In [1]:

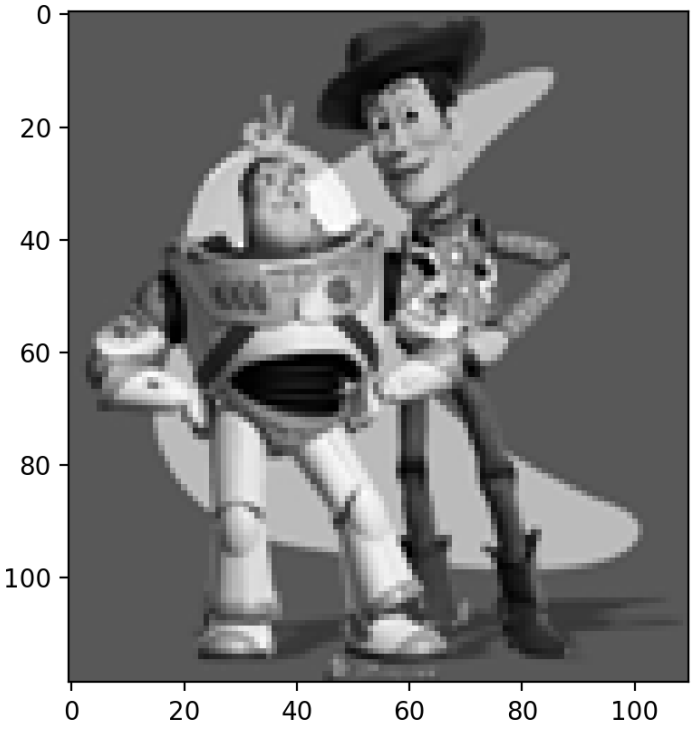
```
import cv2
import numpy as np
%matplotlib notebook
import matplotlib.pyplot as plt
from utils import *
import os

from scipy.sparse import csr_matrix, lil_matrix
from scipy.sparse.linalg import lsqr
from scipy.signal import correlate2d
from scipy.misc import imresize
```

In [2]:

```
def plot_no_frame(img, path=None, title=None, cmap=None):
    fig = plt.figure(frameon=False)
    ax = plt.Axes(fig, [0., 0., 1., 1.])
    ax.set_axis_off()
    fig.add_axes(ax)

    dpi = fig.get_dpi()
    fig.set_size_inches(img.shape[1]/float(dpi), img.shape[0]/float(dpi))

    if cmap is not None:
        ax.imshow(img, cmap=cmap)
    else:
        ax.imshow(img)

    if path is not None:
        fig.savefig(path)

    return fig
```

In [3]:

```
toy_img = cv2.cvtColor(cv2.imread('samples/toy_problem.png'), cv2.COLOR_BGR2GRAY
)
plt.imshow(toy_img, cmap='gray')
```



Out[3]:

```
<matplotlib.image.AxesImage at 0x11e431c88>
```

Part 1 Toy Problem (20 pts)

In [4]:

```
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 i
mage 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 e
ach 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_h, im_w = toy_img.shape
    im2var = np.arange(im_h * im_w).reshape(im_w, im_h).T

    A = np.zeros((im_h*im_w*2 + 1 - im_h - im_w, im_h*im_w))
    b = np.zeros( im_h*im_w*2 + 1 - im_h - im_w)

    toy_img_f = toy_img.astype(np.float32)

    e = 0
    for h in range(im_h):
        for w in range(im_w):
            if h+1 < im_h:
                A[e][im2var[h+1][w]] = 1
                A[e][im2var[h][w]] = -1
                b[e] = toy_img_f[h+1][w] - toy_img_f[h][w]
                e += 1

            if w+1 < im_w:
                A[e][im2var[h][w+1]] = 1
                A[e][im2var[h][w]] = -1
                b[e] = toy_img_f[h][w+1] - toy_img_f[h][w]
                e += 1

    A[e][im2var[0][0]] = 1
    b[e] = toy_img_f[0][0]

    v = np.linalg.solve(A.T.dot(A), A.T.dot(b))
    v = np.reshape(v, (im_w, im_h)).T
    v[v < 0] = 0
    v[v > 255] = 255
    v = v.astype(np.uint8)

    return v
```

