Ph21 Problem Set 3

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1

Imports

```
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.pyplot import imshow
%matplotlib inline
from PIL import Image, ImageFilter
from scipy import ndimage
from scipy.ndimage import filters
```

Import an Image

```
def open_image(fname, print_info=True):
    im  = Image.open(fname)
    if (print_info):
        print('Image format = %s, Image size = %s, Image mode = %s'%(
            im.format, im.size, im.mode))
    return im

def display_image(im):
    imshow(np.asarray(im))
```

Let's try importing an image I downloaded earlier:

```
im = open_image('/Users/tommyalford/Desktop/EdgeDetectImage.jpg')
```

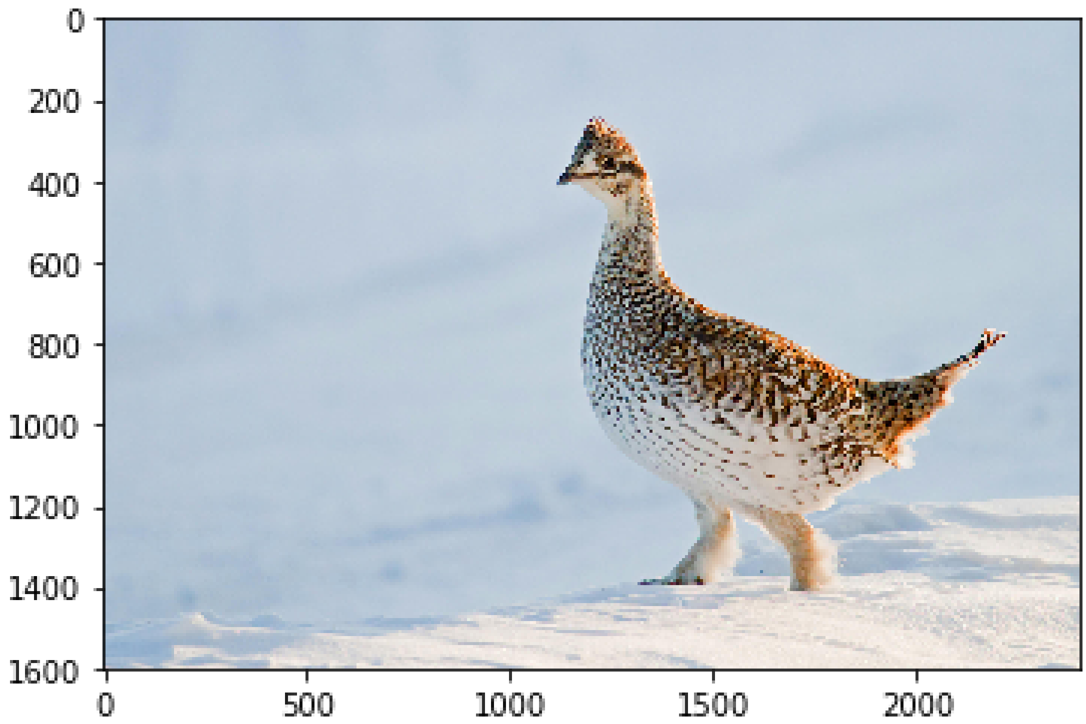
```
Image format = JPEG, Image size = (2400, 1600), Image mode = RGB
```

2

Disply an Image

We can display it inline with matplotlib:

```
display_image(im)
```



3

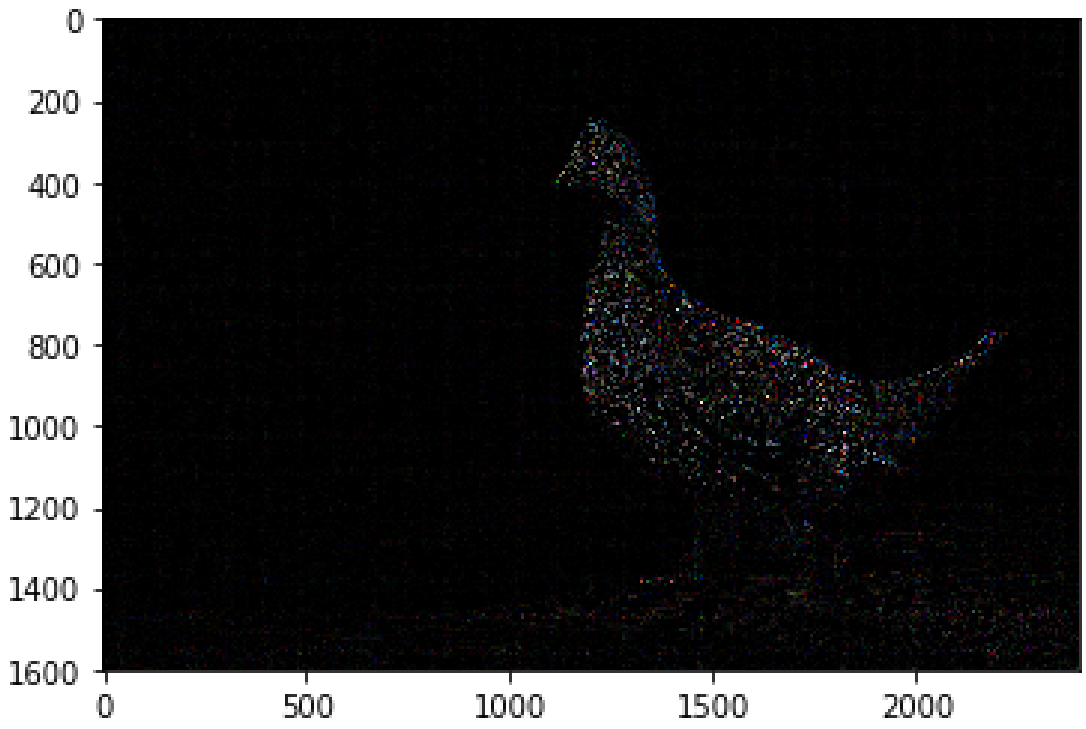
Here I would guess that edge detection has something to do with checking the change in pixel level across different areas and finding where the change is the largest (if we consider the pixels as datapoints in a multi-variable function). I'll look on wikipedia for the official way to do it to save time.

