraints, total_pixels), dtype=np.float64)
         b = np.zeros(n_constraints, dtype=np.float64)
         # print("Sparse Matrixes", A, b, A.shape, b.shape) #(25952, 13090) (25952,)

         # setup objective 3
         e = 0
         A[e][im2var[0][0]] = 1
         b[e]  = im[0][0]
         e = e + 1; # Equation counter

         # for each pixel, calculate gradient
         for y in range(im_h):
             for x in range(im_w):

                 #Solve AX = B for every pixel under the mask.
                 # objective 1
                 if x != im2var.shape[1] - 1:
                     A[e, im2var[y][x+1]] = 1
                     A[e, im2var[y][x]] = -1
```

```
                b[e] = im[y][x+1] - im[y][x]
                e = e + 1

            # objective 2
            if y != im2var.shape[0] - 1:
                A[e, im2var[y+1][x]] = 1
                A[e, im2var[y][x]] = -1
                b[e] = im[y+1][x] - im[y][x]
                e = e + 1

    # solve for v with least square. start with v = scipy.sparse.linalg.lsqr(A,␣
↪b);
    v = lsqr(csr_matrix(A, dtype=np.float64), b)

    # img with 1 channel
    response = np.resize(v[0],(im_w, im_h)).T
    return response
```

[4]:
```
im_out = toy_reconstruct(toy_img)
if im_out.any():
    print("Error is: ", np.sqrt(((im_out - toy_img)**2).sum()))
plt.imshow(im_out, cmap='gray')
```

```
Error is:  0.00031701850079458095
```

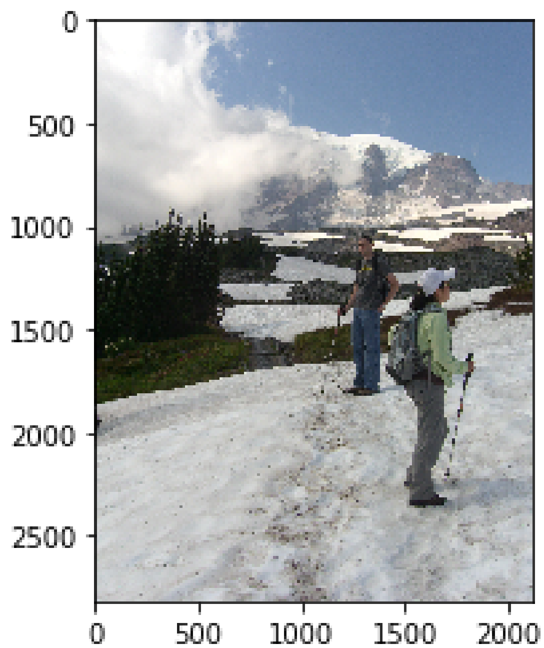
[4]: <matplotlib.image.AxesImage at 0x1048c8c10>



0.2 Preparation

[5]:
```
# Feel free to change image
background_img = cv2.cvtColor(cv2.imread('samples/im2.JPG'), cv2.COLOR_BGR2RGB).
↪astype('double') / 255.0
plt.figure()
plt.imshow(background_img)
```

[5]: <matplotlib.image.AxesImage at 0x12803df50>

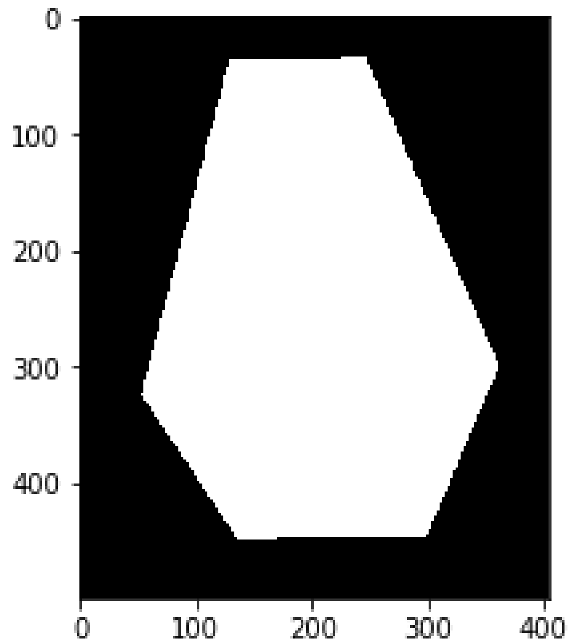


[7]:
```
# Feel free to change image
object_img = cv2.cvtColor(cv2.imread('samples/penguin-chick.jpeg'), cv2.
↪COLOR_BGR2RGB).astype('double') / 255.0
import matplotlib.pyplot as plt
%matplotlib notebook
mask_coords = specify_mask(object_img)
```

```
If it doesn't get you to the drawing mode, then rerun this function again.
<IPython.core.display.Javascript object>


<IPython.core.display.HTML object>
```

[8]:
```
xs = mask_coords[0]
ys = mask_coords[1]
%matplotlib inline
import matplotlib.pyplot as plt
plt.figure()
mask = get_mask(ys, xs, object_img)
```

```
<Figure size 432x288 with 0 Axes>
```



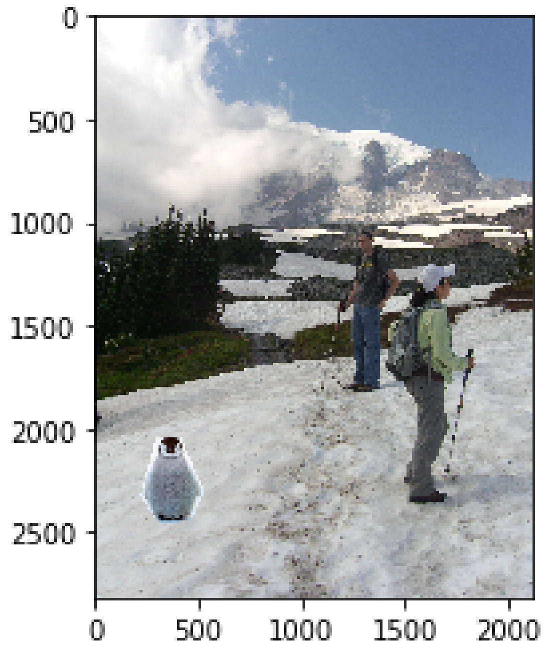
[9]:
```
%matplotlib notebook
import matplotlib.pyplot as plt
bottom_center = specify_bottom_center(background_img)
```

```
If it doesn't get you to the drawing mode, then rerun this function again. Also,
make sure the object fill fit into the background image. Otherwise it will crash
```

```
<IPython.core.display.Javascript object>
```

```
<IPython.core.display.HTML object>
```

[10]:
```
%matplotlib inline
import matplotlib.pyplot as plt
cropped_object, object_mask = align_source(object_img, mask, background_img,␣
↪bottom_center)
```



0.3 Part 2 Poisson Blending (50 pts)

[11]:
```
def poisson_blend(cropped_object, object_mask, background_img):
    """
    :param cropped_object: numpy.ndarray One you get from align_source
    :param object_mask: numpy.ndarray One you get from align_source
    :param background_img: numpy.ndarray
    """
    im = cropped_object;
    im_h, im_w = im.shape[0],im.shape[1]
    # print("Image Check", im_h, im_w)

    # Setup Results/Output Response
    output = np.zeros((im_h, im_w, 3), dtype=np.float64)

    # 3 Channels
    imageChannel = [
        cropped_object[:,:,0],
        cropped_object[:,:,1],
        cropped_object[:,:,2]
    ]

    channelNumber = 1
    channelIndex = 0
```

```
    for im in imageChannel:
        print("Starting Channel #" + str(channelNumber))
        # Setting up im2var = np.arange(im_h * im_w).reshape(im_h, im_w) with␣
↪object mask
        im2var = []
        count = 0
        for row in range(im_h):
            tempColumn = []
            for column in range(im_w):
                if object_mask[row][column] == 1:
                    tempColumn.append(count)
                    count+=1
                else:
                    tempColumn.append(0)
            im2var.append(tempColumn)
        #print("im2var", im2var)
        #n_constraints = 2*im_h*(im_w-1) + 2*(im_h-1)*im_w + 1
        n_constraints = 4*count + 1
        total_pixels = count
        #print("Constraints, Pixels", n_constraints, count)

        # sparse matrix for A and b
        A = lil_matrix((n_constraints,total_pixels),dtype=np.float64)
        #A = np.zeros((n_constraints,total_pixels),dtype=np.float64)
        b = np.zeros(n_constraints,dtype=np.float64)
        # print("Sparse Matrixes", A, b, A.shape, b.shape)
        e = 0