In [ ]:

```
im_out = toy_reconstruct(toy_img)
```

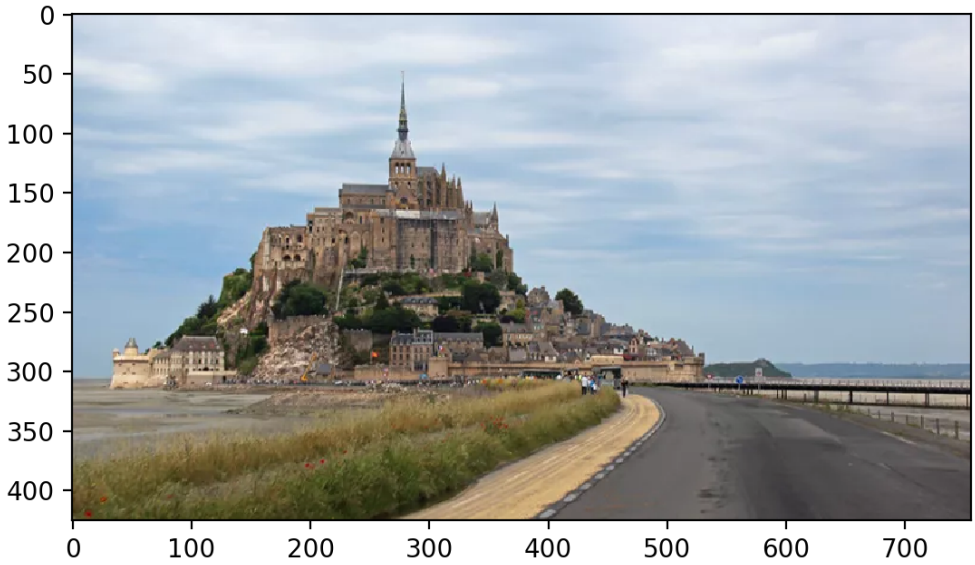
In [ ]:

```
plt.imshow(im_out, cmap="gray")
print("Error is: ", np.sqrt(((im_out - toy_img)**2).sum()))
```

Preparation

In [5]:

```
# Feel free to change image
background_img = cv2.cvtColor(cv2.imread('samples/castle.webp'), cv2.COLOR_BGR2RGB).astype('double') / 255.0
plt.imshow(background_img)
```



Out[5]:

```
<matplotlib.image.AxesImage at 0x10caf35f8>
```

In [6]:

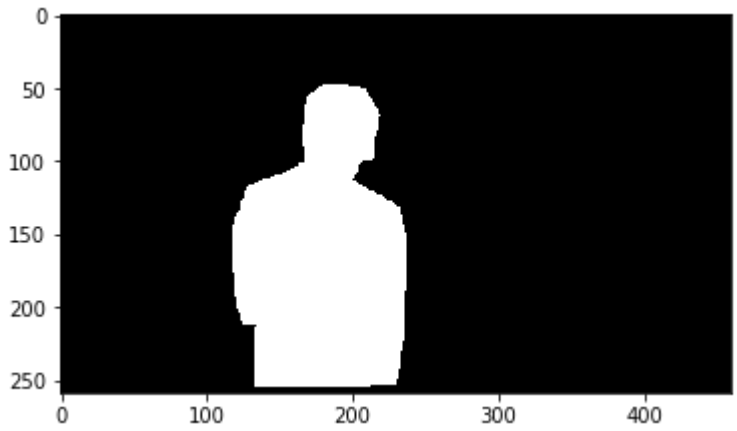
```
# Feel free to change image
object_img = cv2.cvtColor(cv2.imread('samples/me.jpg'), cv2.COLOR_BGR2RGB)#.asty
pe('double') / 255.0
object_img = cv2.resize(object_img, None, fx=0.25, fy=0.25).astype('double') / 2
55.0
import matplotlib.pyplot as plt
mask_coords = specify_mask(object_img)
```

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

In [7]:

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

```
<matplotlib.figure.Figure at 0x10d61e278>
```



In [8]:

```
%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 imag
e. Otherwise it will crash
```

In [9]:

```
import matplotlib.pyplot as plt
cropped_object, object_mask, fused = align_source(object_img, mask, background_i
mg, bottom_center, ret_img=True)

plot_no_frame(fused, path='results/me_at_castle_paste.png')
```