Let's see what the existing image filter does:

Official Edge Detection

```
def get_existing_edge_detection(im):
    edge_im = im.filter(ImageFilter.FIND_EDGES)
    return edge_im
```

```
edge_im = get_existing_edge_detection(im)
plt.imshow(np.array(edge_im), cmap='gray')
plt.show()
```

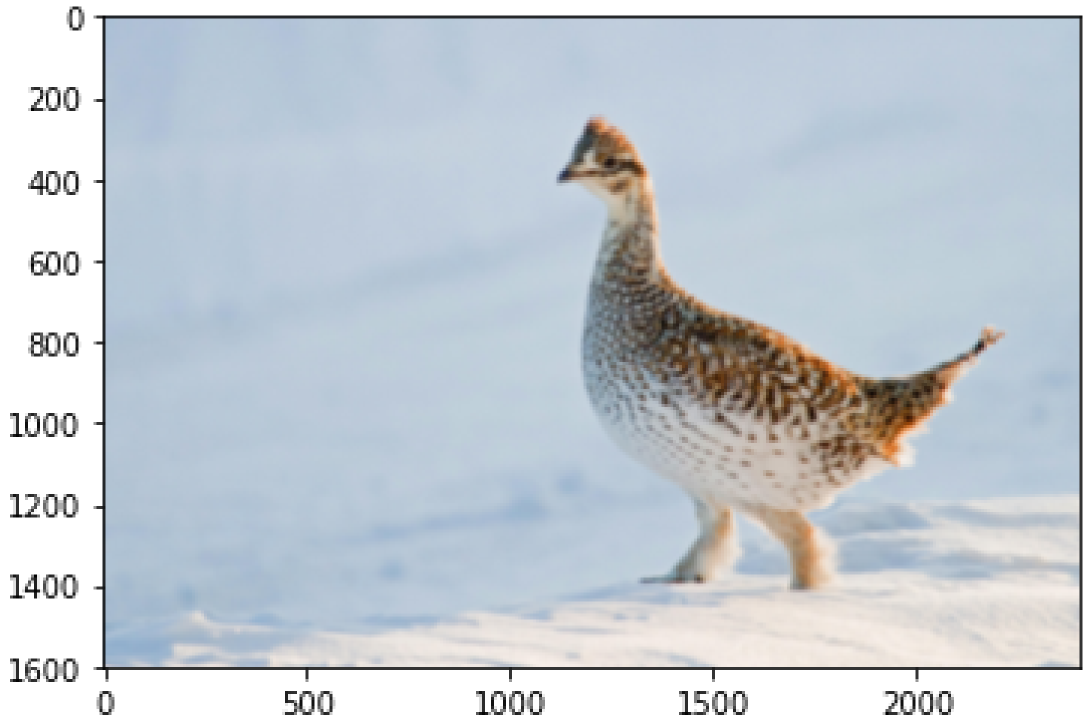


Looks like it worked pretty well!

4

Blurring

```
blurred = im.filter(ImageFilter.GaussianBlur(radius=5))
display_image(blurred)
```



Here we do see the image as blurry but still visible now. This does seem like this would be easier for edge detection. We can test with different radaii later to see which gives us the best edge detection. 5 is probably a little large.

5

Canny Edge Detectionn

Steps:

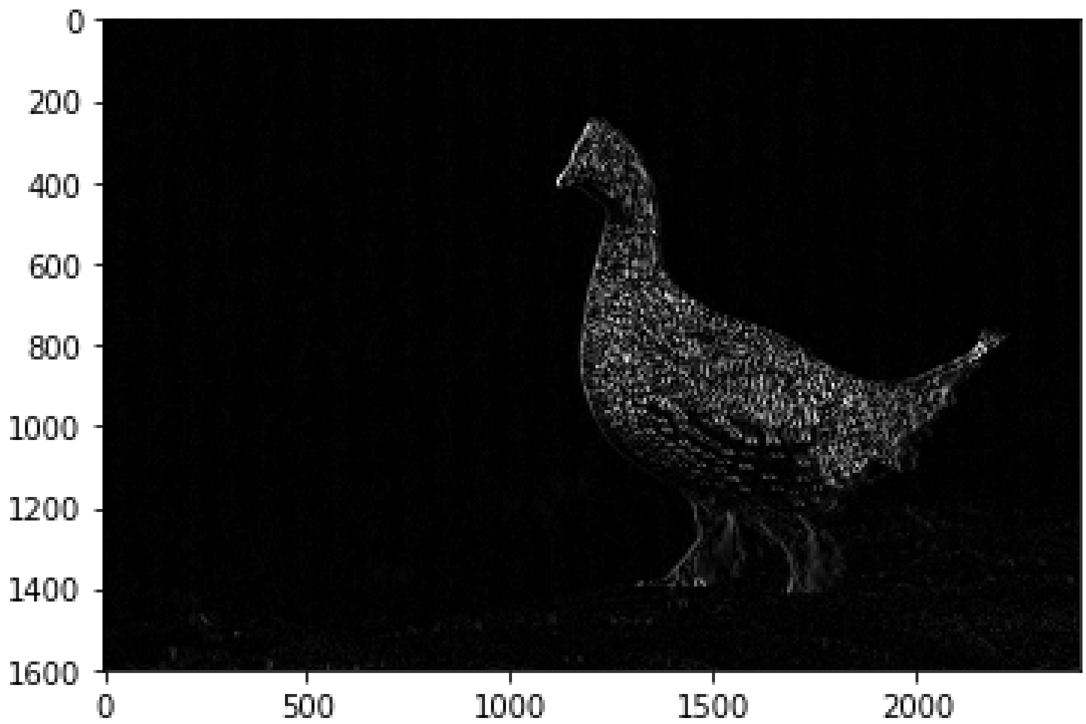
- Smooth the image with a Gaussian blurring filter
- Compute the x and y derivatives at each pixel
- Take out any pixels which are not local maxima
- Apply the double threshold to see wich edge pixels are not as 'intense' as others
- Get rid of the weak edge pixels which do not share a neighbor with any strong edge pixels

Compute X and Y Derivatives

```
def compute_ndimage_grad(im, sigma=1):
    Gx = np.zeros(im.shape);
    Gy = np.zeros(im.shape);
    # use first derivative of a Gaussian
    # x derv
    filters.gaussian_filter(im, sigma=sigma, order=[1, 0], output=Gx,
                            mode='nearest')
    # y derv
    filters.gaussian_filter(im, sigma=sigma, order=[0, 1], output=Gx,
                            mode='nearest')
    magnitude = np.sqrt(Gx**2 + Gy**2)
    direc = np.arctan2(Gy, Gx)
    return magnitude, direc
```

```
blurred = im.filter(ImageFilter.GaussianBlur(radius=3))
gray_blurred = np.array(blurred.convert('L'))
mag, direc = compute_ndimage_grad(gray_blurred)
```

```
plt.imshow(mag, cmap='gray')
plt.show()
```



Round Angles

Now we need to round direc to the nearest quadrant:

```python
def round_angle(theta):
    # divide by pi/4, round to nearest int (mod 4), muliply by pi/4
    return (np.round(theta / (np.pi / 4)) % 4) * (np.pi / 4)

rounded_direcs = round_angle(direc)
```

Apply Non-Max Suppression

Now we need to apply nonmax suppression to take out any pixel which are not local maxima:

Pseudocode here:

for each pixel:

- find neighbors in direction from directional grad
- if val is larger than neighbor vals, make that an 'edge' in new 'edge array'

This will give us our edge pixels. Now we just need to threshhold these values in some way (keep the mags in the edge array), and then check each neighboring 'blob' of 8 pixels. If the blob has no strong pixels then throw out the weak pixel.

```python
def get_pixel_diffs(theta):
    # returns the x and y indeces (can be i, i + 1, j, j + 1)
    # theta is already rounded
    # so using sine and cosine and rounding should get us what we want
    return np.array([np.round(np.cos(theta)), np.round(np.sin(theta))])
```