        #print("Calculating Gradient for Each Pixel")
        for y in range(im_h):
            for x in range(im_w):
                if object_mask[y][x]==1:
                    #1. x+1
                    if object_mask[y][x+1] == 1:
                        A[e, im2var[y][x]] = 1
                        A[e, im2var[y][x+1]] = -1
                        b[e] = im[y][x] - im[y][x+1]
                    else:
                        A[e, im2var[y][x]] = 1
                        b[e] = im[y][x] - im[y][x+1] +␣
↪background_img[y][x+1][channelIndex]
                    e = e + 1

                    #2. y+1
                    if object_mask[y+1][x] == 1:
                        A[e, im2var[y][x]] = 1
                        A[e, im2var[y+1][x]] = -1
```

```
                        b[e] =  im[y][x] - im[y+1][x]
                    else:
                        A[e, im2var[y][x]] = 1
                        b[e] = im[y][x] - im[y+1][x] + background_img[y+1][x][channelIndex]
                    e = e + 1

                    #3. x-1
                    if object_mask[y][x-1] == 1:
                        A[e, im2var[y][x]] = 1
                        A[e, im2var[y][x-1]] = -1
                        b[e] =  im[y][x] - im[y][x-1]
                    else:
                        A[e, im2var[y][x]] = 1
                        b[e] = im[y][x] - im[y][x-1] + background_img[y][x-1][channelIndex]
                    e = e + 1

                    #4. y-1
                    if object_mask[y-1][x] == 1:
                        A[e, im2var[y][x]] = 1
                        A[e, im2var[y-1][x]] = -1
                        b[e] = im[y][x] - im[y-1][x]
                    else:
                        A[e, im2var[y][x]] = 1
                        b[e] = im[y][x] - im[y-1][x] + background_img[y-1][x][channelIndex]
                    e = e + 1

        print("Constraint Solving V with Least Square.")
        v = lsqr(csr_matrix(A, dtype=np.float64), b)

        # Copy the solves values into target image.
        solveCount = 0
        for row in range(im_h):
            for column in range(im_w):
                if object_mask[row][column] == 1:
                    output[row][column][channelIndex] = v[0][solveCount]
                    solveCount += 1
                else:
                    output[row][column][channelIndex] = background_img[row][column][channelIndex]

        # Next Channel
        channelIndex += 1
        channelNumber += 1
```

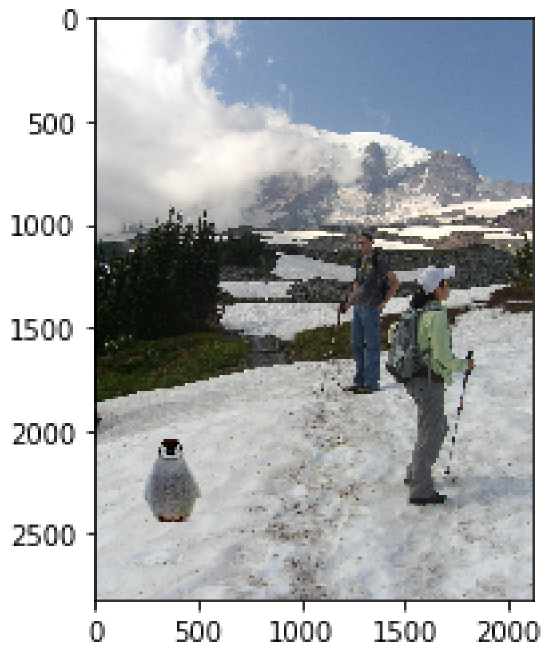
```
    print("Blending Complete")
    return output
```

[12]:
```
im_blend = poisson_blend(cropped_object, object_mask, background_img)
if im_blend.any():
    %matplotlib inline
    import matplotlib.pyplot as plt
    plt.imshow(im_blend)
```

```
Starting Channel #1
Constraint Solving V with Least Square.
Starting Channel #2
Constraint Solving V with Least Square.
Starting Channel #3
Constraint Solving V with Least Square.
```

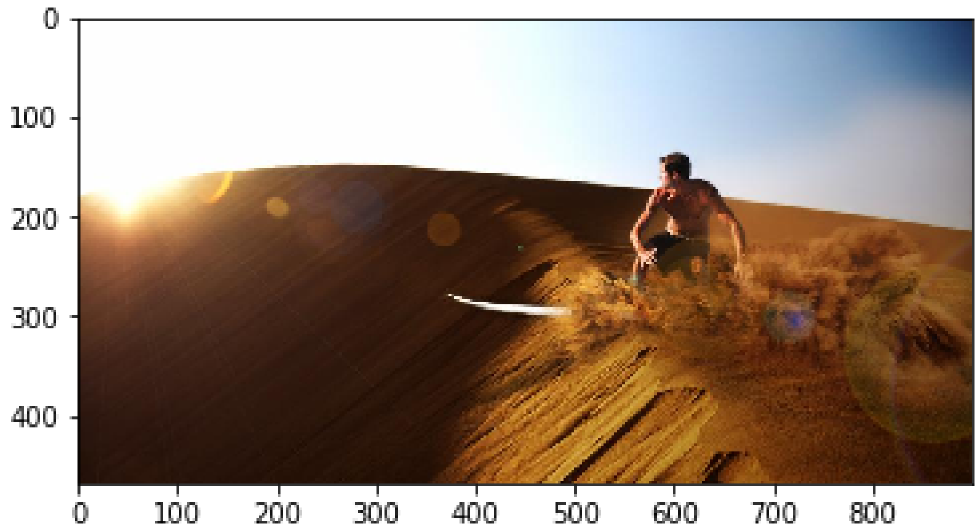
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

```
Blending Complete
```



[13]:
```
# Image 1
background_img2 = cv2.cvtColor(cv2.imread('samples/1-Target.JPG'), cv2.
 ↪COLOR_BGR2RGB).astype('double') / 255.0
plt.figure()
plt.imshow(background_img2)
```

[13]: <matplotlib.image.AxesImage at 0x127fadfd0>



[15]:
```
object_img2 = cv2.cvtColor(cv2.imread('samples/1-Source.JPG'), cv2.
 ↪COLOR_BGR2RGB).astype('double') / 255.0
import matplotlib.pyplot as plt
%matplotlib notebook
mask_coords2 = specify_mask(object_img2)
```

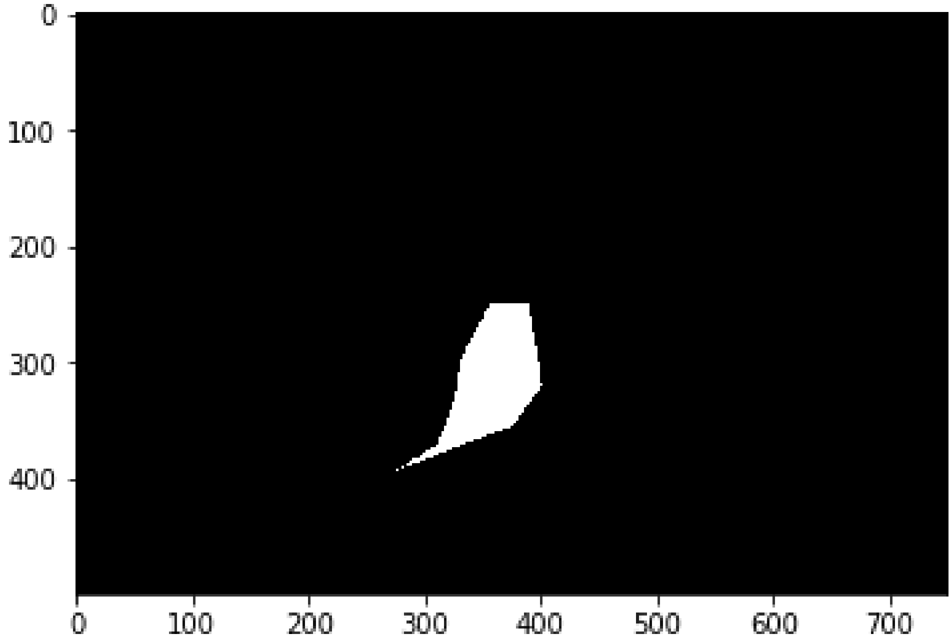
If it doesn't get you to the drawing mode, then rerun this function again.

<IPython.core.display.Javascript object>

<IPython.core.display.HTML object>

[16]:
```
xs2 = mask_coords2[0]
ys2 = mask_coords2[1]
%matplotlib inline
import matplotlib.pyplot as plt
plt.figure()
mask2 = get_mask(ys2, xs2, object_img2)
```

<Figure size 432x288 with 0 Axes>



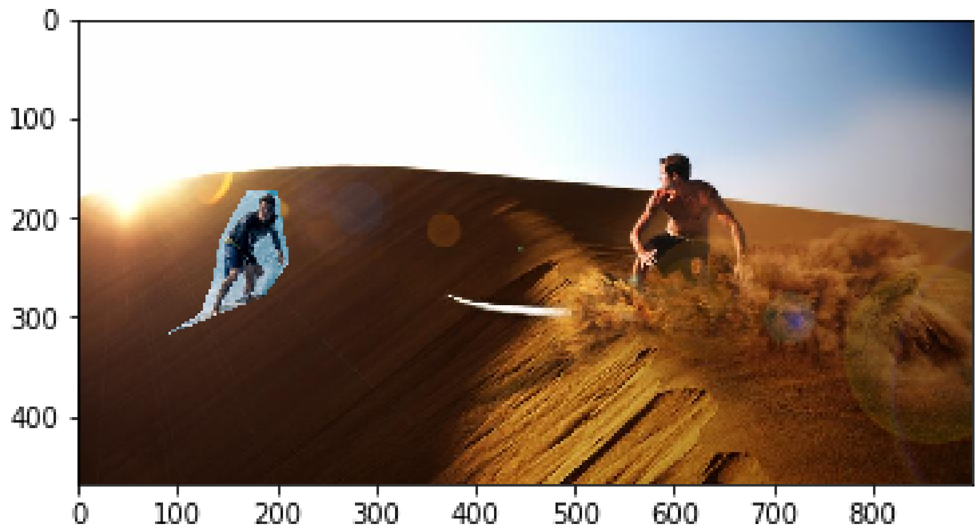
[17]:
```
%matplotlib notebook
import matplotlib.pyplot as plt
bottom_center2 = specify_bottom_center(background_img2)
```