Part 2 Poisson Blending (50 pts)

In [10]:

```
def add_constraint(A, b, im2var, pos_pt, neg_pt, val, e):
    pos_h, pos_w = pos_pt

    if neg_pt is not None:
        neg_h, neg_w = neg_pt
        A[e, im2var[neg_h, neg_w]] = -1

    A[e, im2var[pos_h, pos_w]] = 1
    b[e] = val
    return e + 1

def get_neighbors(h, w, object_mask, im_h, im_w):
    src_pixels, tgt_pixels = [], []
    if h-1 >= 0:
        if object_mask[h-1][w]:
            src_pixels.append((h-1, w))
        else:
            tgt_pixels.append((h-1, w))

    if h+1 < im_h:
        if object_mask[h+1][w]:
            src_pixels.append((h+1, w))
        else:
            tgt_pixels.append((h+1, w))

    if w+1 < im_w:
        if object_mask[h][w+1]:
            src_pixels.append((h, w+1))
        else:
            tgt_pixels.append((h, w+1))

    if w-1 >= 0:
        if object_mask[h][w-1]:
            src_pixels.append((h, w-1))
        else:
            tgt_pixels.append((h, w-1))

    return src_pixels, tgt_pixels
```

In [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_h, im_w, im_c = background_img.shape

    blended = np.zeros_like(background_img)
    num_px = np.sum(object_mask)

    # Create pixel no. mapping
    px_id = 0
    im2var = np.zeros_like(background_img, dtype=np.uint32)
    for h in range(im_h):
        for w in range(im_w):
            if not object_mask[h, w]:
                continue
            im2var[h, w] = px_id
            px_id += 1


    for c in range(im_c):
        e = 0
        A = lil_matrix((num_px * 4, num_px))
        b = np.zeros(num_px * 4)

        for h in range(im_h):
            for w in range(im_w):
                if object_mask[h, w]:
                    src_pixels, tgt_pixels = get_neighbors(h, w, object_mask, im
_h, im_w)
                    for pt in src_pixels:
                        pt_h, pt_w = pt
                        e = add_constraint(A, b, im2var, (h, w), (pt_h, pt_w),
                                cropped_object[h, w, c] - cropped_object[pt_h, p
t_w, c], e)

                    for pt in tgt_pixels:
                        pt_h, pt_w = pt
                        e = add_constraint(A, b, im2var, (h, w), None, \
                                cropped_object[h, w, c] - cropped_object[pt_h, p
t_w, c] + background_img[pt_h, pt_w, c], e)

        A = A[:e]; b = b[:e]
        A = A.tocsr()

        v = lsqr(A, b)[0]
        v[v < 0] = 0
        v[v > 1] = 1

        v_cnt = 0
        for h in range(im_h):
            for w in range(im_w):
                if object_mask[h, w]:
                    blended[h, w, c] = v[v_cnt]
                    v_cnt += 1
```

```
    blended[object_mask == 0] = background_img[object_mask == 0]
    blended *= 255
    return blended.astype(np.uint8)
```

In [12]:

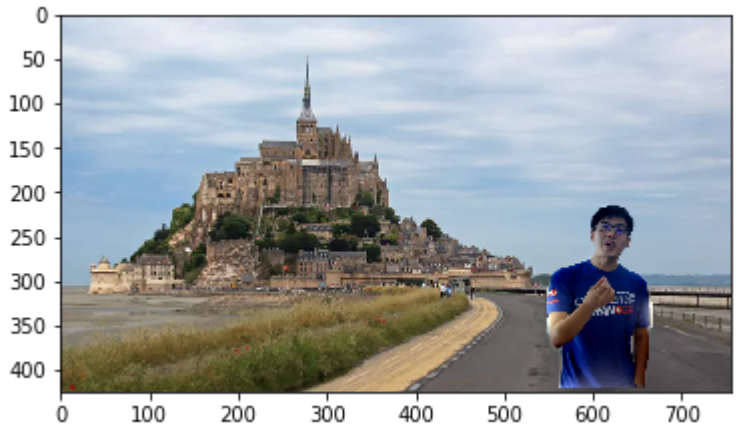
```
im_blend = poisson_blend(cropped_object, object_mask, background_img)
```

In [13]:

```
# if im_blend:

%matplotlib inline
import matplotlib.pyplot as plt
# plot_no_frame(im_blend, path="results/shoot_lion.png")
plt.imshow(im_blend)
```

Out[13]:

```
<matplotlib.image.AxesImage at 0x10cb77a20>
```



Part 3 Mixed Gradients (20 pts)

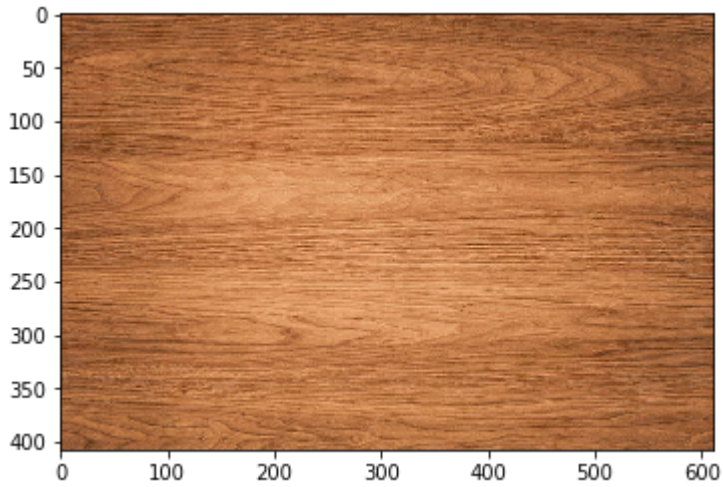
In [20]:

```
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_h, im_w, im_c = background_img.shape

    blended = np.zeros_like(background_img)
    num_px = np.sum(object_mask)

    # Create pixel no. mapping
    px_id = 0
    im2var = np.zeros_like(background_img, dtype=np.uint32)
    for h in range(im_h):
        for w in range(im_w):
            if not object_mask[h, w]:
                continue
            im2var[h, w] = px_id
            px_id += 1


    for c in range(im_c):
        e = 0
        A = lil_matrix((num_px * 4, num_px))
        b = np.zeros(num_px * 4)

        for h in range(im_h):
            for w in range(im_w):
                if object_mask[h, w]:
                    src_pixels, tgt_pixels = get_neighbors(h, w, object_mask, im
_h, im_w)
                    for pt in src_pixels:
                        pt_h, pt_w = pt

                        source_abs = abs(cropped_object[h, w, c] - cropped_objec
t[pt_h, pt_w, c])
                        target_abs = abs(background_img[h, w, c] - background_im
g[pt_h, pt_w, c])
                        val = cropped_object[h, w, c] - cropped_object[pt_h, pt_
w, c] \
                              if source_abs > target_abs else background_img[h,
w, c] - background_img[pt_h, pt_w, c]

                        e = add_constraint(A, b, im2var, (h, w), (pt_h, pt_w), v
al, e)

                    for pt in tgt_pixels:
                        pt_h, pt_w = pt

                        source_abs = abs(cropped_object[h, w, c] - cropped_objec
t[pt_h, pt_w, c])
                        target_abs = abs(background_img[h, w, c] - background_im
g[pt_h, pt_w, c])
                        val = cropped_object[h, w, c] - cropped_object[pt_h, pt_
w, c] \
                              if source_abs > target_abs else background_img[h,
w, c] - background_img[pt_h, pt_w, c]
```

```
                        e = add_constraint(A, b, im2var, (h, w), None, val + bac
kground_img[pt_h, pt_w, c], e)

        A = A[:e]; b = b[:e]
        A = A.tocsr()

        v = lsqr(A, b)[0]
        v[v < 0] = 0
        v[v > 1] = 1

        v_cnt = 0
        for h in range(im_h):
            for w in range(im_w):
                if object_mask[h, w]:
                    blended[h, w, c] = v[v_cnt]
                    v_cnt += 1

    blended[object_mask == 0] = background_img[object_mask == 0]
    blended *= 255
    return blended.astype(np.uint8)
```

In [21]:

```
background_img = cv2.cvtColor(cv2.imread('samples/wood.jpg'), cv2.COLOR_BGR2RGB)
.astype('double') / 255.0
plt.imshow(background_img)
plt.show()

object_img = cv2.cvtColor(cv2.imread('samples/hand_writing.jpg'), cv2.COLOR_BGR2
RGB).astype('double') / 255.0
plt.imshow(object_img)
plt.show()
```



In [23]:

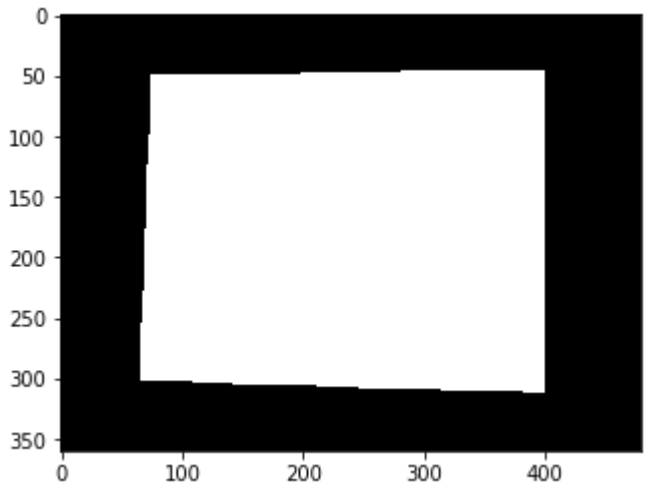
```
import matplotlib.pyplot as plt
%matplotlib notebook
mask_coords = specify_mask(object_img)
```

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

In [24]:

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

```
<matplotlib.figure.Figure at 0x1233b6278>
```



In [25]:

```
%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 imag
e. Otherwise it will crash
```

In [26]:

```
%matplotlib inline
import matplotlib.pyplot as plt
cropped_object, object_mask = align_source(object_img, mask, background_img, bot
tom_center)
```

In [27]:

```
im_mix = mix_blend(cropped_object, object_mask, background_img)
```

In [28]:

```
%matplotlib inline
import matplotlib.pyplot as plt
# plot_no_frame(im_mix, "results/writing_on_wood.png")
plt.imshow(im_mix)
```

Out[28]:

```
<matplotlib.image.AxesImage at 0x1232a9d68>
```

Bells & Whistles (Extra Points)

Color2Gray (20 pts)

In [29]:

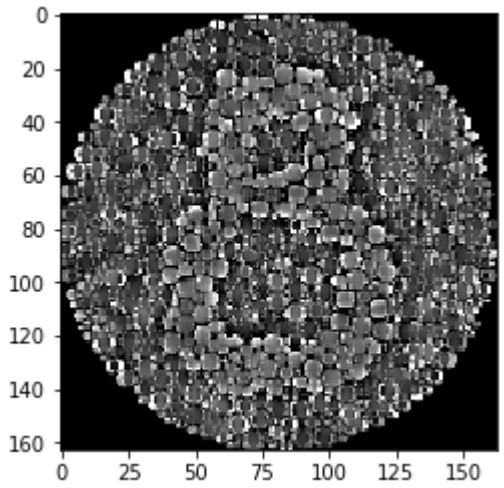
```
def color2gray(img):
    im_h, im_w, im_c = img.shape
    im2var = np.arange(im_h * im_w).reshape(im_w, im_h).T

    gray = cv2.cvtColor(img, cv2.COLOR_RGB2GRAY)

    img = img.astype('double') / 255.0
    gray = gray.astype('double') / 255.0

    gradients = np.gradient(img)
    norm = np.sqrt(gradients[1] ** 2 + gradients[2] ** 2)
    norm = np.mean(norm, axis=-1)

    A = lil_matrix((im_h * im_w * 5, im_h * im_w))
    b = np.zeros(im_h * im_w * 5)
    e = 0
    weight = 20

    object_mask = np.ones_like(gray, dtype=bool)
    for h in range(im_h):
        for w in range(im_w):
            neighbors, _ = get_neighbors(h, w, object_mask, im_h, im_w)

            for pt in neighbors:
                pt_h, pt_w = pt

                norm_abs = abs(norm[h, w] - norm[pt_h, pt_w])
                gray_abs = abs(gray[h, w] - gray[pt_h, pt_w])
                val = weight * norm[h, w] - norm[pt_h, pt_w] \
                      if norm_abs > gray_abs else gray[h, w] - gray[pt_h, pt_w]

                e = add_constraint(A, b, im2var, (h, w), (pt_h, pt_w), val, e)

            e = add_constraint(A, b, im2var, (h, w), None, gray[h, w], e)