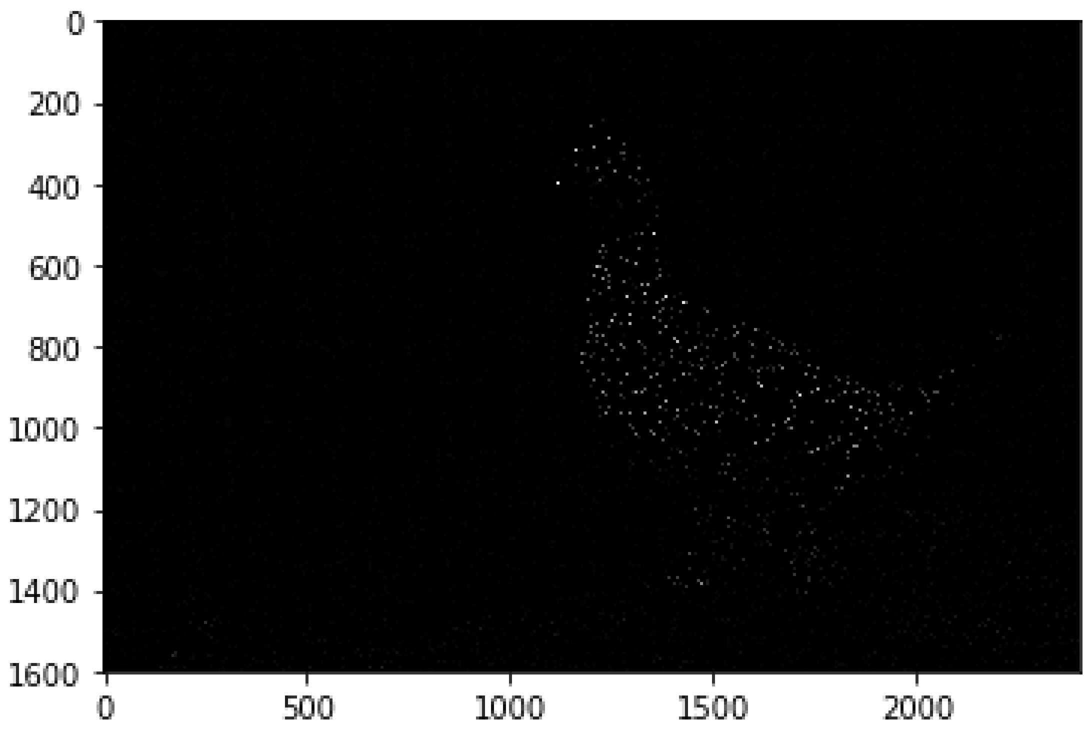
```python
def get_ind(r_direcs):
    indices = np.dstack(np.indices(r_direcs.shape))
    diffs = get_pixel_diffs(r_direcs)
    xy_ind = []
    for i, d in enumerate([diffs, -1 * diffs]):
        xind = np.array(indices[:, :, 0] + d[0], dtype='int')
        yind = np.array(indices[:, :, 1] + d[1], dtype='int')
        xy_ind.append([xind, yind])

    return xy_ind[0], xy_ind[1]
```

```python
def suppress_nonmax(mag, direcs):
    #rounded_direcs = round_angle(direcs)
    pad = np.pad(mag, pad_width=1, mode='constant', constant_values=0)
    # get new indeces from the angles of which we get our neighbors
    pos_ind, neg_ind = get_ind(direcs)
    # get negative neighbors
    neg_slice = pad[neg_ind[0] + 1, neg_ind[1] + 1]
    # get positive neighbors
```

```
    pos_slice = pad[pos_ind[0] + 1, pos_ind[1] + 1]
    # now just take max of pos and neg ind slices
    max_vals = np.maximum(neg_slice, pos_slice)
    suppressed_mags = (mag >= max_vals) * mag
    return suppressed_mags
```

```
suppressed_grad = suppress_nonmax(mag, rounded_direcs)
plt.imshow(suppressed_grad, cmap='gray')
```

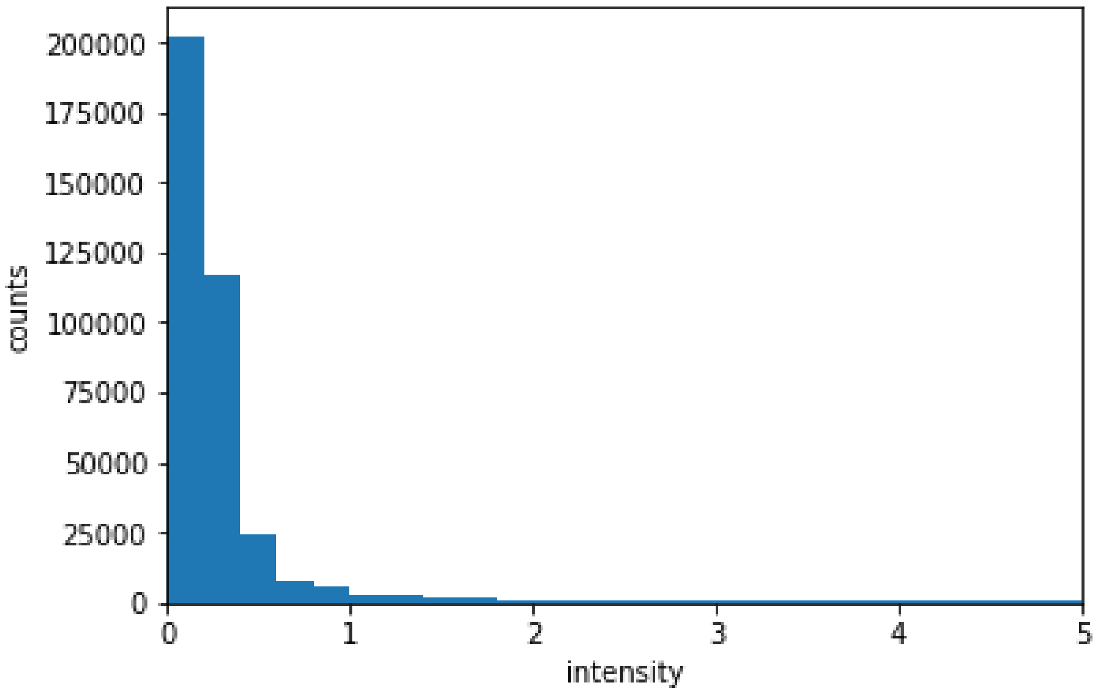
```
<matplotlib.image.AxesImage at 0x161d0af28>
```



This looks pretty close to the earlier edge detection image now! All we have to do is double threshhold the pixels now to remove any weak gradient values

Double Threshold

```
plt.hist(suppressed_grad[suppressed_grad > 0], bins=100)
plt.xlabel('intensity')
plt.ylabel('counts')
plt.xlim([0, 5])
plt.show()
```