```
If it doesn't get you to the drawing mode, then rerun this function again. Also,
make sure the object fill fit into the background image. Otherwise it will crash
```

<IPython.core.display.Javascript object>

<IPython.core.display.HTML object>

[18]:
```
%matplotlib inline
import matplotlib.pyplot as plt
cropped_object2, object_mask2 = align_source(object_img2, mask2,␣
 ↪background_img2, bottom_center2)
```

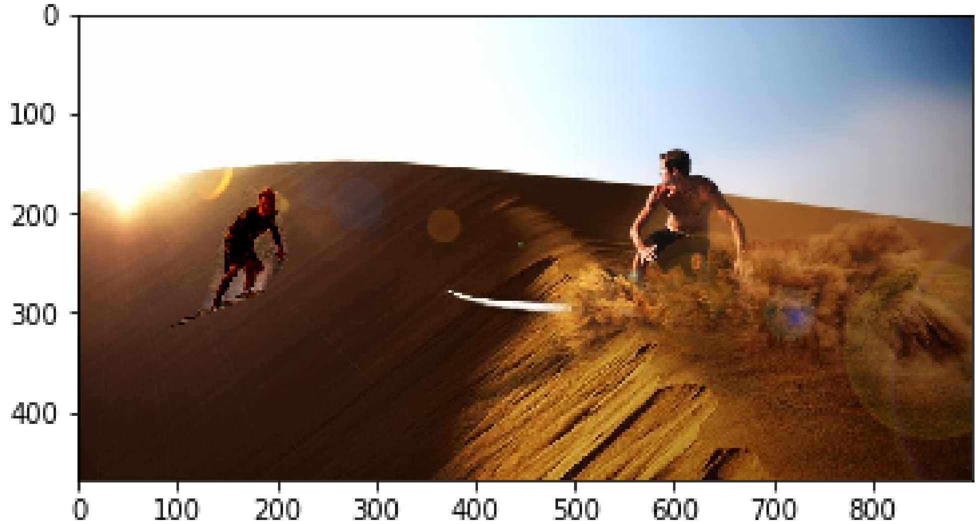


[19]:
```
im_blend2 = poisson_blend(cropped_object2, object_mask2, background_img2)
if im_blend.any():
    %matplotlib inline
    import matplotlib.pyplot as plt
    plt.imshow(im_blend2)
```

```
Starting Channel #1
Constraint Solving V with Least Square.
Starting Channel #2
Constraint Solving V with Least Square.
Starting Channel #3
Constraint Solving V with Least Square.
```

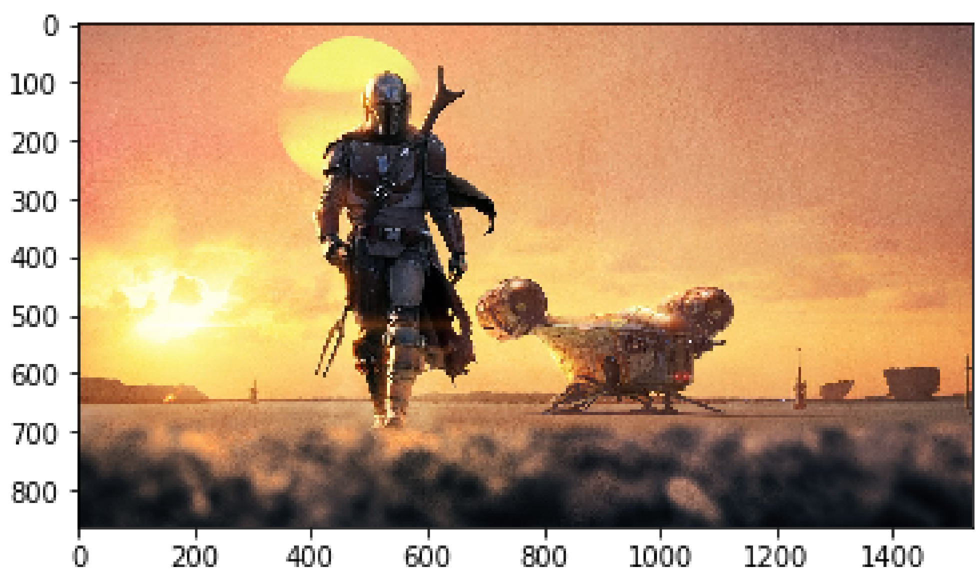
```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

```
Blending Complete
```



[20]:
```
# Image 2
background_img3 = cv2.cvtColor(cv2.imread('samples/2-Target.JPG'), cv2.
 ↪COLOR_BGR2RGB).astype('double') / 255.0
plt.figure()
plt.imshow(background_img3)
```

[20]: <matplotlib.image.AxesImage at 0x13fd04710>



[22]:
```
object_img3 = cv2.cvtColor(cv2.imread('samples/2-Source.PNG'), cv2.
↪COLOR_BGR2RGB).astype('double') / 255.0
import matplotlib.pyplot as plt
%matplotlib notebook
mask_coords3 = specify_mask(object_img3)
```

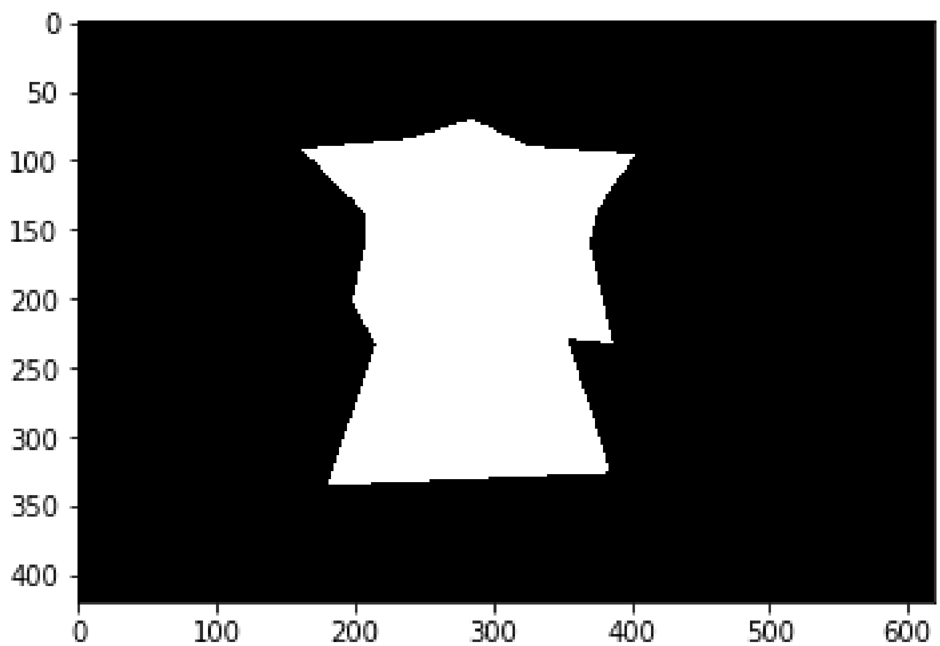
If it doesn't get you to the drawing mode, then rerun this function again.