    A = A[:e]; b = b[:e]
    A = A.tocsr()

    v = lsqr(A, b)[0]
    v = np.reshape(v, (im_w, im_h)).T
    v[v < 0] = 0
    v[v > 1] = 1

    return (v * 255).astype(np.uint8)
```

In [30]:

```
img = cv2.cvtColor(cv2.imread('samples/colorBlind8.png'), cv2.COLOR_BGR2RGB)

gray = cv2.cvtColor(img, cv2.COLOR_RGB2GRAY)
# plot_no_frame(gray, "results/gray_8.png", cmap="gray")
plt.imshow(gray, cmap='gray')

convert = color2gray(img)
# plot_no_frame(convert, "results/8.png", cmap="gray")
plt.imshow(convert, cmap='gray')
```

Out[30]:

```
<matplotlib.image.AxesImage at 0x11f6a6f98>
```



Laplacian pyramid blending (20 pts)

In [15]:

```
def laplacian_pyramid(im, freq=10, level=3):
    low_pass = gaussian_kernel(freq, 3 * freq)

    lap_pyr = []

    im_cur = im
    for l in range(level):
        tmp_lap = np.zeros_like(im_cur)
        tmp_im = np.zeros_like(im_cur[::2, ::2])

        for c in range(im_cur.shape[-1]):
            im_blurred = correlate2d(im_cur[:,:,c], low_pass, mode='same')

            im_laplacian = im_cur[:,:,c] - im_blurred
            tmp_lap[:,:,c] = im_laplacian

            im_subsampled = im_blurred[::2, ::2]
            tmp_im[:,:,c] = im_subsampled

        lap_pyr.append(tmp_lap)
        im_cur = tmp_im

    return lap_pyr
```

In [18]:

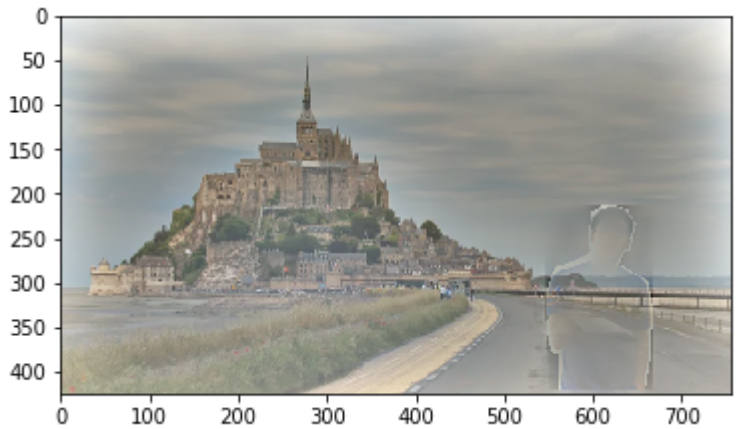
```
def upsample(img):
    return cv2.resize(img, None, fx=2, fy=2)

def laplacian_blend(cropped_object, object_mask, background_img):
    obj_pyr = laplacian_pyramid(cropped_object)
    bimg_pyr = laplacian_pyramid(background_img)
    mask_pyr = laplacian_pyramid(object_mask.astype(np.float32)[:, :, np.newaxis
].repeat(3, axis=-1))

    imgs = []
    for i in range(len(obj_pyr)-1, -1, -1):
        obj, bimg, mask = obj_pyr[i], bimg_pyr[i], mask_pyr[i]

        img = obj * mask + bimg * (1 - mask)
        imgs.append(img)

    img = imgs[0]
    for i in range(1, len(imgs)):
        img = upsample(img)
        img = img[:imgs[i].shape[0], :imgs[i].shape[1], :] + imgs[i]

    for c in range(img.shape[-1]):
        img[:, :, c] = (img[:, :, c] - np.min(img[:, :, c])) / (np.max(img[:, :,
c]) - np.min(img[:, :, c]))

    return (img*255).astype(np.uint8)
```

In [19]:

```
im_blend = laplacian_blend(cropped_object, object_mask, background_img)
plt.imshow(im_blend)
```

Out[19]:

```
<matplotlib.image.AxesImage at 0x10cd84470>
```



More gradient domain processing (up to 20 pts)