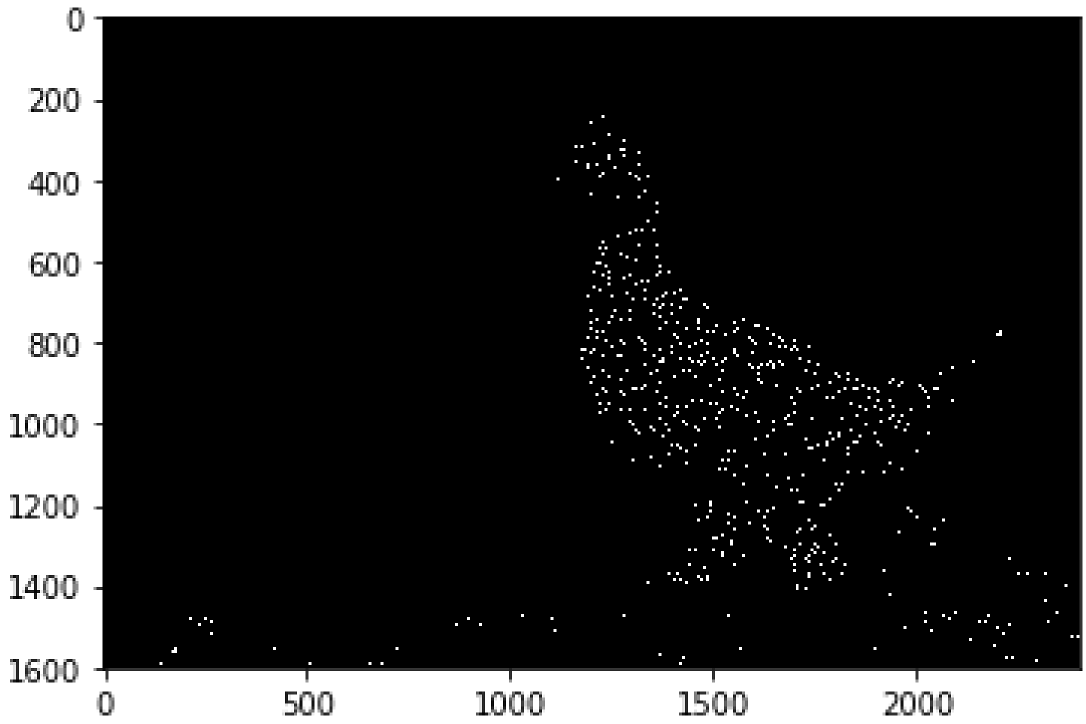
Looking at the histogram of gradient values, we'll try thresholding for a low value of .5 and a high value of 3.

Applying Hysteresis

```
def get_8_neighbors(mag):
    indices = np.dstack(np.indices(mag.shape))
    # these diffs are basically (1, 0), (1, 1), (0, 1), (1, -1), (0, -1), ...
    diffs = [(0, 1), (1, 0), (0, -1), (-1, 0), (1, 1),
             (1, -1), (-1, 1), (-1, -1)]
    xy_ind = []
    for d in diffs:
        xind = np.array(indices[:, :, 0] + d[0], dtype='int')
        yind = np.array(indices[:, :, 1] + d[1], dtype='int')
        xy_ind.append([xind, yind])

    return xy_ind
def apply_hysteresis(low_thresh, high_thresh, grad):
    pad = np.pad(grad, pad_width=1, mode='constant', constant_values=0)
    # get new indeces from the angles of which we get our neighbors
    neighbor_inds = get_8_neighbors(grad)
    slices = []
    for ind in neighbor_inds:
        ind_slice = pad[ind[0] + 1, ind[1] + 1]
        slices.append(ind_slice)
    # if we get the max value of all the slices, and this value is below the
    # strong threshold cutoff, we know that we can remove the weak pixel
    max_intensity = np.amax(np.array(slices), axis=0)
    hyster_mask = ((max_intensity < high_thresh) & (grad < low_thresh))
    # this shows any values which should be suppressed
    # so we need to invert this before masking
    return grad * np.logical_not(hyster_mask)
```

Here we'll also put all edge pixels at the maximum brightness in order to see them more clearly:

```
hyster_edge = apply_hysteresis(1, 3, suppressed_grad)
# make all edges very bright now to easily see them
max_vals = 255 * (hyster_edge > 0)
plt.imshow(max_vals, cmap='gray')
plt.show()
```



Looks pretty good!

Optimization

Try over various filter, images

Let's put this all into one method now:

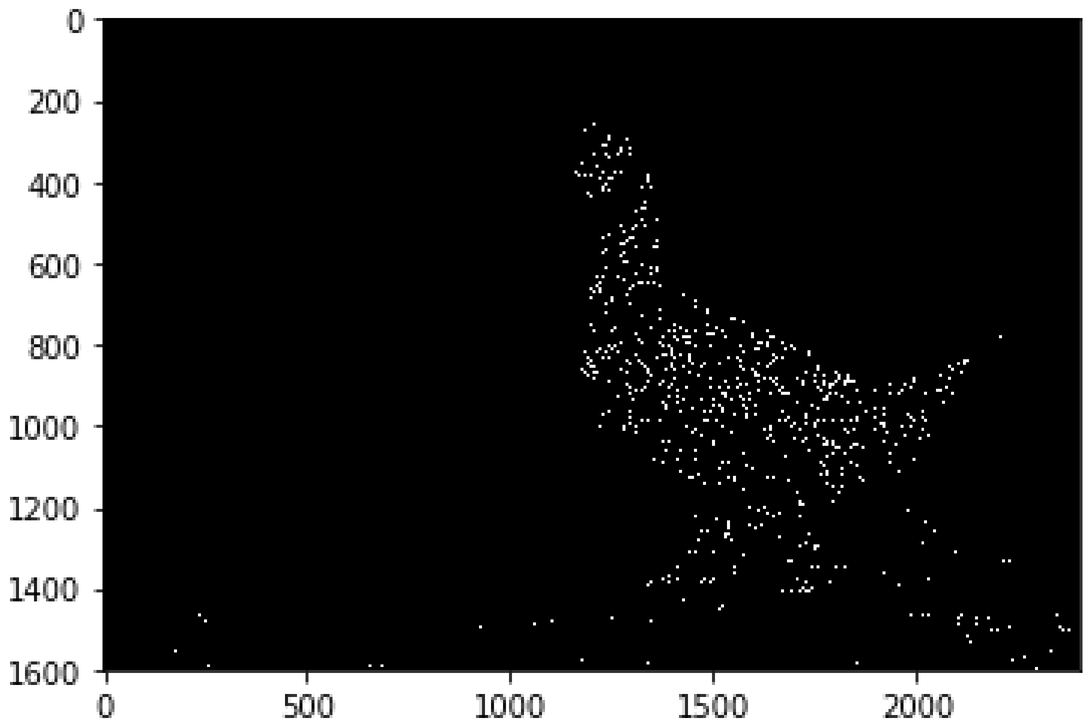
```
def get_edge_detection(im, gaussian_r, low_thresh, high_thresh,
                       stencil_width=1, apply_max=True):
    blurred = im.filter(ImageFilter.GaussianBlur(radius=gaussian_r))
    gray_blurred = np.array(blurred.convert('L'))
    mag, direc = compute_ndimage_grad(gray_blurred, sigma=stencil_width)
    rounded_direcs = round_angle(direc)
```

```
    suppressed_grad = suppress_nonmax(mag, rounded_direcs)
    hyster_edge = apply_hysteresis(low_thresh, high_thresh, suppressed_grad)
    max_vals = 255 * (hyster_edge > 0)
    if (apply_max):
        return max_vals
    return hyster_edge
```

Now we can try this over different radaii and thresholds for our initial blurring filter:

```
plt.imshow(get_edge_detection(im, 2, 1, 3, stencil_width=.4, apply_max=True),
           cmap='gray')
```

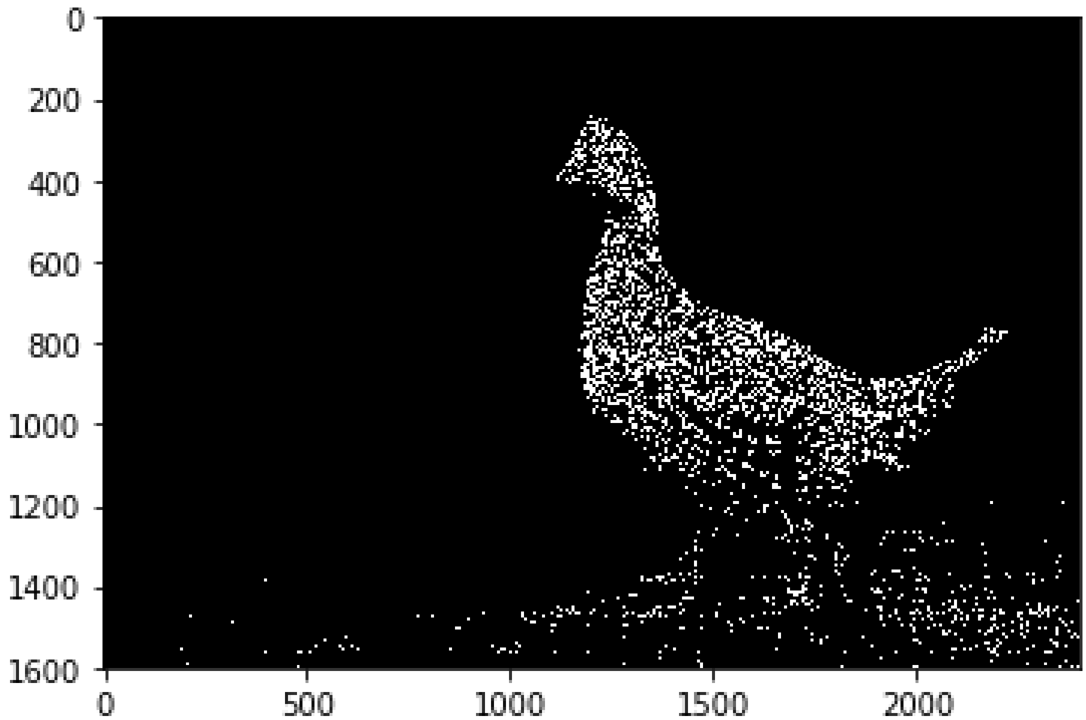
```
<matplotlib.image.AxesImage at 0x17115ac88>
```



Let's compare this now to using the original image and then using PIL's edge detection: we'll also apply some hysteresis and make each pixel the maximum intensity to better see these edges.

```
blurred_im = im.filter(ImageFilter.GaussianBlur(radius=0))
gray_blurred_im = blurred_im.convert('L')
edge_im = np.array(get_existing_edge_detection(gray_blurred_im))
hyster_edge = apply_hysteresis(20, 50, edge_im)
max_vals = 255 * (hyster_edge > 0)
plt.imshow(max_vals, cmap='gray')
```

```
<matplotlib.image.AxesImage at 0x137329550>
```