<IPython.core.display.Javascript object>

<IPython.core.display.HTML object>

[23]:
```
xs3 = mask_coords3[0]
ys3 = mask_coords3[1]
%matplotlib inline
import matplotlib.pyplot as plt
plt.figure()
mask3 = get_mask(ys3, xs3, object_img3)
```

<Figure size 432x288 with 0 Axes>



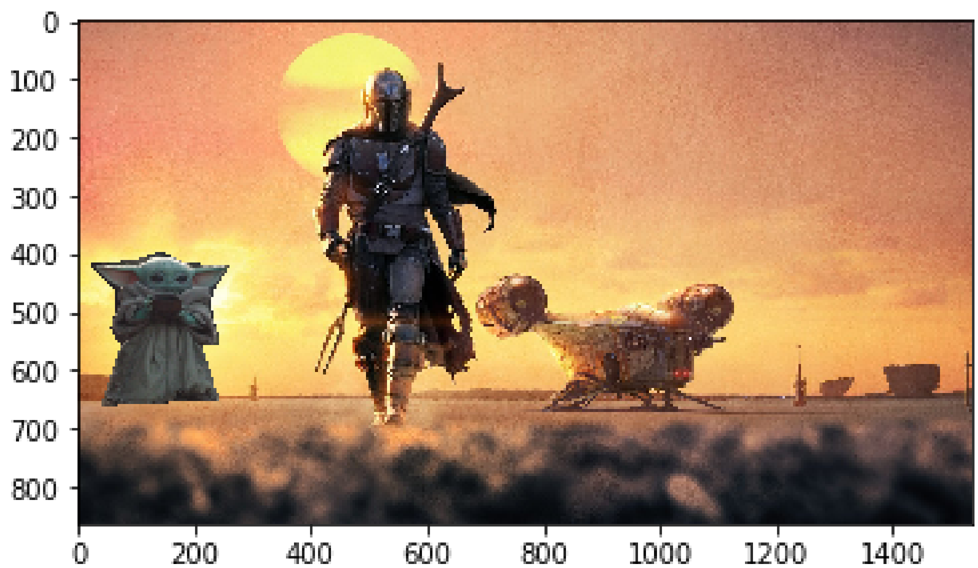
[24]:
```
%matplotlib notebook
import matplotlib.pyplot as plt
bottom_center3 = specify_bottom_center(background_img3)
```

If it doesn't get you to the drawing mode, then rerun this function again. Also, make sure the object fill fit into the background image. Otherwise it will crash

<IPython.core.display.Javascript object>

<IPython.core.display.HTML object>

[25]:
```
%matplotlib inline
import matplotlib.pyplot as plt
cropped_object3, object_mask3 = align_source(object_img3, mask3,␣
↪background_img3, bottom_center3)
```

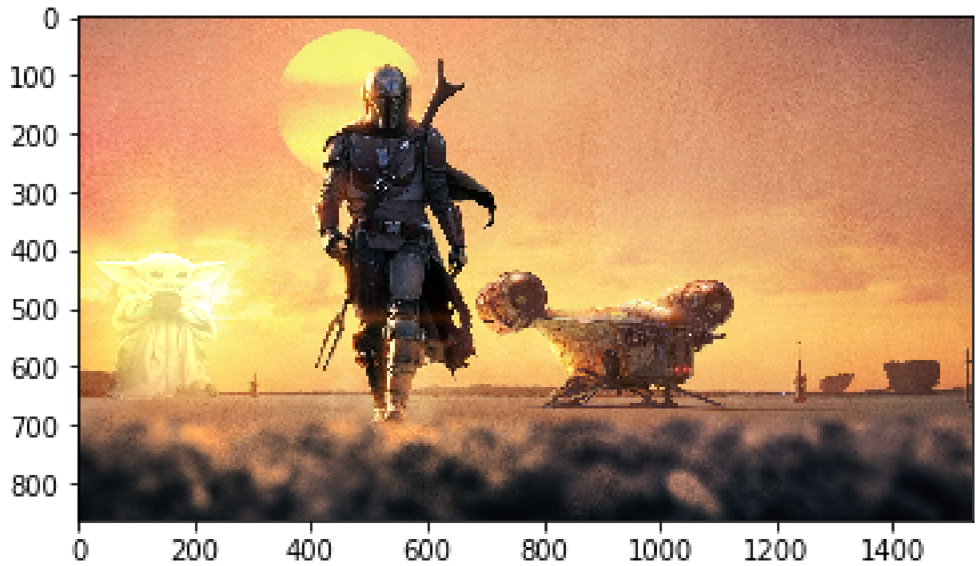


[26]:
```
im_blend3 = poisson_blend(cropped_object3, object_mask3, background_img3)
if im_blend.any():
    %matplotlib inline
    import matplotlib.pyplot as plt
    plt.imshow(im_blend3)
```

```
Starting Channel #1
Constraint Solving V with Least Square.
Starting Channel #2
Constraint Solving V with Least Square.
Starting Channel #3
Constraint Solving V with Least Square.
```

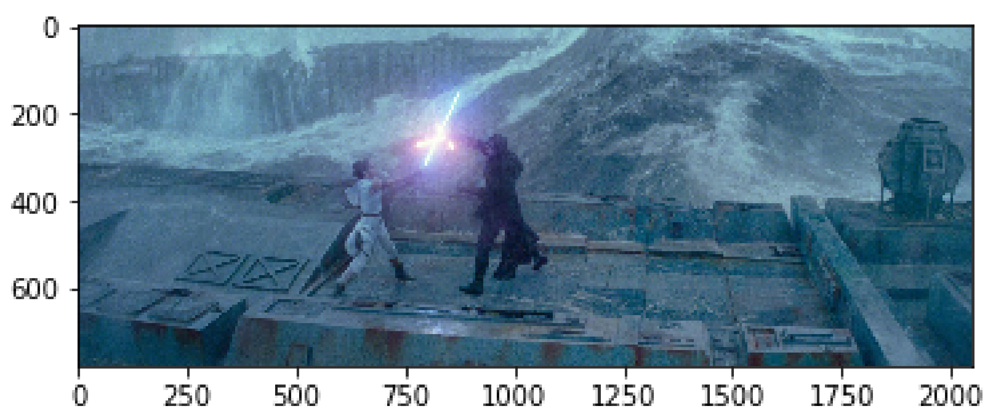
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).

Blending Complete



[27]:
```
# Image 3
background_img4 = cv2.cvtColor(cv2.imread('samples/3-Target.JPG'), cv2.
 ↪COLOR_BGR2RGB).astype('double') / 255.0
plt.figure()
plt.imshow(background_img4)
```

[27]: <matplotlib.image.AxesImage at 0x12823b690>



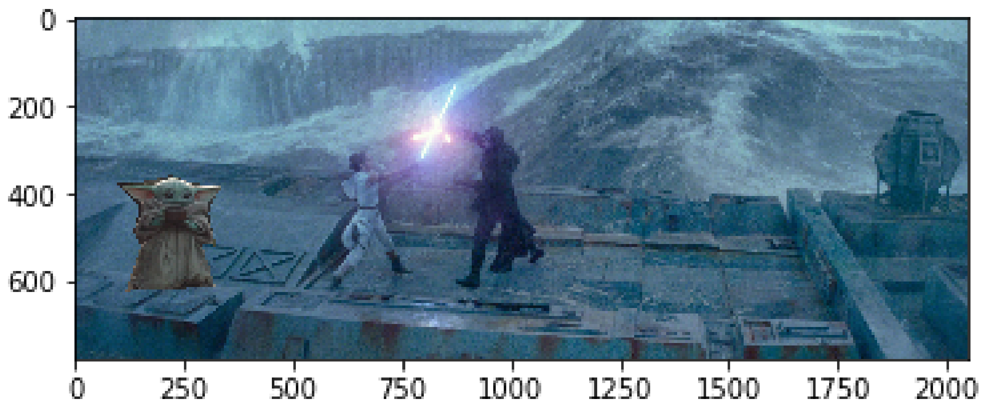
[29]:
```
%matplotlib notebook
import matplotlib.pyplot as plt
bottom_center4 = specify_bottom_center(background_img4)
```

If it doesn't get you to the drawing mode, then rerun this function again. Also, make sure the object fill fit into the background image. Otherwise it will crash

<IPython.core.display.Javascript object>

<IPython.core.display.HTML object>

[30]:
```
%matplotlib inline
import matplotlib.pyplot as plt
cropped_object4, object_mask4 = align_source(object_img3, mask3,␣
↪background_img4, bottom_center4)
```

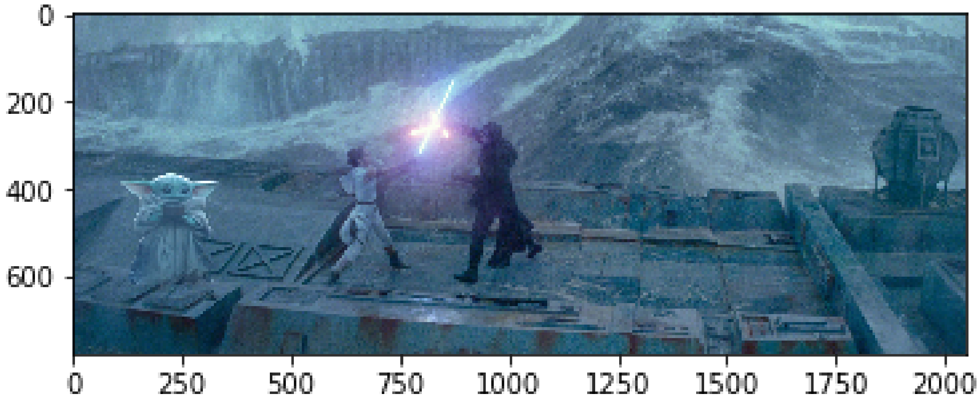


[31]:
```
im_blend4 = poisson_blend(cropped_object4, object_mask4, background_img4)
if im_blend.any():
    %matplotlib inline
    import matplotlib.pyplot as plt
    plt.imshow(im_blend4)
```

```
Starting Channel #1
Constraint Solving V with Least Square.
Starting Channel #2
Constraint Solving V with Least Square.
Starting Channel #3
Constraint Solving V with Least Square.
```

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

```
Blending Complete
```



0.4 Part 3 Mixed Gradients (20 pts)

[32]:
```
#"d_ij" is the value of the gradient from the source or the target image with␣
↪larger magnitude.
#Note that larger magnitude is not the same as greater value. -> use abs()
def d_ij(source_x, source_y, target_x, target_y):
    sourceValue = source_x - source_y
    targetValue = target_x - target_y
    sourceMagnitude = abs(sourceValue)
    targetMagnitude = abs(targetValue)
    if (sourceMagnitude > targetMagnitude):
        return sourceValue
    else:
        return targetValue

def mix_blend(cropped_object, object_mask, background_img):
    """
    :param cropped_object: numpy.ndarray One you get from align_source
    :param object_mask: numpy.ndarray One you get from align_source
    :param background_img: numpy.ndarray
    """
    im = cropped_object/255;
    im_h, im_w = im.shape[0],im.shape[1]
    # print("Image Check", im_h, im_w)

    # Setup Results/Output Response
    output = np.zeros((im_h, im_w, 3), dtype=np.float64)

    # 3 Channels
    imageChannel = [
        cropped_object[:,:,0],
        cropped_object[:,:,1],
```

```
        cropped_object[:,:,2]
    ]

    channelNumber = 1
    channelIndex = 0

    for im in imageChannel:
        print("Starting Channel #" + str(channelNumber))
        # Setting up im2var = np.arange(im_h * im_w).reshape(im_h, im_w) with␣
↪object mask
        im2var = []
        count = 0
        for row in range(im_h):
            tempColumn = []
            for column in range(im_w):
                if object_mask[row][column] == 1:
                    tempColumn.append(count)
                    count+=1
                else:
                    tempColumn.append(0)
            im2var.append(tempColumn)

        #print("im2var", im2var)
        #n_constraints = 2*im_h*(im_w-1) + 2*(im_h-1)*im_w + 1
        n_constraints = 4*count + 1
        total_pixels = count
        #print("Constraints, Pixels", n_constraints, count)

        # sparse matrix for A and b
        A = lil_matrix((n_constraints,total_pixels),dtype=np.float64)
        #A = np.zeros((n_constraints,total_pixels),dtype=np.float64)
        b = np.zeros(n_constraints,dtype=np.float64)
        # print("Sparse Matrixes", A, b, A.shape, b.shape)
        e = 0

        #print("Calculating Gradient for Each Pixel")
        for y in range(im_h):
            for x in range(im_w):
                if object_mask[y][x]==1:
                    #1. x+1
                    if object_mask[y][x+1] == 1:
                        A[e, im2var[y][x]] = 1
                        A[e, im2var[y][x+1]] = -1
                        b[e] = d_ij(im[y][x], im[y][x+1],␣
↪background_img[y][x][channelIndex], background_img[y][x+1][channelIndex])
                    else:
                        A[e, im2var[y][x]] = 1
```

```
                    b[e] = d_ij(im[y][x], im[y][x+1],␣
↪background_img[y][x][channelIndex], background_img[y][x+1][channelIndex]) +␣
↪background_img[y][x+1][channelIndex]
                e = e + 1

                #2. y+1
                if object_mask[y+1][x] == 1:
                    A[e, im2var[y][x]] = 1
                    A[e, im2var[y+1][x]] = -1
                    b[e] = d_ij(im[y][x], im[y+1][x],␣
↪background_img[y][x][channelIndex], background_img[y+1][x][channelIndex])
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = d_ij(im[y][x], im[y+1][x],␣
↪background_img[y][x][channelIndex], background_img[y+1][x][channelIndex]) +␣
↪background_img[y+1][x][channelIndex]
                e = e + 1

                #3. x-1
                if object_mask[y][x-1] == 1:
                    A[e, im2var[y][x]] = 1
                    A[e, im2var[y][x-1]] = -1
                    b[e] = d_ij(im[y][x], im[y][x-1],␣
↪background_img[y][x][channelIndex], background_img[y][x-1][channelIndex])
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = d_ij(im[y][x], im[y][x-1],␣
↪background_img[y][x][channelIndex], background_img[y][x-1][channelIndex]) +␣
↪background_img[y][x-1][channelIndex]
                e = e + 1

                #4. y-1
                if object_mask[y-1][x] == 1:
                    A[e, im2var[y][x]] = 1
                    A[e, im2var[y-1][x]] = -1
                    b[e] = d_ij(im[y][x], im[y-1][x],␣
↪background_img[y][x][channelIndex], background_img[y-1][x][channelIndex])
                else:
                    A[e, im2var[y][x]] = 1
                    b[e] = d_ij(im[y][x], im[y-1][x],␣
↪background_img[y][x][channelIndex], background_img[y-1][x][channelIndex]) +␣
↪background_img[y-1][x][channelIndex]
                e = e + 1

        print("Constraint Solving V with Least Square.")
        v = lsqr(csr_matrix(A, dtype=np.float64), b)
```

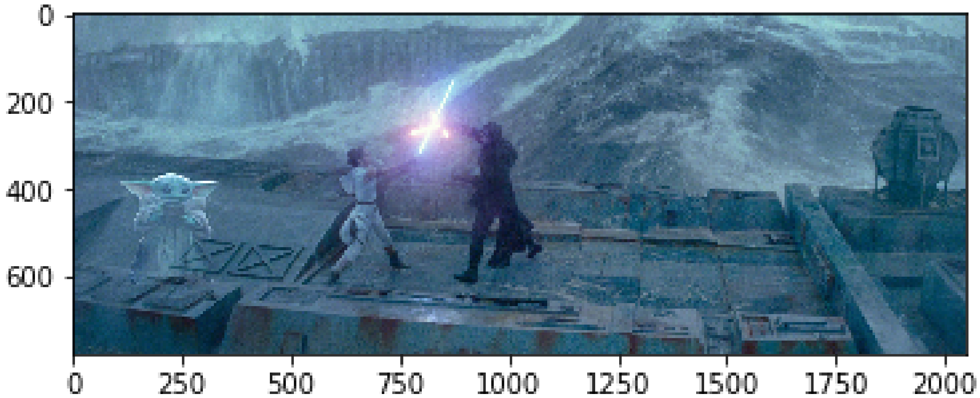
```
        # Copy the solves values into target image.
        solveCount = 0
        for row in range(im_h):
            for column in range(im_w):
                if object_mask[row][column] == 1:
                    output[row][column][channelIndex] = v[0][solveCount]
                    solveCount += 1
                else:
                    output[row][column][channelIndex] =␣
↪background_img[row][column][channelIndex]

        # Next Channel
        channelIndex += 1
        channelNumber += 1

    print("Blending Complete")
    return output
```