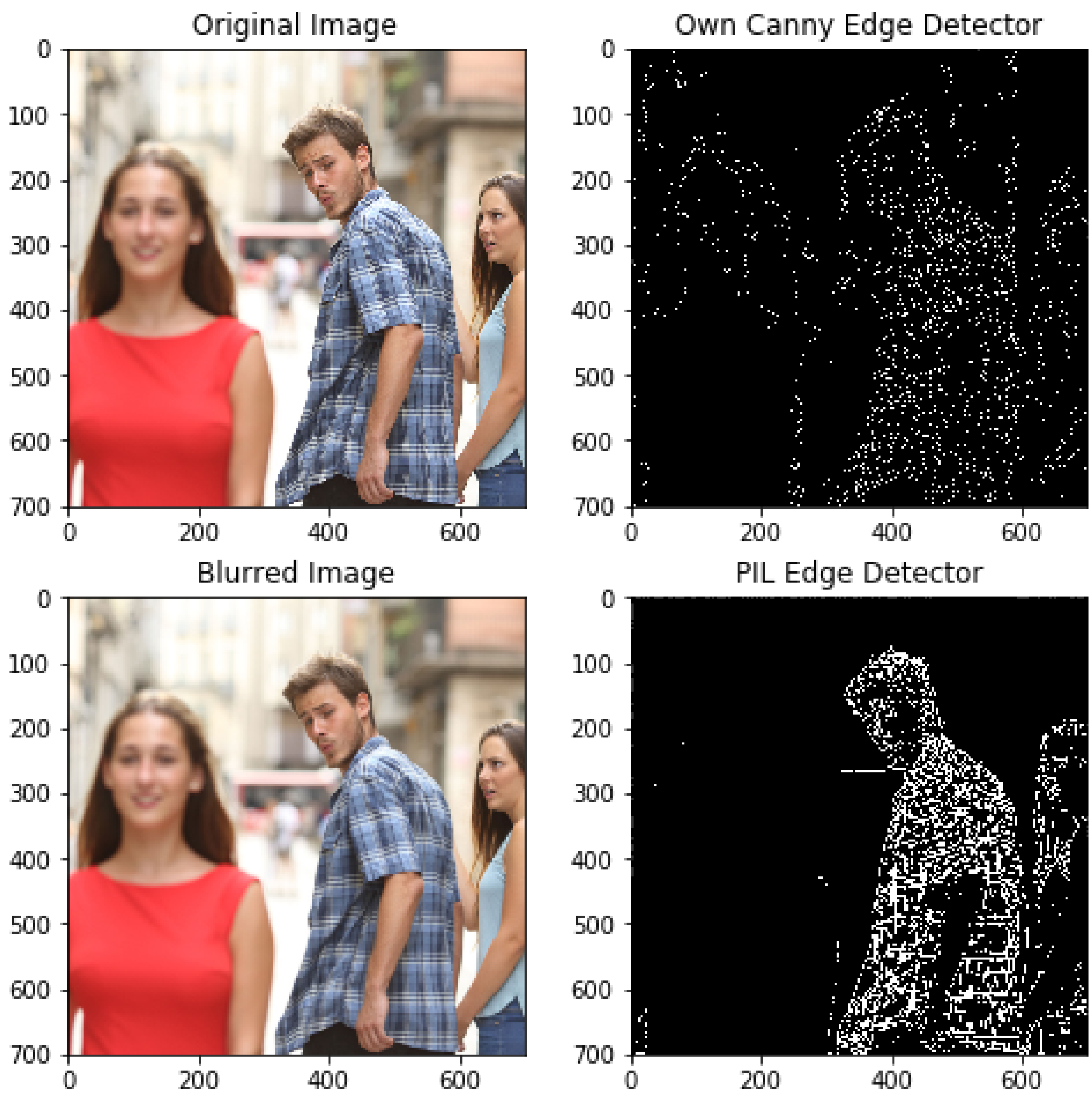
Additional Images

We'll look at a couple more images now. Note: I'm only including the final choices for thresholds and blur radaii for our own filter in order to keep things at a reasonable length. There was a decent amount of trial-and-error in order to correctly find the items we wanted.

```
def plot_comparisons(im, blur_r, low, high, PIL_low, PIL_high, stencil_width=1,
                     apply_max=True):
    fig, axes = plt.subplots(2, 2, figsize=(8, 8))
    axes[0][0].imshow(np.asarray(im))
    axes[0][0].set_title('Original Image')
    blurred = im.filter(ImageFilter.GaussianBlur(radius=blur_r))
    axes[1][0].imshow(blurred, cmap='gray', label='blurred image')
    axes[1][0].set_title('Blurred Image')
    axes[0][1].imshow(get_edge_detection(
        im, blur_r, low, high, stencil_width=stencil_width,
        apply_max=apply_max), cmap='gray')
    axes[0][1].set_title('Own Canny Edge Detector')
    gray_blurred_im = im.convert('L')
    edge_im = np.array(get_existing_edge_detection(gray_blurred_im))
    hyster_edge = apply_hysteresis(PIL_low, PIL_high, edge_im)
    max_vals = 255 * (hyster_edge > 0)
    if (apply_max):
        axes[1][1].imshow(max_vals, cmap='gray')
    else:
```