[33]:
```
# Image Set 1
im_mix = mix_blend(cropped_object4, object_mask4, background_img4)
if im_mix.any():
    %matplotlib inline
    import matplotlib.pyplot as plt
    plt.imshow(im_mix)
```

```
Starting Channel #1
Constraint Solving V with Least Square.
Starting Channel #2
Constraint Solving V with Least Square.
Starting Channel #3
Constraint Solving V with Least Square.
```

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

```
Blending Complete
```

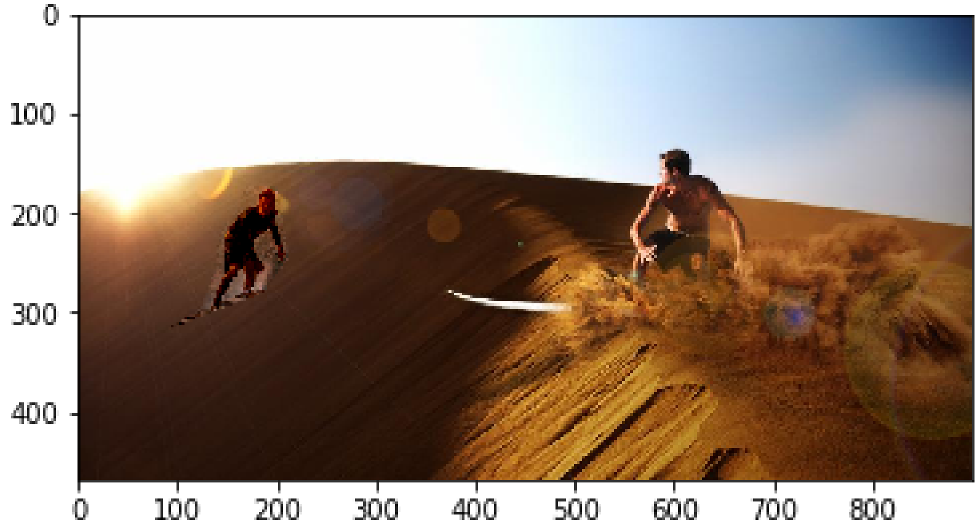


[34]:
```
# Image Set 2
im_mix1 = mix_blend(cropped_object2, object_mask2, background_img2)
if im_mix.any():
    %matplotlib inline
    import matplotlib.pyplot as plt
    plt.imshow(im_mix1)
```

```
Starting Channel #1
Constraint Solving V with Least Square.
Starting Channel #2
Constraint Solving V with Least Square.
Starting Channel #3
Constraint Solving V with Least Square.
```

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

```
Blending Complete
```

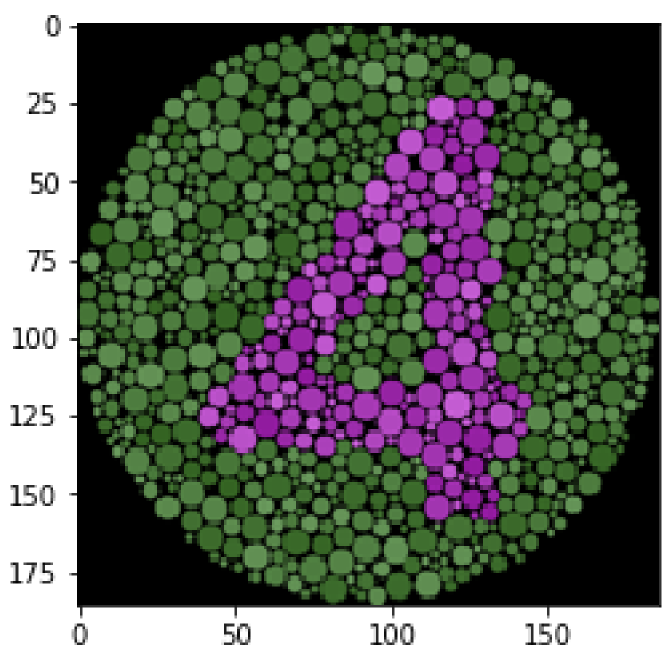


1 Bells & Whistles (Extra Points)

1.1 Color2Gray (20 pts)

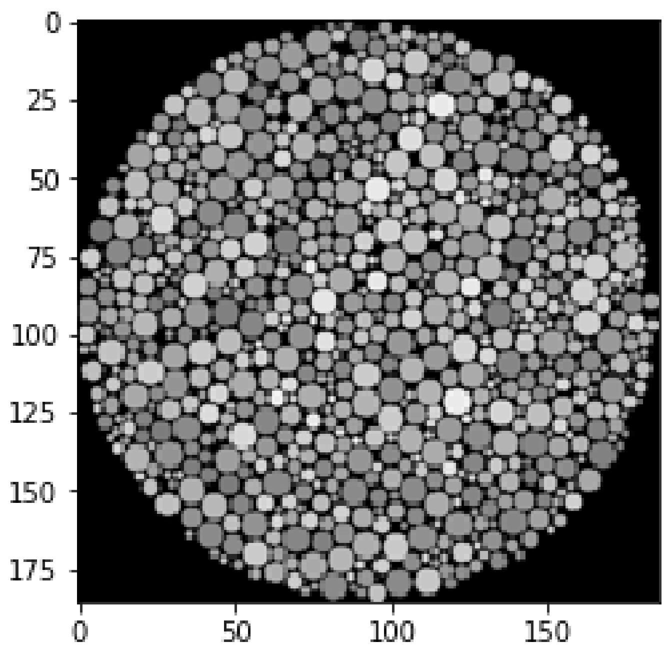
[36]:
```
colorBlind4 = cv2.imread('samples/colorBlind4.png')
plt.imshow(colorBlind4)
```

[36]: <matplotlib.image.AxesImage at 0x13fb0de90>



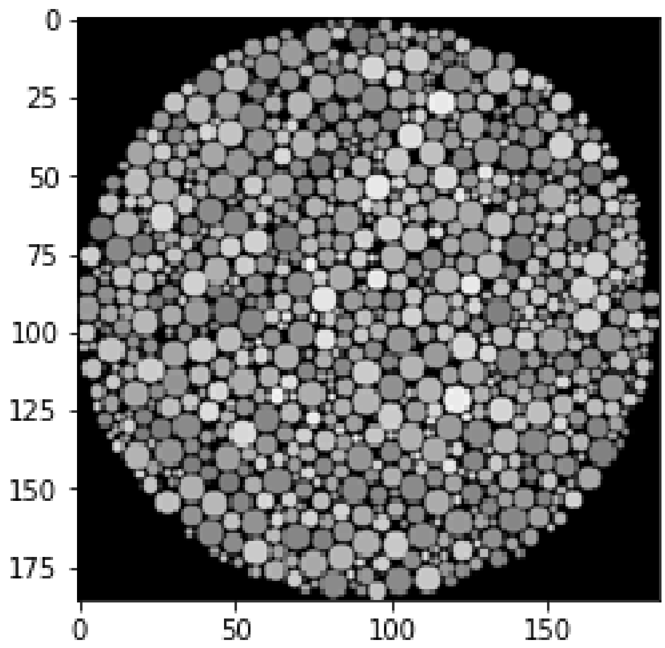
[37]:
```
grey4 = cv2.cvtColor(colorBlind4, cv2.COLOR_BGR2GRAY)
plt.imshow(grey4, cmap="gray")
```

[37]: <matplotlib.image.AxesImage at 0x13fcb6dd0>



[38]:
```
colorBlind8 = cv2.imread('samples/colorBlind8.png')
grey8 = cv2.cvtColor(cv2.imread('samples/colorBlind4.png'), cv2.COLOR_BGR2GRAY).
 ↪astype('double') / 255.0
plt.imshow(grey8, cmap="gray")
```