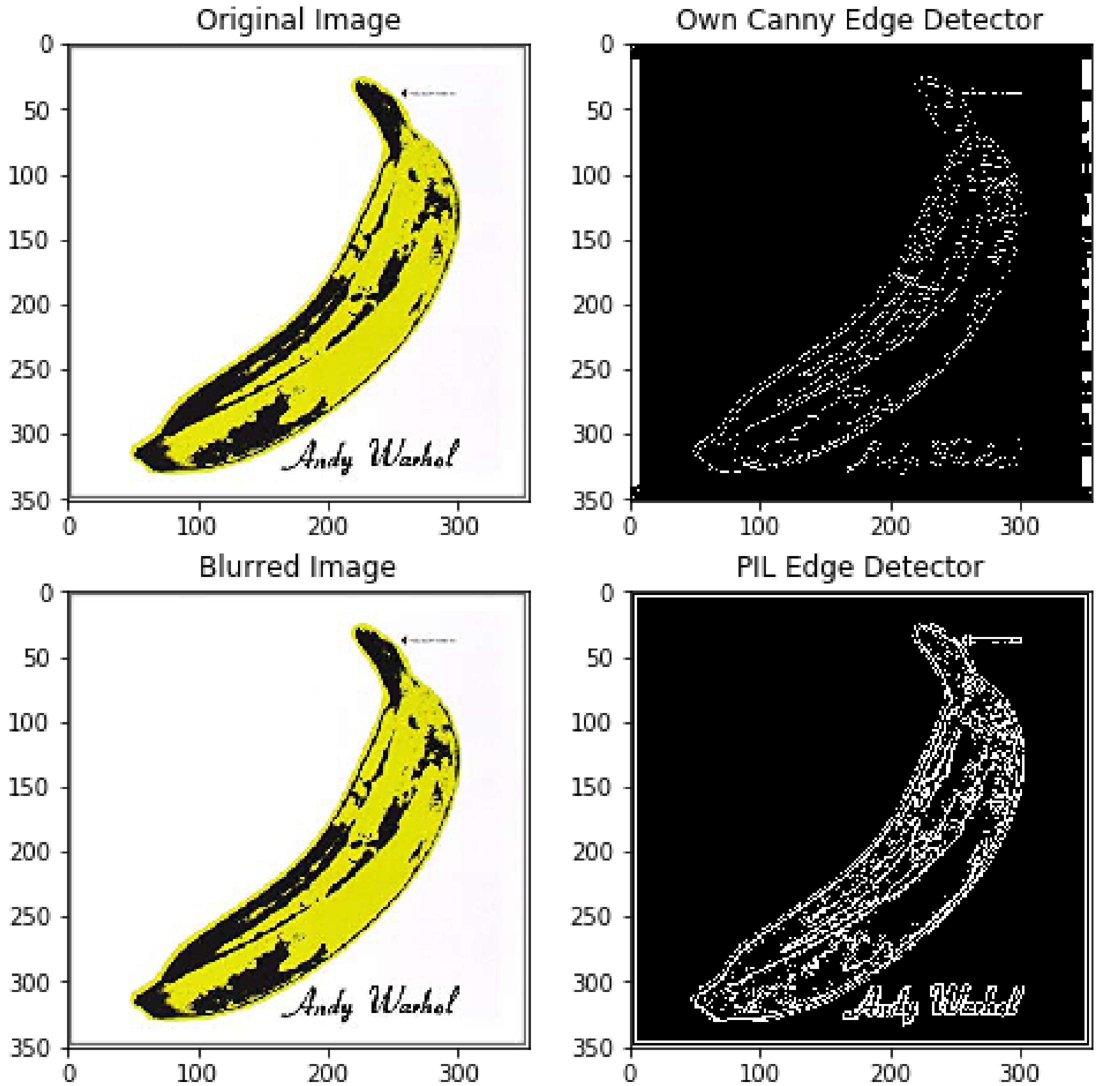
```
        axes[1][1].imshow(edge_im, cmap='gray')
    axes[1][1].set_title('PIL Edge Detector')
```

```
meme2 = open_image('/Users/tommyalford/Desktop/meme2.jpg', print_info=False)
plot_comparisons(meme2, 1, 3, 200, 30, 200, stencil_width=1, apply_max=True)
```



Here PIL's image does look much crisper, but it's also completely missing the girl on the left..

```
velvet = open_image('/Users/tommyalford/Desktop/velvet.jpg', print_info=False)
plot_comparisons(velvet, 0, 3, 20, 50, 250, stencil_width=1, apply_max=True)
```



This image was probably a lot easier to edge detect on, and both detectors worked pretty well. The PIL detector actually has the writing as readable, whereas our edge detector didn't get the writing too clearly. Attempts to make this work without blurring the image didn't result in any better results at readable writing, and the banana edge detection was worse as well.

Conclusion

After completing this assigment, my thoughts on edge detectors begin to mirror my thoughts from the start of the assignment: what is an edge? It seems like edge detectors don't even really know themselves until you tell them what you want them to look for. Even PIL's filter generally needed some thresholding to get rid of some of really low-intensity 'edges' it still had in its images. However, regardless it is pretty magical what a simple stencil can do do suppress everything besides the edges in an image. The nonmax suppression and thresholding parts are also nice, but the real bulk of the algorithm seems to be done purely with the gradient.