[38]: <matplotlib.image.AxesImage at 0x12a346210>



[46]:
```
# Copied over toy problem + mixed gradient functions & update gradient␣
↪calculation.
def grayGradient(source_i, source_j):
    maximum = 0
    channel = 0
    while channel < 3:
        diff = source_i[channel] - source_j[channel]
        if abs(diff) > abs(maximum):
            maximum = diff
        channel+=1
    return maximum
# minimum setup
#     minimum = 1000
#     channel = 0
#     while channel < 3:
#         diff = source_i[channel] - source_j[channel]
#         if abs(diff) < abs(minimum):
#             minimum = diff
#         channel+=1
#     return min
# average setup
#     total = 0
#     channel = 0
#     while channel < 3:
#         diff = source_i[channel] - source_j[channel]
```

```
#         total += diff
#         channel+=1
#     return total/3

def color2gray(img):
    im = img
    im_h, im_w = im.shape[0], im.shape[1]
    im2var = np.arange(im_h*im_w).reshape(im_w, im_h).T

    n_constraints = im_h*(im_w-1) + (im_h-1)*im_w+1
    total_pixels = im_h*im_w
    A = np.zeros((n_constraints, total_pixels), dtype=np.float64)
    b = np.zeros(n_constraints, dtype=np.float64)

    e = 0
    A[e][im2var[0][0]] = 1
    b[e] = 0
    e = e + 1;

    for y in range(im_h):
        for x in range(im_w):
            if x != im2var.shape[1] - 1:
                A[e, im2var[y][x]] = 1
                A[e, im2var[y][x+1]] = -1
                #A[e, im2var[y][x]] = -1
                #A[e, im2var[y][x+1]] = 1
                b[e] = grayGradient(im[y][x], im[y][x+1])
                e = e + 1

            if y != im2var.shape[0] - 1:
                A[e, im2var[y][x]] = 1
                A[e, im2var[y+1][x]] = -1
                #A[e, im2var[y][x]] = -1
                #A[e, im2var[y+1][x]] = 1
                b[e] = grayGradient(im[y][x], im[y+1][x])
                e = e + 1

    print("Ready")
    v = lsqr(csr_matrix(A, dtype=np.float64), b)
    print("Done")
    response = np.resize(v[0],(im_w, im_h)).T
    return response
```

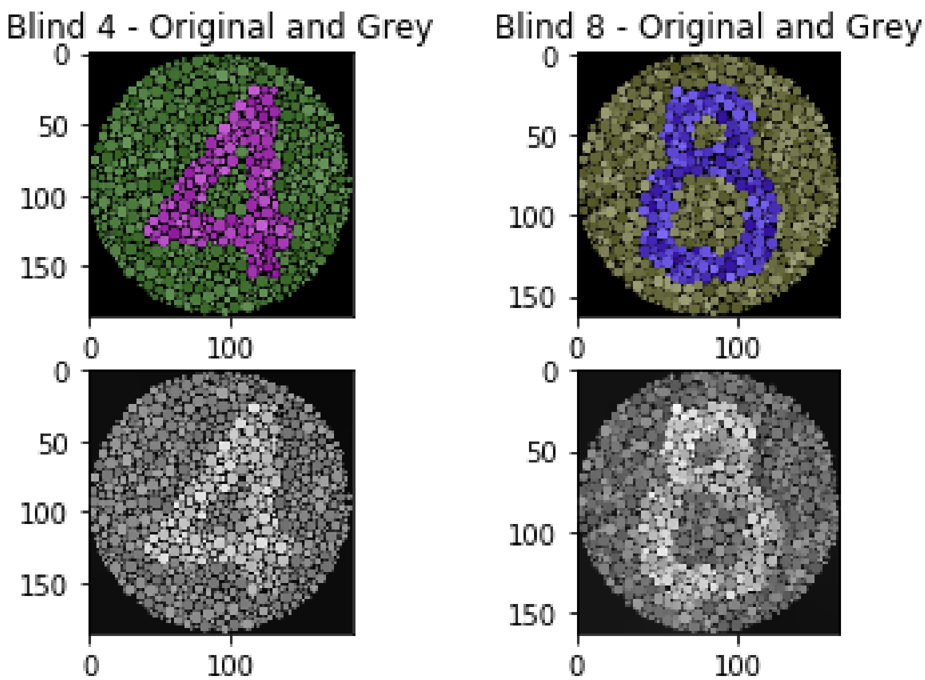
[47]:
```
userGrey4 = color2gray(colorBlind4.astype("float64"))
userGrey8 = color2gray(colorBlind8.astype("float64"))
```

```
Ready
```

```
Done
Ready
Done
```

[48]:
```python
fig, axes = plt.subplots(2, 2)
axes[0, 0].imshow(colorBlind4)
axes[0, 0].set_title('Blind 4 - Original and Grey')
axes[0, 1].imshow(colorBlind8)
axes[0, 1].set_title('Blind 8 - Original and Grey')
axes[1, 0].imshow(userGrey4, cmap='gray')
axes[1, 1].imshow(userGrey8, cmap='gray')
```

[48]: <matplotlib.image.AxesImage at 0x1437c87d0>



1.2 Laplacian pyramid blending (20 pts)

[49]:
```python
# def laplacian_blend(img1, img2):
#     pass

def gaussianPyramid(image, levels):
    down = image.copy()
    gaussianPyr = [down]
    for i in range(levels):
        down = cv2.pyrDown(down)
```

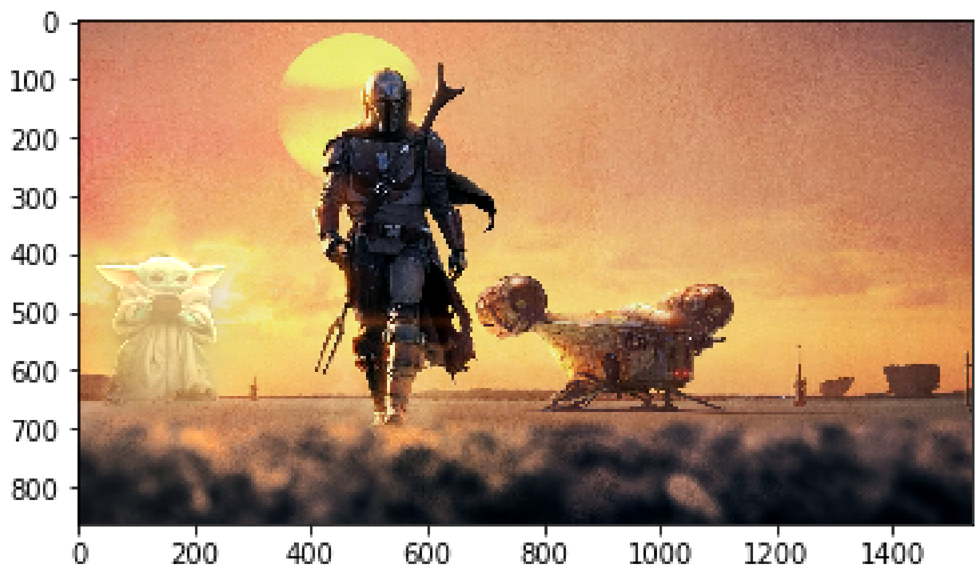
```
        gaussianPyr.append(np.float64(down))
    return gaussianPyr

def laplacianPyramid(gaussianPyr):
    levels = len(gaussianPyr) - 1
    laplacianPyramidOutput = [gaussianPyr[levels-1]]
    for i in range(levels - 1 , 0, -1):
        gaussianUp = cv2.pyrUp(gaussianPyr[i])[:gaussianPyr[i-1].shape[0], :
↪gaussianPyr[i-1].shape[1],:]
        laplacianUp = np.subtract(gaussianPyr[i-1], gaussianUp)
        laplacianPyramidOutput.append(np.float64(laplacianUp))
    return laplacianPyramidOutput

def laplacian_blend(img1, img2, objMask):
    # Mask setup, img1 is cropped_object
    mask = np.zeros((img1.shape[0], img2.shape[1], 3), dtype=np.float64)
    for i in range(3):
        mask[:,:,i] = objMask

#     mask = [
#         objMask[:,:,0],
#         objMask[:,:,1],
#         objMask[:,:,2]
#     ]
    levels = 100

    # gaussian pyramids for both images and mask
    gaussianPyramidImage1 = gaussianPyramid(img1, levels)
    gaussianPyramidImage2 = gaussianPyramid(img2, levels)
    gaussianPyramindMask = gaussianPyramid(mask, levels)
    gaussianPyramindMask.reverse()

    # laplacian pyramids for both images
    laplacianPyramidImage1 = laplacianPyramid(gaussianPyramidImage1)
    laplacianPyramidImage2 = laplacianPyramid(gaussianPyramidImage2)

    # Blend each level according to mask
    LS = []
    for la, lb, mask in zip(laplacianPyramidImage1, laplacianPyramidImage2,␣
↪gaussianPyramindMask[1:]):
        ls = la * mask + lb * (1.0 - mask)
        LS.append(ls)

    # Reconstruct
    laplacianResult = LS[0]
    for i in range(1, levels):
        laplacianUp = cv2.pyrUp(laplacianResult)
```

```
        laplacianResult = cv2.add(laplacianUp[:LS[i].shape[0],:LS[i].shape[1]],␣
↪np.float64(LS[i]))

    return laplacianResult
```

[50]:
```
laplacianResult = laplacian_blend(cropped_object3, background_img3,␣
↪object_mask3)
plt.imshow(laplacianResult)
```

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

[50]: <matplotlib.image.AxesImage at 0x12a329f10>



[51]:
```
laplacianResult = laplacian_blend(cropped_object4, background_img4,␣
↪object_mask4)
plt.imshow(laplacianResult)
```

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

[51]: <matplotlib.image.AxesImage at 0x128a98e50>

1.3 More gradient domain processing (up to 20 pts)

[52]:
```
# Texture transfer
def allPatches(sample, patch_size):
    allPatchesDict = {}
    countIndex = 0
    #print("Sample", sample.shape)
    for x in range(sample.shape[0]):
        if sample.shape[0] - x < patch_size:
            break
        for y in range(sample.shape[1]):
            #print("Sample[0, 1]", sample.shape[0], sample.shape[1])
            if sample.shape[1] - y < patch_size:
                continue
            allPatchesDict[countIndex] = sample[x : x + patch_size, y : y +␣
↪patch_size, :]
            countIndex += 1
    #print("All Patches", allPatchesDict)
    return allPatchesDict

def ssd_patch2(M, T, I):
    template = np.zeros(I.shape)
    template[:,:,0], template[:,:,1], template[:,:,2] = M * I[:,:,0], M * I[:,:
↪,1], M * I[:,:,2]
    return np.sum((T - template) ** 2, -1)

def addSampleToResultImage(x, y, overlap, patch_size, updatedSample, output):
    overlapPixels = overlap // 2
    endX = x + patch_size
    endY = y + patch_size
```

```
    if x == 0 and y == 0:
        output[x : endX, y : endY] = updatedSample
    elif x == 0 and y != 0:
        output[x: endX, y + overlapPixels : endY] = updatedSample[:,␣
↪overlapPixels:, :]
    elif x != 0 and y == 0:
        output[x + overlapPixels : endX, y : endY] =␣
↪updatedSample[overlapPixels:, :, :]
    else:
        output[x + overlapPixels : endX, y + overlapPixels : endY] =␣
↪updatedSample[overlapPixels:, overlapPixels:, :]

def choose_sample_with_extra_cost(targetImage, patch_size, M, T, tol,␣
↪allPatchesDict):
    tolerance = tol
    imageCosts = {}
    imageCostSSD = {}
    candidates = []
    imageCostsArray = []
    randomIndex = (np.random.choice(len(allPatchesDict), int(0.01 *␣
↪len(allPatchesDict))))

    for i in randomIndex:
        # calculating the additional cost. as noted from the paper
        alpha = np.sum(M) / (M.shape[0] * M.shape[1])
        cost = ssd_patch2(M, T, allPatchesDict[i])
        cost2 = ssd_patch2(np.ones([patch_size, patch_size]), targetImage,␣
↪allPatchesDict[i])
        imageCosts[i] = alpha * np.sum(cost) + (1 - alpha) * np.sum(cost2)
        imageCostSSD[i] = cost

    minc = min(imageCosts.values())
    for key in imageCosts.keys():
        if imageCosts[key] <= minc * (1 + tolerance):
            candidates.append(allPatchesDict[key])
            imageCostsArray.append(imageCostSSD[key])

    randomIndexSelection = np.random.choice(len(candidates))
    return candidates[randomIndexSelection],␣
↪imageCostsArray[randomIndexSelection]

def cut(err_patch):
    # create padding on top and bottom with very large cost
    padding = np.expand_dims(np.ones(err_patch.shape[1]).T*1e10,0)
    err_patch = np.concatenate((padding, err_patch, padding), axis=0)
    h, w = err_patch.shape
```

```python
    path = np.zeros([h,w], dtype="int")
    cost = np.zeros([h,w])
    cost[:,0] = err_patch[:, 0]
    cost[0,:] = err_patch[0, :]
    cost[cost.shape[0]-1,:] = err_patch[err_patch.shape[0]-1, :]

    # for each column, compute the cheapest connected path to the left
    # cost of path for each row from left upper/same/lower pixel
    for x in range(1,w):
        # cost of path for each row from left upper/same/lower pixel
        tmp = np.vstack((cost[0:h-2,x-1], cost[1:h-1, x-1], cost[2:h, x-1]))
        mi = tmp.argmin(axis=0)
        path[1:h-1, x] = np.arange(1, h-1, 1).T + mi # save the next step of␣
↪the path
        cost[1:h-1, x] = cost[path[1:h-1, x] - 1, x-1] + err_patch[1:h-1, x]

    path = path[1:path.shape[0]-1, :] - 1
    cost = cost[1:cost.shape[0]-1, :]

    # create the mask based on the best path
    mask = np.zeros(path.shape, dtype="int")
    best_path = np.zeros(path.shape[1], dtype="int")
    best_path[len(best_path)-1] = np.argmin(cost[:, cost.shape[1]-1]) + 1
    mask[0:best_path[best_path.shape[0]-1], mask.shape[1]-1] = 1
    for x in range(best_path.size-1, 0, -1):
        best_path[x-1] = path[best_path[x]-1, x]
        mask[:best_path[x-1], x-1] = 1
    mask ^= 1
    return mask

def texture_transfer(texture, target, patch_size, overlap, tol):
    texture = texture.copy() / 255.0
    output = target.copy() / 255.0
    patches = allPatches(texture, patch_size)

    for x in range(0, target.shape[0], patch_size - overlap):
        overlapX = x + overlap
        endX = x + patch_size
        if target.shape[0] - x < patch_size:
            break
        for y in range(0, target.shape[1], patch_size - overlap):
            overlapY = y + overlap
            endY = y + patch_size
            if target.shape[1] - y < patch_size:
                continue
            M = (output[x : endX, y : endY, 0] != 0).astype(int)
            T = (output[x : endX, y : endY, :])
```

```
            newTexturedImage, cost = choose_sample_with_extra_cost(output[x:
↪endX, y:endY], patch_size, M, T, tol, patches)

            if x == 0 and y == 0:
                addSampleToResultImage(x, y, overlap, patch_size,␣
↪newTexturedImage, output)
            elif x == 0 and y != 0:
                template = cost[:, 0 : overlap]
                mask1 = cut(template.T).T
                overlappedRegion = output[x : endX, y: overlapY, :]
                for z in range(3):
                    overlappedRegion[:,:,z] = newTexturedImage[:,:overlap,z] *␣
↪mask1  + (1 - mask1) * overlappedRegion[:,:,z]
                output[x:endX, overlapY:endY,:] = newTexturedImage[:, overlap:,:
↪]
            elif x != 0 and y == 0:
                mask2 = cut(cost[0 : overlap, :])
                overlappedRegion = output[x : overlapX, y: endY, :]
                for z in range(3):
                    overlappedRegion[:,:,z] =  newTexturedImage[:overlap,:,z] *␣
↪mask2  + (1 - mask2) * overlappedRegion[:,:,z]
                output[overlapX:endX, y:endY,:] = newTexturedImage[overlap:,:,:]
            else:
                template = cost[:, 0 : overlap]
                mask3 = cut(template.T).T
                overlappedRegion = output[x : endX, y: overlapY, :]
                for z in range(3):
                    overlappedRegion[:,:,z] = newTexturedImage[:,:overlap,z] *␣
↪mask3  + (1 - mask3) * overlappedRegion[:,:,z]
                mask4 = cut(cost[0 : overlap, :])
                overlappedRegion = output[x : overlapX, y: endY, :]
                for z in range(3):
                    overlappedRegion[:,:,z] =  newTexturedImage[:overlap,:,z] *␣
↪mask4  + (1 - mask4) * overlappedRegion[:,:,z]
                output[overlapX:endX, overlapY:endY,:] =␣
↪newTexturedImage[overlap:,overlap:,:]
    return output
```

[54]:

```
# Image Result #1.
# background_img4 = cv2.cvtColor(cv2.imread('samples/3-Target.JPG'), cv2.
↪COLOR_BGR2RGB).astype('double') / 255.0
backTT = cv2.pyrDown(background_img4)
objTT = cv2.pyrDown(cropped_object4)
ttResult = texture_transfer(objTT, backTT, 150, 50, 0.5)
plt.imshow(ttResult)
```

[54]: <matplotlib.image.AxesImage at 0x1b82e7350>